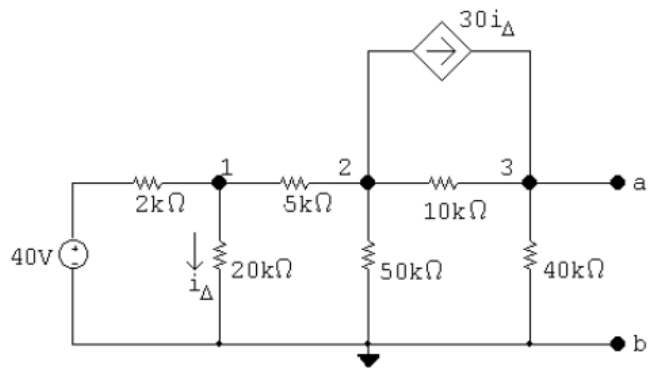
Open book, open notes, and use of a laptop equipped with Freemat is allowed.

1) **Find the Thevenin equivalent of the circuit at a-b**

P 4.73



The node voltage equations are:

$$\frac{v_1 - 40}{2000} + \frac{v_1}{20{,}000} + \frac{v_1 - v_2}{5000} = 0$$

$$\frac{v_2 - v_1}{5000} + \frac{v_2}{50{,}000} + \frac{v_2 - v_3}{10{,}000} + 30\frac{v_1}{20{,}000} = 0$$

$$\frac{v_3 - v_2}{10{,}000} + \frac{v_3}{40{,}000} - 30\frac{v_1}{20{,}000} = 0$$

In standard form:

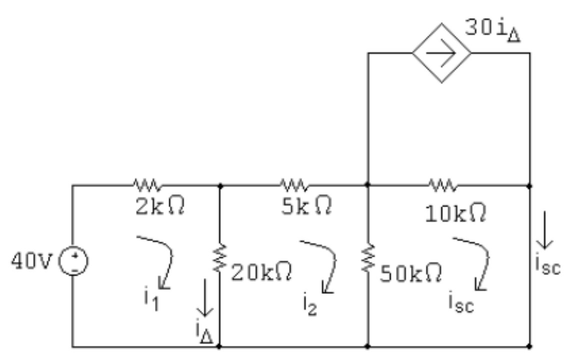
$$v_1\left(\frac{1}{2000} + \frac{1}{20{,}000} + \frac{1}{5000}\right) + v_2\left(-\frac{1}{5000}\right) + v_3(0) = \frac{40}{2000}$$

$$v_1\left(-\frac{1}{5000} + \frac{30}{20{,}000}\right) + v_2\left(\frac{1}{5000} + \frac{1}{50{,}000} + \frac{1}{10{,}000}\right) + v_3\left(-\frac{1}{10{,}000}\right) = 0$$

$$v_1\left(-\frac{30}{20{,}000}\right) + v_2\left(-\frac{1}{10{,}000}\right) + v_3\left(\frac{1}{10{,}000} + \frac{1}{40{,}000}\right) = 0$$

Solving, $v_1 = 24$ V; $v_2 = -10$ V; $v_3 = 280$ V

$V_{\rm Th} = v_3 = 280$ V



The mesh current equations are:

$$-40 + 2000i_1 + 20{,}000(i_1 - i_2) = 0$$
$$5000i_2 + 50{,}000(i_2 - i_{sc}) + 20{,}000(i_2 - i_1) = 0$$
$$50{,}000(i_{sc} - i_2) + 10{,}000(i_{sc} - 30i_\Delta) = 0$$

The constraint equation is:

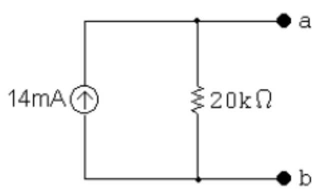
$$i_\Delta = i_1 - i_2$$

Put these equations in standard form:

$$i_1(22{,}000) + i_2(-20{,}000) + i_{sc}(0) + i_\Delta(0) = 40$$
$$i_1(-20{,}000) + i_2(75{,}000) + i_{sc}(-50{,}000) + i_\Delta(0) = 0$$
$$i_1(0) + i_2(-50{,}000) + i_{sc}(60{,}000) + i_\Delta(-300{,}000) = 0$$
$$i_1(-1) + i_2(1) + i_{sc}(0) + i_\Delta(1) = 0$$

Solving, $i_1 = 13.6$ mA; $i_2 = 12.96$ mA; $i_{sc} = 14$ mA; $i_\Delta = 640\,\mu$A

$$R_{Th} = \frac{280}{0.014} = 20\ \text{k}\Omega$$



Finding Rth using a test source: apply 1V source at V3 or Vth. Find io

1) **V1/2 + V1/20 + (V1-V2)/5 = 0**
2) **(V2-V1)/5 + V2/50 + (V2-1)/10 + 30 id = 0**

id = V1/20 so swap 1.5V1 for 30id above

3) **io = 1/40 + (1-V2)/10 – 30id = 1/40 + (1-V2)/10 - 1.5V1**

Rearranging

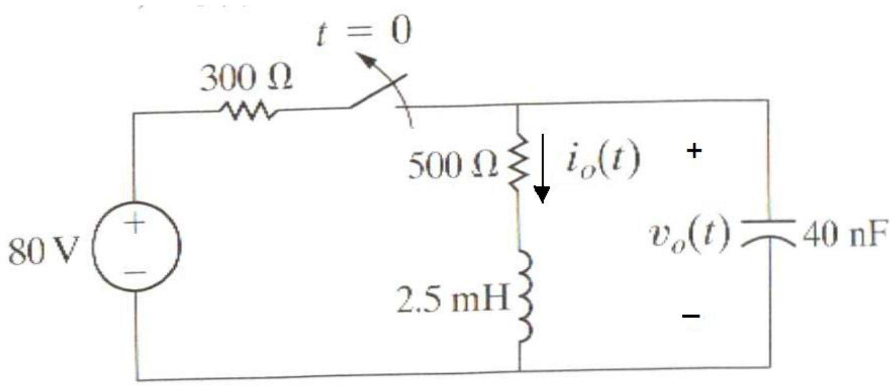
1) **15V1 – 4V2 = 0**
2) **-10V1 +16V2 + 75V1 = 5, 65V1 + 16V2 = 5**

(freemat) V1 = .04, V2 = .15, therefore io = .025 + (.85)/10 - .06 = 0.05 mA,

so Rth = Vo/Io = 1/.05 = 20 k Ohms

2) The switch has been closed a long time before opening at t=0. Find

a. $i_o(t)$ **b. $v_o(t)$**



P 8.47 [a] $t < 0$:

$$i_o = \frac{80}{800} = 100\,\text{mA}; \qquad v_o = 500 i_o = (500)(0.01) = 50\,\text{V}$$

$t > 0$:

$$\alpha = \frac{R}{2L} = \frac{500}{2(2.5\times10^{-3})} = 10^5 \text{ rad/s}$$

$$\omega_o^2 = \frac{1}{LC} = \frac{1}{(2.5\times10^{-3})(40\times10^{-9})} = 100\times10^8$$

$$\alpha^2 = \omega_o^2 \quad \therefore \quad \text{critically damped}$$

$$\therefore \; i_o(t) = D_1 t e^{-10^5 t} + D_2 e^{-10^5 t}$$

$$i_o(0) = D_2 = 100\,\text{mA}$$

$$\frac{di_o}{dt}(0) = -\alpha D_2 + D_1 = 0$$

$$\therefore \quad D_1 = 10^5(100\times10^{-3}) = 10{,}000$$

$$i_o(t) = 10{,}000 t e^{-10^5 t} + 0.1 e^{-10^5 t}\,\text{A}, \qquad t \ge 0^+$$

[b] $v_o(t) = D_3 t e^{-10^5 t} + D_4 e^{-10^5 t}$

$$v_o(0) = D_4 = 50$$

$$C\frac{dv_o}{dt}(0) = -0.1$$

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OR,

Vo(t) = 500 Io(t) + 0.0025 dIo(t)/dt

dIo(t)/dt = 10000t (-10^5)exp(-10^5t) + 10000exp(-10^5t) + 0.1(-10^5)exp(-10^5t)

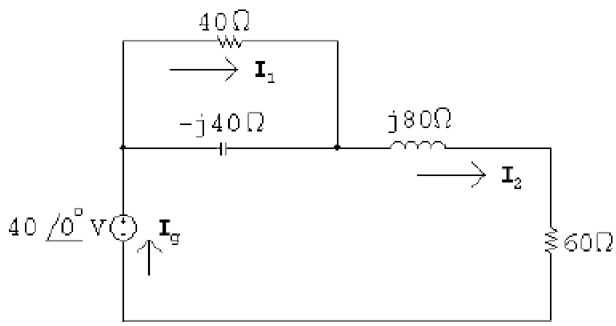
= -10^9 t exp(-10^5t) + **these two terms cancel out!**

so Vo(t) = 500 (10000t)exp(-10^5t) + 50exp(-10^5t) – 25x10^5 t exp(-10^5t)

$$500\left(10\,000\,e^{-100\,000\,t}\,t + 0.1\,e^{-100\,000\,t}\right) - 2.5\times 10^{6}\,e^{-100\,000\,t}\,t$$

= 250000t exp(-100000t) + 50 exp(-100000t)

P 10.18 [a] $\dfrac{1}{j\omega C} = -j40\,\Omega; \qquad j\omega L = j80\,\Omega$



$$Z_{\text{eq}} = 40\| - j40 + j80 + 60 = 80 + j60\,\Omega$$

$$\mathbf{I}_g = \frac{40/0^\circ}{80 + j60} = 0.32 - j0.24\,\text{A}$$

$$S_g = -\frac{1}{2}\mathbf{V}_g\mathbf{I}_g^* = -\frac{1}{2}40(0.32 + j0.24) = -6.4 - j4.8\,\text{VA}$$

$$P = 6.4\,\text{W (del)}; \qquad Q = 4.8\,\text{VAR (del)}$$

$$|S| = |S_g| = 8\,\text{VA}$$

[b] $\mathbf{I}_1 = \dfrac{-j40}{40 - j40}\mathbf{I}_g = 0.04 - j0.28\,\text{A}$

$$P_{40\Omega} = \frac{1}{2}|\mathbf{I}_1|^2(40) = 1.6\,\text{W}$$

$$P_{60\Omega} = \frac{1}{2}|\mathbf{I}_g|^2(60) = 4.8\,\text{W}$$

$$\sum P_{\text{diss}} = 1.6 + 4.8 = 6.4\,\text{W} = \sum P_{\text{dev}}$$

[c] $\mathbf{I}_{-j40\Omega} = \mathbf{I}_g - \mathbf{I}_1 = 0.28 + j0.04\,\text{A}$

$$Q_{-j40\Omega} = \frac{1}{2}|\mathbf{I}_{-j40\Omega}|^2(-40) = -1.6\,\text{VAR (del)}$$

$$Q_{j80\Omega} = \frac{1}{2}|\mathbf{I}_g|^2(80) = 6.4\,\text{VAR (abs)}$$

$$\sum Q_{\text{abs}} = 6.4 - 1.6 = 4.8\,\text{VAR} = \sum Q_{\text{dev}}$$

P 9.69 $\mathbf{V}_g = 4\angle 0^\circ\,\text{V}; \qquad \frac{1}{j\omega C} = -j20\,\text{k}\Omega$

Let $\mathbf{V}_a$ = voltage across the capacitor, positive at upper terminal
Then:

$$\frac{\mathbf{V}_a - 4\angle 0^\circ}{20{,}000} + \frac{\mathbf{V}_a}{-j20{,}000} + \frac{\mathbf{V}_a}{20{,}000} = 0; \qquad \therefore \;\; \mathbf{V}_a = (1.6 - j0.8)\,\text{V}$$

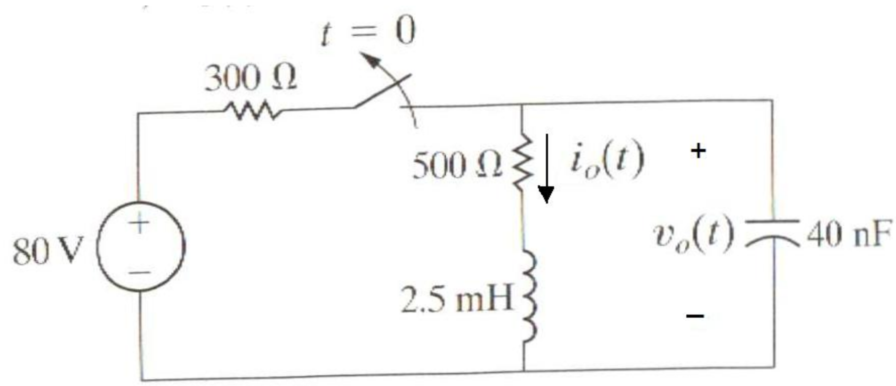
$$\frac{0 - \mathbf{V}_a}{20{,}000} + \frac{0 - \mathbf{V}_o}{10{,}000} = 0; \qquad \mathbf{V}_o = -\frac{\mathbf{V}_a}{2}$$

$$\therefore \;\; \mathbf{V}_o = -0.8 + j0.4 = 0.89\angle 153.43^\circ\,\text{V}$$

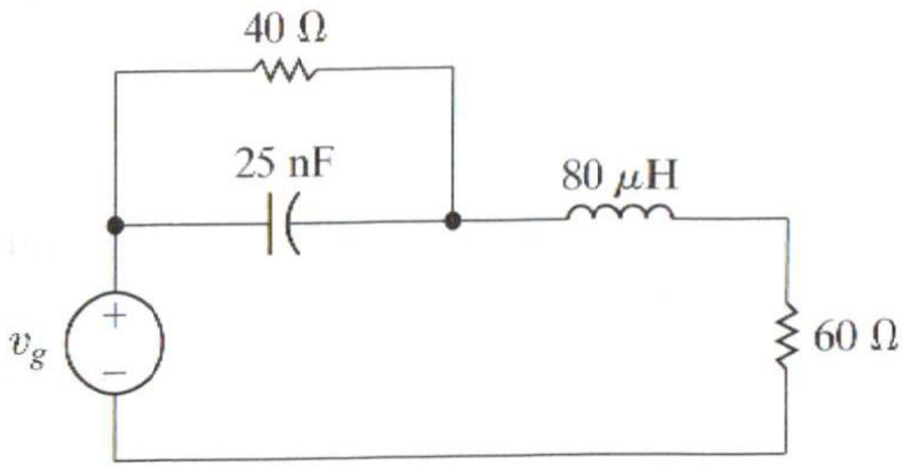
$$v_o = 0.89\cos(200t + 153.43^\circ)\,\text{V}$$

2) **The switch has been closed a long time before opening at t=0. Find**

a. $i_o(t)$ **b. $v_o(t)$**



3) **Find the average power, the reactive power and the apparent power supplied by the voltage source in the circuit if vg = 40cos(1000000t) Volts (this is magnitude, not rms).**



4) **The sinusoidal voltage source Vg = 4cos(200t). If the op-amp is ideal, find the output voltage Vo(t)**