Problem 1:

A) A linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}, where V_{Th} is the open-circuit voltage at the terminals and R_{Th} is the input or equivalent resistance at the terminals when the independent sources are turned off.

B) A linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source I_N in parallel with a resistor R_N, where I_N is the sort-circuit current through the terminals and R_N is the input or equivalent resistance at the terminals when the terminals when the independent sources are turned off.

Grading criteria: 3 pts for equivalent circuit with a resistor and a source
5 pts for mentioning R_{Th} and V_{Th} in series
5 pts for mentioning R_N and I_N in parallel

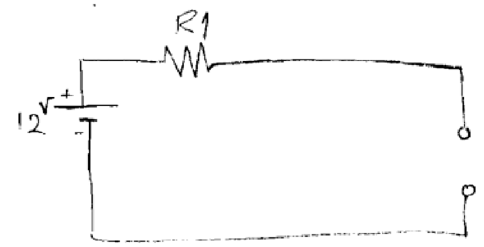
Problem 2:

Complete response = transient response + steady-state response
A complete response consists of a transient response (temporary response) and a steady-state response (permanent response). The transient response is the circuit's temporary response that will die out with time. And the steady-state response is the behavior of the circuit a long time after an external excitation is applied.

Grading criteria: 5 pts for mentioning transient and steady-state responses for the complete response
5 pts for temporary responses for the transient response

Problem 3:

$t < 0$:

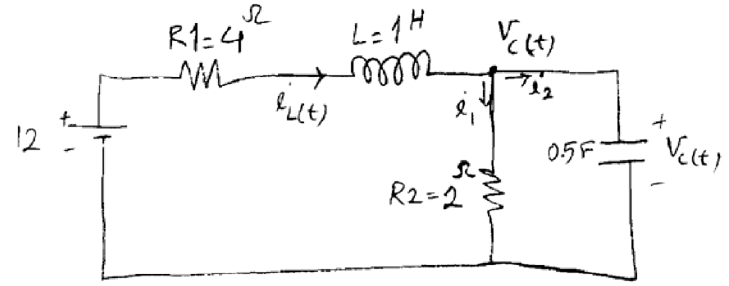


initial conditions:

$i_L(0^-) = 0 = i_L(0^+)$

$V_C(0^-) = 12^V = V_C(0^+)$

$t > 0$:



$i_{L(t)} = i_1 + i_2$: KCL

$\Downarrow$

$i_L = \frac{V_c}{2} + 0.5\frac{dV_c}{dt}$ (1)

$12^V = 4i_L + V_L + V_C = 4i_L + 1.\frac{di_L}{dt} + V_c$ (2)

(1) $\xrightarrow{\frac{d}{dt}}$ $\frac{di_L}{dt} = \frac{1}{2}\frac{dV_c}{dt} + 0.5\frac{d^2V_c}{dt^2}$

$\Rightarrow 12^V = 4\left(\frac{V_c}{2} + 0.5\frac{dV_c}{dt}\right) + \left(\frac{1}{2}\frac{dV_c}{dt} + 0.5\frac{d^2V_c}{dt^2}\right) + V_c$

$\Rightarrow 12 = V_c + 2V_c + 2\frac{dV_c}{dt} + \frac{1}{2}\frac{dV_c}{dt} + \frac{1}{2}\frac{d^2V_c}{dt^2} \Rightarrow \frac{d^2V_c}{dt^2} + 5\frac{dV_c}{dt} + 6V_c = 12$

$\Rightarrow S^2 + 5S + 6 = 0 \longrightarrow (S+2)(S+3) = 0 \Rightarrow S = -2$ & $S = -3 \longrightarrow$ Overdamped

$$\Rightarrow \quad V_{c}(t) = A e^{-2t} + B e^{-3t} + V_{ss}$$

$$V_{ss} = V_{C}(t \to \infty) = \frac{2}{4+2} \times 12 = 4^{V}$$

$$V_{C}(0) = 12 = A + B$$

$$① \xrightarrow{t=0} \quad i_{L}(0) = \frac{V_{C}(0)}{2} + 0.5 \frac{dV_c}{dt}\Big|_{t=0} \Longrightarrow 0 = \frac{12}{2} + \frac{1}{2}\left[-2A - 3B\right] \Rightarrow 2A + 3B = 12$$

$$\begin{cases} A + B = 12 \\ 2A + 3B = 12 \end{cases} \Longrightarrow \begin{cases} A = 24 \\ B = -12 \end{cases} \Rightarrow \boxed{V_{C}(t) = 24 e^{-2t} - 12 e^{-3t} + 4}$$

$$i_{L}(t) = \frac{1}{2} V_{c}(t) + \frac{1}{2} \frac{dV_c}{dt} = 12 e^{-2t} - 6 e^{-3t} + 2 + \frac{1}{2}\left[-48 e^{-2t} + 36 e^{-3t}\right]$$

$$\Rightarrow \quad \boxed{i_{L}(t) = -12 e^{-2t} + 12 e^{-3t} + 2}$$

Grading criteria:

Initial conditions 4pts.

Writing correct KCL/KVL leading to correct second order equation and correct characteristic equation 6pts (defining the Overdamped case 2pts).

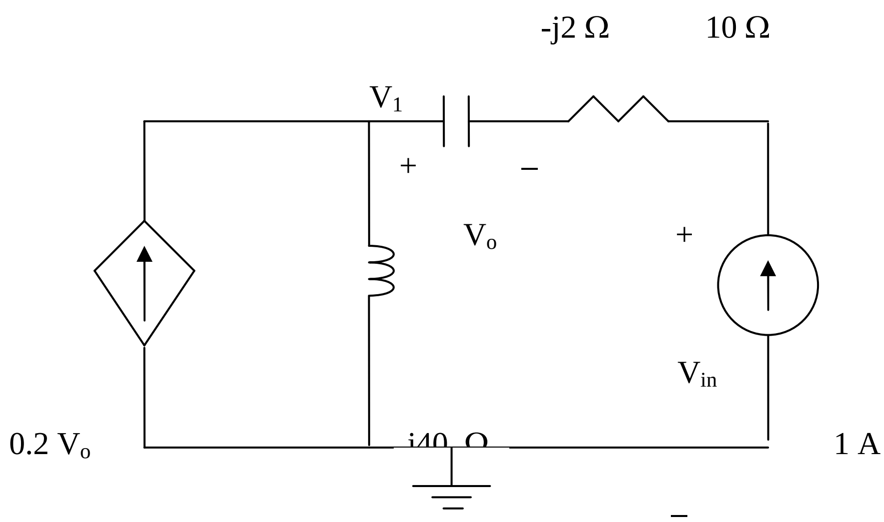
Finding Vc(t) 5pts.

Finding $i_L(t)$ 5pts.

Any attempt 3pts.

Problem 4:

Insert a 1-A current source at the output as shown below.



$$0.2v_o + 1 = \frac{V_1}{j40}$$

But $v_o = -1(-j2) = j2$

$$j2x0.2 + 1 = \frac{V_1}{j40} \longrightarrow V_1 = -16 + j40$$

$V_{in} = V_1 - V_o + 10 = -6 + j38 = 1xZ_{in}$

$Z_{in} =$ **$-6 + j38\ \Omega$**.

Grading criteria:

Adding 1A soure 2pts,

Finding Vo 4pts, KCL at the node (or KVL at loop) 5pts,

Finding Vin 5pts,

Mentioning Zin = Vin/1A and find Zin 4pts.

Writing everything up to end of nodal without solving it 15 pts,

Any wrong attempt 3points

Problem 5:

Consider the circuit in the frequency domain as shown below.

Let $\mathbf{Z} = (R_2 + j\omega L) \parallel \frac{1}{j\omega C}$

$$\mathbf{Z} = \frac{\frac{1}{j\omega C}(R_2 + j\omega L)}{R_2 + j\omega L + \frac{1}{j\omega C}} = \frac{R_2 + j\omega L}{1 + j\omega R_2 - \omega^2 LC}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{\mathbf{Z}}{\mathbf{Z} + R_1} = \frac{\frac{R_2 + j\omega L}{1 - \omega^2 LC + j\omega R_2 C}}{R_1 + \frac{R_2 + j\omega L}{1 - \omega^2 LC + j\omega R_2 C}}$$

$$\frac{\mathbf{V}_o}{\mathbf{V}_s} = \underline{\frac{\mathbf{R_2 + j\omega L}}{\mathbf{R_1 + R_2 - \omega^2 LCR_1 + j\omega(L + R_1 R_2 C)}}}$$

Grading criteria:

Finding Z or writing related nodal 10 pts.

Writing correct voltage divider or solving the nodal correctly and find H(w) 10pts.

Any attempt 5 pts.

Problem 6:

$$\frac{V - V_s}{R} + \frac{V}{j\omega L + \frac{1}{j\omega C}} + j\omega CV = 0$$

$$V + \frac{j\omega RCV}{-\omega^2 LC + 1} + j\omega RCV = V_s$$

$$\left(\frac{1 - \omega^2 LC + j\omega RC + j\omega RC - j\omega^3 RLC^2}{1 - \omega^2 LC}\right) V = V_s$$

$$V = \frac{(1 - \omega^2 LC)V_s}{\underline{1 - \omega^2 LC + j\omega RC(2 - \omega^2 LC)}}$$

Grading criteria:

Writing correct nodal 10pts.

Arranging the nodal in regards to V and Vs 5pts.

Solving the equations and find V correctly 5pts.

Any attempt 5pts.