ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2019 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

16-EL-A1-CIRCUITS

Question 1 (15 points)

For the circuit shown in Figure 1, considering that the ideal operational amplifier operates in its linear region and that the capacitor is totally discharged initially,

a) Find the expression of the transfer function $H(s) = V_L(s)/V_i(s)$
b) Considering that $R = 50\ \Omega$, $R_1 = 30\Omega$, $R_2 = 100\Omega$, $R_3 = 150\Omega$, $C = 1mF$, $R_L = 15\ \Omega$ and the output current in steady state is $i_L(t) = 10 \sin(300t + 48^o)$, find the input voltage $v_i(t)$.

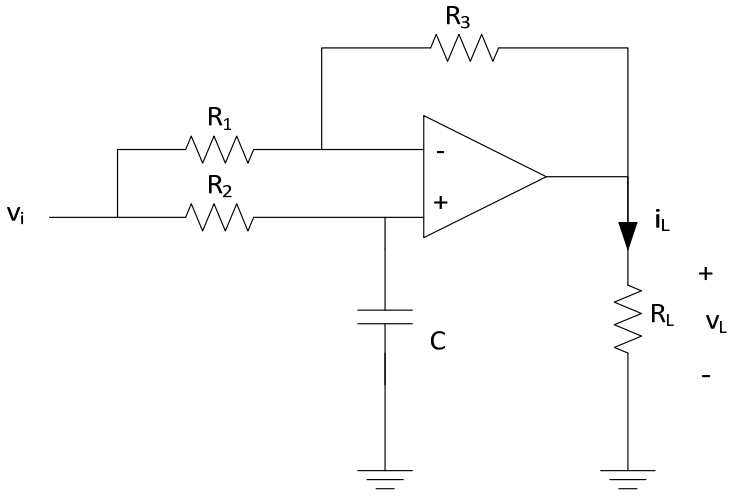

Figure 1

Question 2 (15 points)

Calculate the voltage at nodes v_1 and v_2 in the circuit shown in Figure 2.

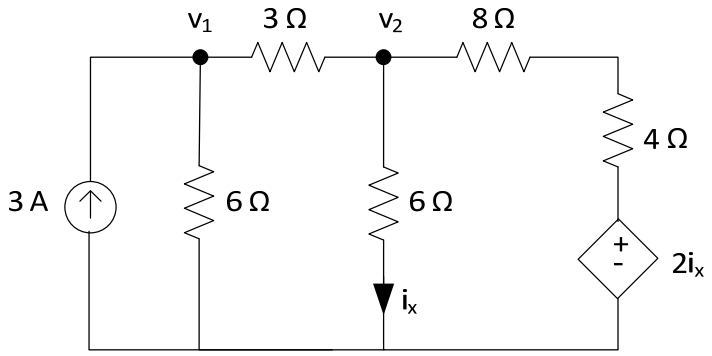

Figure 2

Question 3 (10 points)

For the circuit shown in Figure 3,

a) Draw the equivalent Norton circuit le circuit.
b) Draw the equivalent Thevenin circuit.

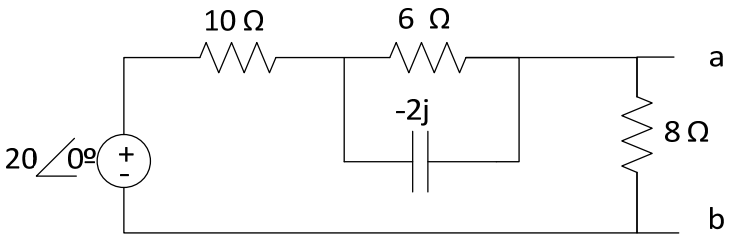

Figure 3

Question 4 (15 points)

For the circuit shown in Figure 4 where I = 50 mA, C = 250 μF, L = 4 mH, R_1 = 300 Ω, R_2 = 600 Ω and where no energy is stored initially,

a) Provide the equation of the current $i_L(t)$ for $t \geq 0$.
b) Provide the equation of v(t) for $t \geq 0$?
c) Which step response of Figure 5 corresponds to the current $i_L(t)$ once the switch is closed?
d) Is it possible to obtain a circuit which behaves like a critically damped system by only changing the value of the resistor R_2? If so, what would be this value of R_2? If not, justify your answer by appropriate calculations.

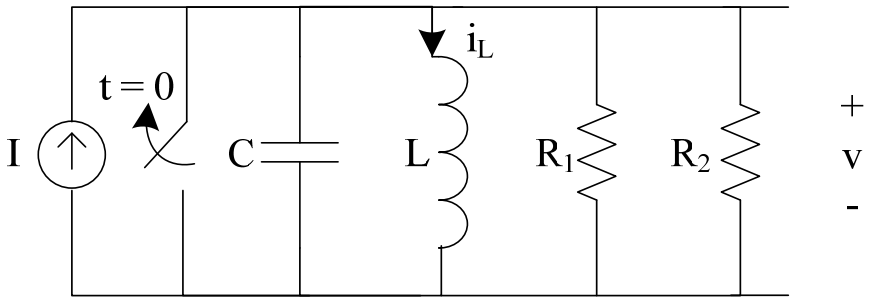

Figure 4

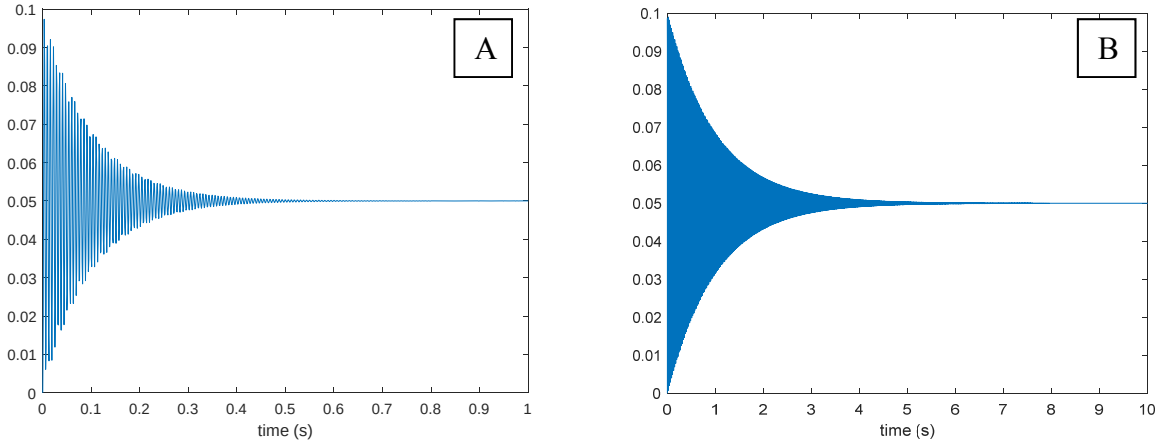

Figure 5

Question 5 (20 points)

Considering that for the circuit shown in Figure 6,

- The RMS voltage of the source (V_s) is $100\angle 0^o$ V
- $L_1 = 4j$;
- $R_2 = 35\ \Omega$;
- $L_2 = 26j$;
- The source provides a reactive power of 120 VAR ;
- The average power and the reactive power provided to the load are respectively 140 W and 104 VAR ;

a) Calculate the value of the resistor R_1 in the line.
b) Calculate the average power lost in the transmission line.

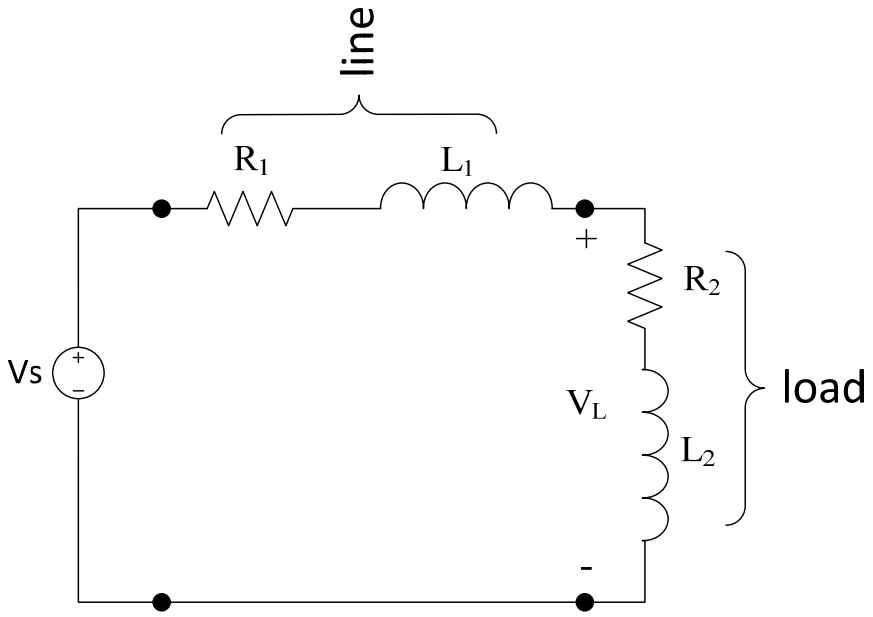

Figure 6

Question 6 (10 points)

For the circuit shown in Figure 7,

a) Provide the Thevenin equivalent circuit.
b) What would be the values of the resistor and the capacitor to connect between ports a and b in order to maximize the average power at the output of the circuit?
c) Calculate this maximal average power.

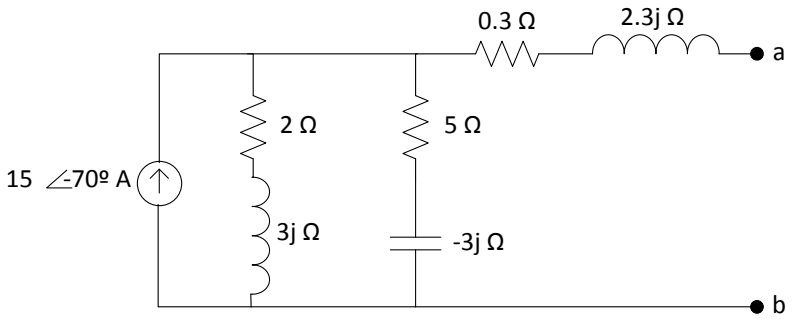

Figure 7

Question 7 (15 points)

For the circuit shown in Figure 8,

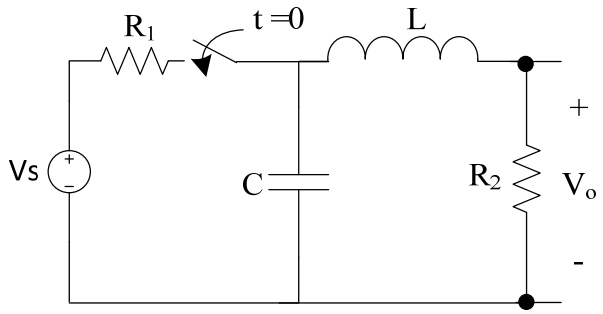

Figure 8

a) Considering that the voltage in the capacitor and the current in the inductor are both zero for t < 0, find the expression of the transfer function $H(s) = \frac{V_o(s)}{V_s(s)}$ which describes the behavior of the circuit once the switch is closed.
b) At t = 0, the switch is closed and the input voltage (V_s) is 10V with R1 = 5 Ω, R2 = 15 Ω, C = 5mF and L = 5mH. What will be the final value of the output voltage (V_o)?
c) What is the value of the current in the inductor at $t = 0^+$?
d) What is the value of the current in the capacitor at $t = 0^+$?