National Exams December 2009

04-BS-4 Electric Circuits and Power

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of assumptions made;
2. Candidates may use one of two calculators, a Casio or Sharp approved models. This is a **Closed-Book** exam. **One** aid sheet written on both sides is permitted.
3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
4. All questions are of equal value.

Marking Scheme

Question 1: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 2: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 3: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 4: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 5: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 6: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 7: (a) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 1

In the DC circuit of Figure 1 assume the following: $R_1 = 10\,\Omega$, $R_2 = 7\,\Omega$, $R_3 = 10\,\Omega$, $R_4 = 4\,\Omega$, $R_5 = 1\,\Omega$, and $V_s = 4\,\text{V}$. It is observed that $I_2 = 4\,\text{A}$.

a) Write Kirchhoff's Current Law (KCL) equations for nodes A, B, and C;

b) Write Kirchhoff's Voltage Law (KVL) equations for loops ABCA, ACDA and BCDB;

c) Calculate R_0;

d) Calculate current I_0 and the power dissipated in resistor R_0.

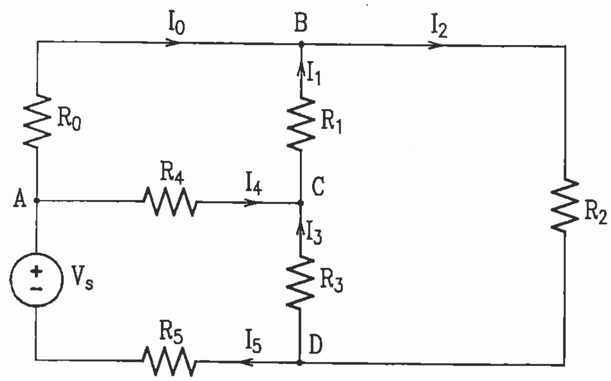

Figure 1: Circuit diagram for Question 1

Question 2:

Consider the circuit below. Known parameters are: $R_1 = 50\,\Omega$, $R_2 = 20\,\Omega$, $R_3 = 50\,\Omega$, $R_4 = 100\,\Omega$, $R_5 = 100\,\Omega$, $R_6 = 20\,\Omega$, $R_7 = 80\,\Omega$, $V_{s1} = 20\,\text{V}$, $V_{s2} = 10\,\text{V}$, and $I_s = 3\,\text{A}$. Determine the following:

a) Thevenin equivalent voltage seen by the load;

b) Thevenin equivalent resistance seen by the load;

c) Determine the load resistance corresponding to the maximum power transfer. Determine the maximum power transferred to the load.

d) What is the power transferred to the load, if the load resistance is $R_L = 72\,\Omega$?

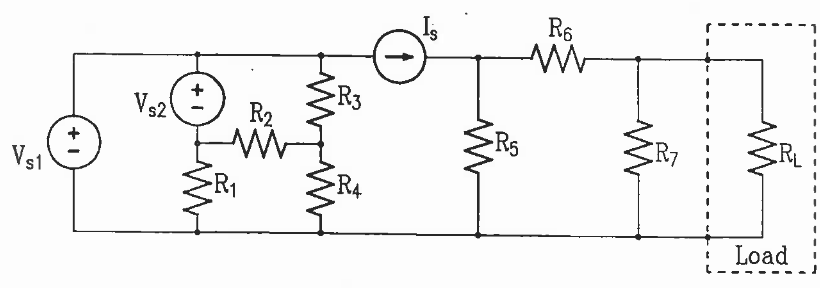

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3, $R_1 = 5\,\text{k}\Omega$, $R_2 = 2\,\text{k}\Omega$, $R_3 = 3\,\text{k}\Omega$, $R_4 = 6\,\text{k}\Omega$, $C = 5\,\mu\text{F}$, $V_1 = 24\,\text{V}$, and $V_2 = 15\,\text{V}$. Consider the steady-state operating condition when switch S is open.

a) Calculate $i_1(0^-)$, $v_R(0^-)$, and $v_C(0^-)$;

b) Assume that S is closed at $t = 0$. Calculate the time constant of the current transient.

c) Draw $i_1(t)$, $v_R(t)$, and $v_C(t)$ from $t = 0\,\mu\text{s}$ to $t = 0.5\,\mu\text{s}$;

d) Calculate the steady-state current $i_1(\infty)$ and steady-state voltages $v_R(\infty)$ and $v_C(\infty)$ when S is in a closed position for a long time.

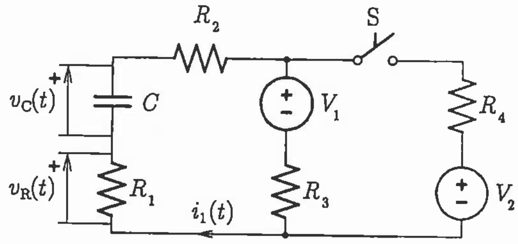

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4, parameters are: $R = 10\,\Omega$, $L_1 = 10\,\text{mH}$, $L_2 = 5\,\text{H}$, $C_1 = 10\,\mu\text{F}$, $C_2 = 200\,\text{pF}$, and $V_s(t) = 100\cos(\omega t)\,\text{V}$.

a) Assume that the source frequency is 60 Hz. Calculate the current $i(t)$ and the voltage $v_1(t)$.

b) For the source frequency 60 Hz, Calculate active and reactive power supplied by the source.

c) Determine the source frequency so that the current $i(t)$ is in phase with the voltage $v_2(t)$. What is this frequency called?

d) Determine the source frequency so that the power supplied by the source is zero.

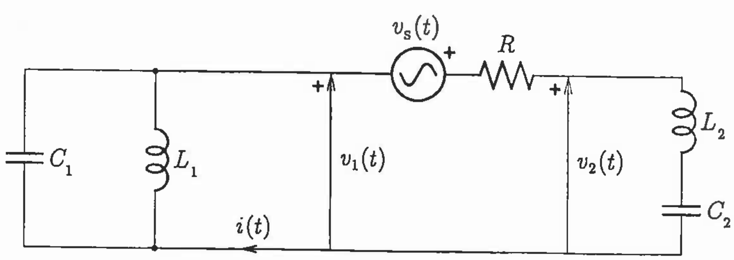

Figure 4: Circuit diagram for Question 4

Question 5

In the circuit of Figure 5 assume the following: $L_1 = 160\,\text{mH}$, $L_2 = 80\,\text{mH}$, $R = 4\,\Omega$, $C = 10\,\text{mF}$, $v_{s1}(t) = \sqrt{2}\,10\cos(25\,t + \frac{\pi}{4})\,\text{V}$, and $v_{s2}(t) = 10\cos(25\,t)\,\text{V}$. Assume that the circuit is in a steady-state operating condition. Calculate the following:

a) Impedances $\underline{Z_{L1}}$, $\underline{Z_{L2}}$, and $\underline{Z_C}$;

b) Voltage phasor $\underline{V_1}$;

c) Current phasors $\underline{I_{L1}}$ and $\underline{I_{L2}}$;

d) Resistor current in time-domain, $i_R(t)$.

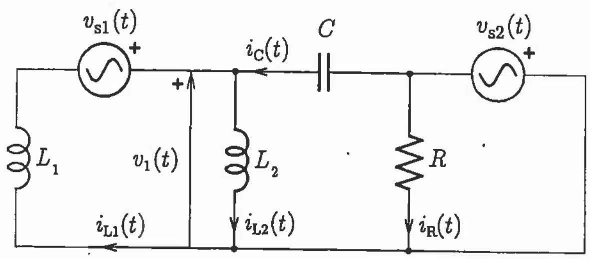

Figure 5: Circuit diagram for Question 5

Question 6

A full-bridge bridge diode rectifier is used to provide a DC current to a $50\,\text{k}\Omega$ resistive load. Rectifier will be supplied by an ideal AC voltage source ($60\,\text{Hz}$, $20\,\text{V}_{\text{RMS}}$).

a) Draw the rectifier schematic diagram. Sketch the input voltage, the output voltage, the output current, and the current through each of the four rectifier diodes.

b) Find the peak and the average current in the load.

c) Sketch the input and the output voltage if the rectifier diode has on-state voltage drop of $0.5\,\text{V}$.

d) Using a $R = 100\,\Omega$ resistance, design an RC low-pass filter (for DC side) that can attenuate a $120\,\text{Hz}$ sinusoidal voltage by $20\,\text{dB}$ with respect to the DC gain.

Question 7

A logic platform controls a heating and air-conditioning system. To operate, it uses the following sensors:

A) Time elapsed from the last compressor turn-off instant (1 if the minimal time is exceeded)

B) Over-temperature (1 if the ambient temperature is higher than t_{HI})

C) Under-temperature (1 if the ambient temperature is lower than t_{LO})

D) Heating function switch (1 if ON)

E) Cooling function switch (1 if ON)

F) Furnace over-temperature (1 if the furnace temperature is higher than $t_{Furnace}$)

The furnace should be turned on if the heating function switch is in the ON position and the ambient temperature is lower than the set value for heating t_{LO}. The compressor should be turned on if the cooling function switch is in the ON position ant the ambient temperature is higher than the set value for cooling t_{HI}. Once the compressor is turned off there is a minimum time delay before it is allowed to turn it on again. This is controlled by the appropriate sensor. Fan should work if the compressor is ON or if the furnace temperature is higher than $t_{Furnace}$.

a) Design the logic circuit that controls the furnace.

b) Design the logic circuit that controls the compressor.

c) Construct the truth table for controlling the fan.

d) Design the logic circuit that controls the fan.

Note:

All types of gates could be used to construct the logic circuits.