National Exams May 2010

# 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: $R_1 = 10\,\Omega$, $R_2 = 7\,\Omega$, $R_3 = 1\,\Omega$, $R_5 = 1\,\Omega$, $R_6 = 2\,\Omega$, $R_7 = 8\,\Omega$, $I_2 = 5\,\text{A}$, $I_4 = 10\,\text{A}$, and $V_5 = 6\,\text{V}$. It is observed that $I_5 = 4\,\text{A}$.

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

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

c) Calculate $R_0$;

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

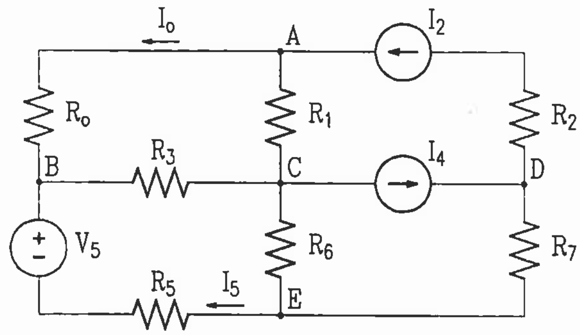


Figure 1: Circuit diagram for Question 1

Consider the circuit below. Known parameters are: $R_1 = 3\,\Omega$, $R_2 = 6\,\Omega$, $R_3 = 6\,\Omega$, $R_4 = 3\,\Omega$, $V_s = 3\,\text{V}$, and $I_s = 1\,\text{A}$. 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 $R_L = 21\,\Omega$?

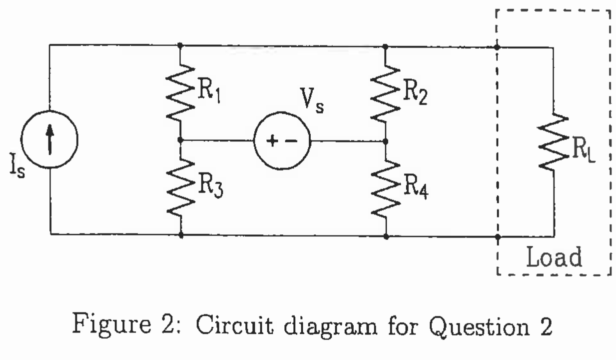


Figure 2: Circuit diagram for Question 2

## Question 3

In the circuit of Figure 3 $R_1 = 5\,\mathrm{k}\Omega$, $R_2 = 2\,\mathrm{k}\Omega$, $R_3 = 3\,\mathrm{k}\Omega$, $R_4 = 3\,\mathrm{k}\Omega$, $R_5 = 6\,\mathrm{k}\Omega$, $R_6 = 18\,\mathrm{k}\Omega$, $R_0 = 1\,\Omega$, $C_1 = 10\,\mu\mathrm{F}$, $C_2 = 3\,\mu\mathrm{F}$, $C_3 = 6\,\mu\mathrm{F}$, $V_s = 24\,\mathrm{V}$, and $I_s = 200\,\mathrm{mA}$. The switch is in position 0 for a long time (more than 10 minutes). At $t = 0$, the switch moves to position 1 and stays there for 5ms. After 5 seconds, the switch moves to position 2. Assume that the energy stored in capacitors C2 and C3 is zero at t=0.

a) Calculate the time constant of the circuit when the switch is in position 1;

b) Calculate the voltage across the capacitor $C_1$ after 1 second.

c) Draw the current $i_1(t)$ and voltage $v_C(t)$ from $t = 0$ to $t = 200\,\mathrm{ms}$;

d) What is the total energy stored in all three capacitors at $t = 6$ seconds.

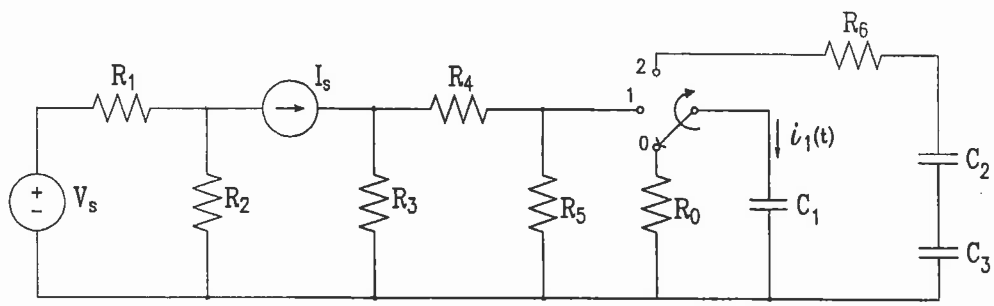


Figure 3: Circuit diagram for Question 3

## Question 4

In the circuit of Figure 4, parameters are: $R = 10\,\Omega$, $L_1 = 10\,\mathrm{mH}$, $L_2 = 5\,\mathrm{H}$, $C_1 = 1\,\mu\mathrm{F}$, $C_2 = 0.6\,\mu\mathrm{F}$, and $V_s(t) = 100\cos(\omega\, t)\,\mathrm{V}$.

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

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

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

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

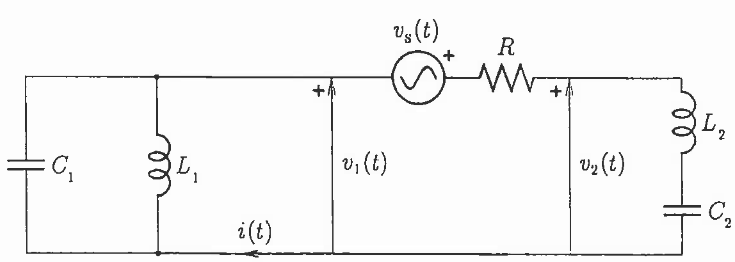


Figure 4: Circuit diagram for Question 4

## Question 5

In the circuit of Figure 5 assume the following: $L_1 = 160\,\text{mH}$, $L_2 = 80\,\text{mH}$, $R = 2\,\Omega$, $C = 20\,\text{mF}$, $v_{s1}(t) = \sqrt{2}\,10\cos(25\,t + \frac{\pi}{4})\,\text{V}$, 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, $i_R(t)$.

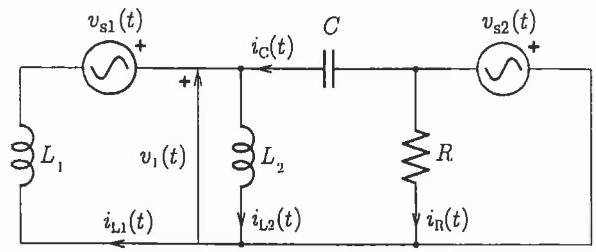


Figure 5: Circuit diagram for Question 5

## Question 6

A half-wave diode rectifier is used to provide a DC current to a $50\,\text{k}\Omega$ resistive load. Rectifier is supplied by an ideal AC voltage source (60 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 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 0.6 V.

d) Using a $100\,\Omega$ resistance, design an RC low-pass filter (for DC side) that can attenuate a 60 Hz sinusoidal voltage by 20 dB with respect to the DC gain.

## Question 7

A logic platform provides control system for a subway. To operate, it uses the following sensors:

A) Train movement (1 if moving)

B) Position of doors (1 if open)

C) Train location (1 if at a station)

D) Push button for opening doors (1 if pressed)

E) Push button for closing doors (1 if pressed)

F) Door obstruction sensor (1 if obstruction is detected)

G) Signal (1 if green)

The subway doors should open when the train it is not moving, if it is at a station, and if an open door action has been requested. Once opened, the subway doors should not close if the signal is not green or if the door obstruction has been detected. Pressing the button for opening doors should result in no action if the doors are already open and pressing the button for closing doors should result in no action if the doors are closed.

Neglect the possibility that two button can be pressed at the same time.

a) Write a truth table for the circuit that opens the subway doors when the push button for opening doors is pressed and all conditions are met.

b) Write a truth table for the circuit that closes the subway doors when the push button for closing doors is pressed and all conditions are met.

c) Design a logic circuit that opens the subway doors when the push button for opening doors is pressed and all conditions are met.

d) Design a logic circuit that closes the subway doors when the push button for closing doors is pressed and all conditions are met.

## Note:

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