National Exams May 2018

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.

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) 10 marks, (b) 10 marks.

Question 1

In the DC circuit of Figure 1 assume the following: $R_1 = 2\,\Omega$, $R_2 = 2\,\Omega$, $R_3 = 4\,\Omega$, $R_4 = 2\,\Omega$, $R_5 = 2\,\Omega$, $V_{s1} = 8\,\text{V}$, $V_{s3} = 12\,\text{V}$, and $V_{s5} = 16\,\text{V}$.

a) Write Kirchhoff's current law equations for nodes B and D;

b) Write Kirchhoff's voltage law equations for loops ABDA, and BCDB;

c) Calculate power dissipated on resistor R_1;

d) Calculate power produced by the source V_{s3}.

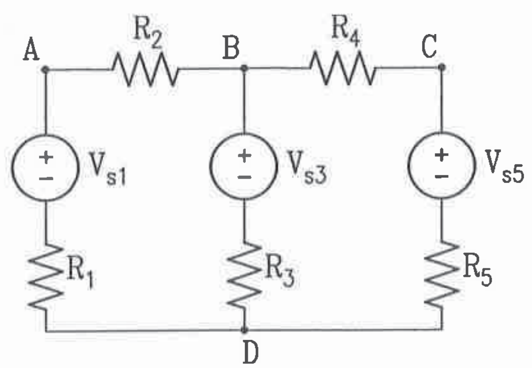

Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 2.5\,\text{k}\Omega$, $R_2 = 2\,\text{k}\Omega$, $R_3 = 50\,\Omega$, $R_4 = 350\,\Omega$, $C_4 = 7\,\mu\text{F}$, $R_5 = 40\,\text{k}\Omega$, $R_6 = 10\,\text{k}\Omega$, $I_s = 1\,\text{mA}$, $V_{s1} = 10\,\text{V}$, and $V_{s2} = 40\,\text{V}$. Determine the following:

a) Thevenin equivalent resistance with respect to the load terminals;

b) Thevenin equivalent voltage with respect to the load terminals;

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

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

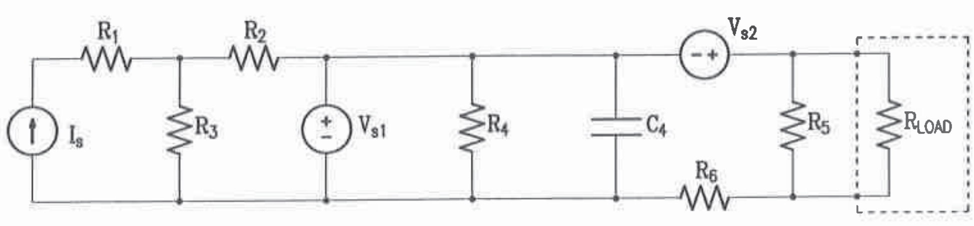

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3 $R_1 = 3\,\Omega$, $R_2 = 3\,\Omega$, $R_3 = 6\,\Omega$, $R_4 = 4\,\Omega$, $R_5 = 4\,\Omega$, $R_6 = 8\,\Omega$, $L = 20\,\text{mH}$, and $V_s = 12\,\text{V}$. The switch S is closed for a long time. At $t = 0\,\text{s}$, the switch S opens.

a) Calculate the voltage across the resistor R_4 and the inductor current in steady-state while the switch S is closed.

b) What is the energy stored in the inductor before the switch is opened.

c) Calculate the time constant of the circuit when the switch is open;

d) Plot the current $I_L(t)$ from $t = -5\,\text{ms}$ to $t = 25\,\text{ms}$;

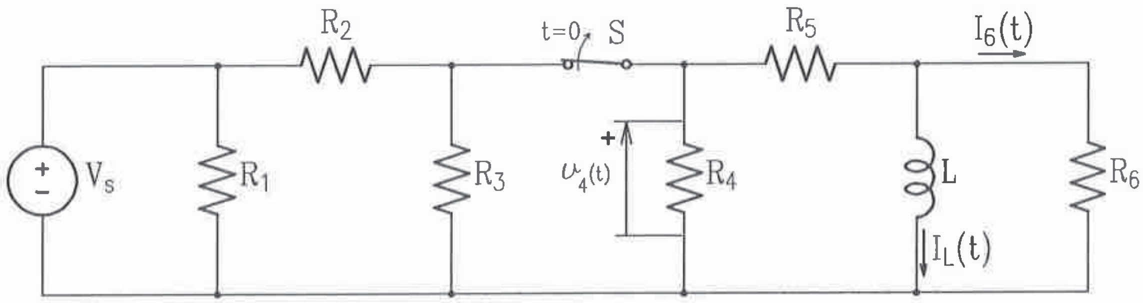

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 assume the following: $L_1 = 80\,\text{mH}$, $L_2 = 20\,\text{mH}$, $R_1 = 8\,\Omega$, $R_2 = 2\,\Omega$, $C = 5\,\text{mF}$, and $v_s(t) = \sqrt{2}\,10\cos(100\,t)\,\text{V}$. 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 phasor $\underline{I_1}$;

d) Equivalent impedance seen by the source.

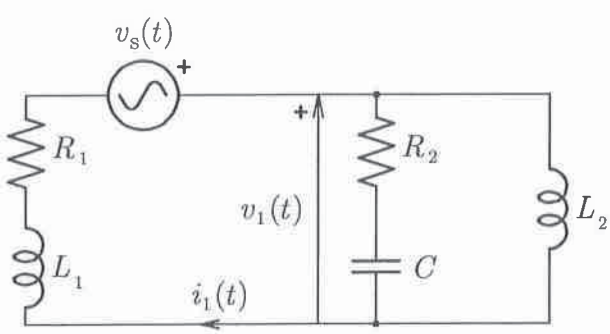

Figure 4: Circuit diagram for Question 4

Question 5

A magnetic circuit consisting of a fixed horseshoe core and a moveable core element (relay armature) is shown in Figure 5. Consider the relative permeability of the core $\mu_r = 2000$, total number of turns on both legs $N = 1000$.

a) Calculate the equivalent reluctance of each part of the magnetic circuit.

b) Calculate the current needed to produce the magnetic flux $\phi = 2\,\text{mWb}$ in the air gap;

c) Calculate the magnetic flux density and magnetic field intensity in the air gap.

d) Calculate the total electromagnetic force acting on the relay armature.

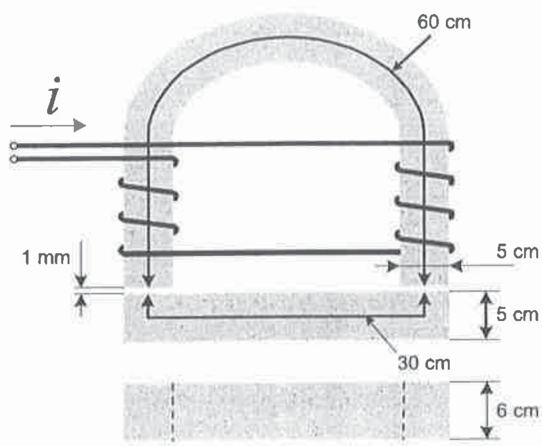

Figure 5: Magnetic core for Question 5

Question 6

Design a rectifier to provide a DC current to a 50 kΩ resistive load. Rectifier will be supplied by an ideal AC voltage source (60 Hz, 20 V_{RMS}).

a) How many diodes you need for such rectifier? Draw the rectifier schematic diagram.

b) Sketch the input voltage,the output voltage, the output current, and the current through each of the four rectifier diodes.

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

d) Sketch the input and the output voltage if the rectifier diode has on-state voltage drop of 0.5 V.

Question 7

A logic platform provides control for a simple elevator that operates between the first and the second floor only. The following coditions should be considered:

A) There is a person in the elevator (1 if yes).

B) The elevator is on the first floor (1 if yes).

C) The elevator is on the second floor (1 if yes).

D) Push button located at the first floor corridor (1 if pressed).

E) Push button located at the second floor corridor (1 if pressed).

F) First floor push button located inside the elevator (1 if pressed).

G) Second floor push button located inside the elevator (1 if pressed).

H) Elevator doors are closed (1 if yes).

Controls located at the corridor should be disabled if there is a person inside the elevator. Controls located inside the elevator should be disabled if there is no one in the elevator. No action should be possible while elevator doors are open. When the elevator is instructed to move to the other floor, the logic should check if all conditions are met and then the elevator starts moving toward the other floor, otherwise it should not take any action.

Design the logic circuit that does the following:

a) Initiates elevator movement from the first to the second floor when the push button located on the second floor corridor is pressed.

b) Initiates appropriate elevator action when one of the push buttons located inside the elevator is pressed.

Note:

All kinds of gates can be used to construct the logic circuits. Neglect the possibility that any two sensors are activated simultaneously.