

National Exams May 2016
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 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) 5 marks, (b) 5 marks, (c) 5 marks, (d) 5 marks.

Question 1

In the DC circuit of Figure 1 assume the following: $R_1 = 10\ \Omega$, $R_2 = 11\ \Omega$, $R_3 = 2\ \Omega$, $R_4 = 5\ \Omega$, and $V_6 = 50\ \text{V}$. Measurement shows that $I_4 = 2\ \text{A}$.

- Write Kirchhoff's current law equations for nodes A, B, and C;
- Write Kirchhoff's voltage law equations for loops ACBA, ACDA, and ABCDA;
- Calculate I_5 ;
- Calculate power dissipated in resistor R_1 .

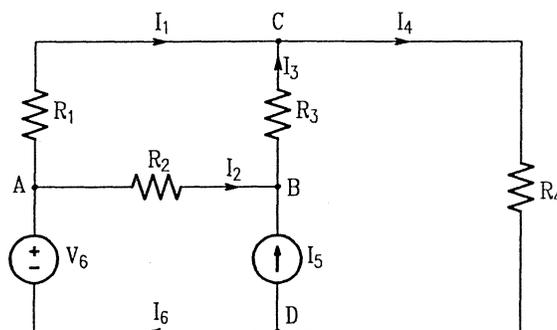


Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 12.5\ \text{k}\Omega$, $R_2 = 22\ \text{k}\Omega$, $R_3 = 50\ \Omega$, $R_4 = 350\ \Omega$, $R_5 = 40\ \text{k}\Omega$, $R_6 = 10\ \text{k}\Omega$, $I_s = 1\ \text{mA}$, $V_{s1} = 10\ \text{V}$, and $V_{s2} = 40\ \text{V}$. Determine the following:

- Thevenin equivalent resistance with respect to the load terminals;
- Thevenin equivalent voltage with respect to the load terminals;
- Determine the load resistance for the maximum power transfer. Determine the maximum power transferred to the load.
- Determine the power transferred to the load if the load resistance is $R_L = 2\ \text{k}\Omega$.

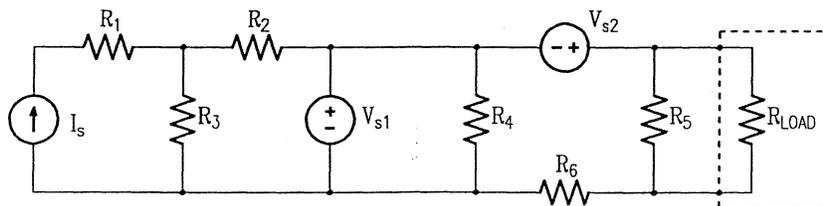


Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3 $R_1 = 3\text{ k}\Omega$, $R_2 = 3\text{ k}\Omega$, $R_3 = 6\text{ k}\Omega$, $R_4 = 1\ \Omega$, $C_1 = 10\ \mu\text{F}$, $C_2 = 3\ \mu\text{F}$, $C_3 = 6\ \mu\text{F}$, and $I_s = 200\text{ mA}$. The switch is in position 0. At $t = 0\text{ s}$, the switch moves to position 1. At $t = 5\text{ s}$, the switch moves to position 2. Assume that none of the capacitors has any stored energy at $t = 0\text{ s}$.

- Calculate the time constant of the circuit when the switch is in position 1;
- Calculate the voltage across the capacitor C_1 at $t = 1\text{ s}$.
- Calculate the time constant of the circuit when the switch is in position 2;
- What is the total energy stored in all three capacitors at $t = 6\text{ s}$.

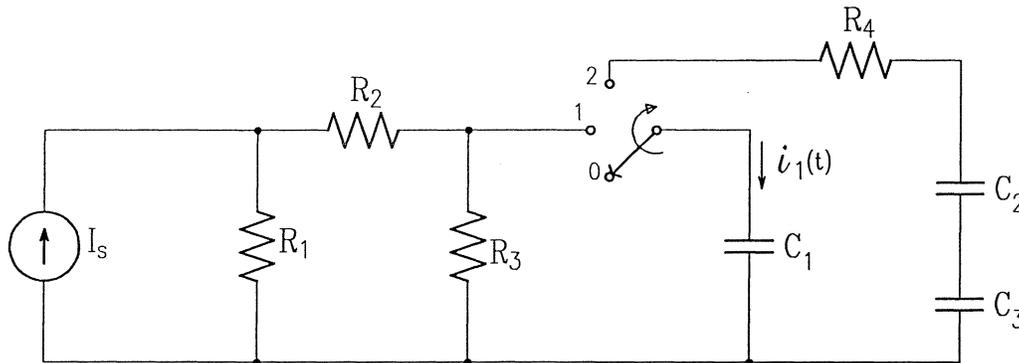


Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 assume the following: $L_1 = 160\text{ mH}$, $L_2 = 80\text{ mH}$, $R = 2\ \Omega$, $C = 20\text{ mF}$, $v_{s1}(t) = \sqrt{2} 10 \cos(25t + \frac{\pi}{4})\text{ V}$, and $v_{s2}(t) = 10 \cos(25t)\text{ V}$. Assume that the circuit is in a steady-state operating condition. Calculate the following:

- Impedances Z_{L1} , Z_{L2} , and Z_C ;
- Voltage phasor V_1 ;
- Current phasors I_{L1} and I_{L2} ;
- Resistor current in time-domain, $i_R(t)$.

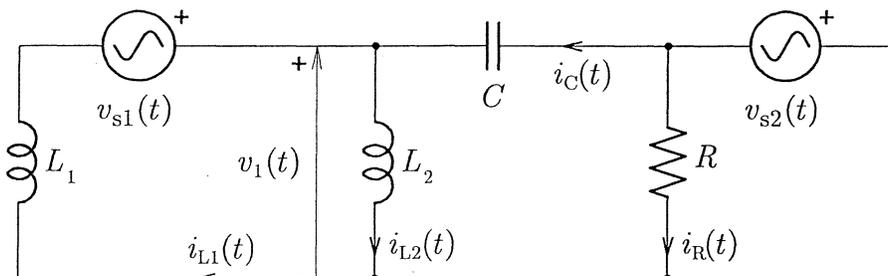


Figure 4: Circuit diagram for Question 4

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 $N = 1000$, and the current $i = 1\text{A}$.

- Calculate the total magnetomotive force in both windings.
- Calculate the equivalent reluctance of each part of the magnetic circuit.
- Calculate the magnetic flux, flux density and magnetic field intensity in the air gap.
- Calculate the total electromagnetic force acting on the relay armature.

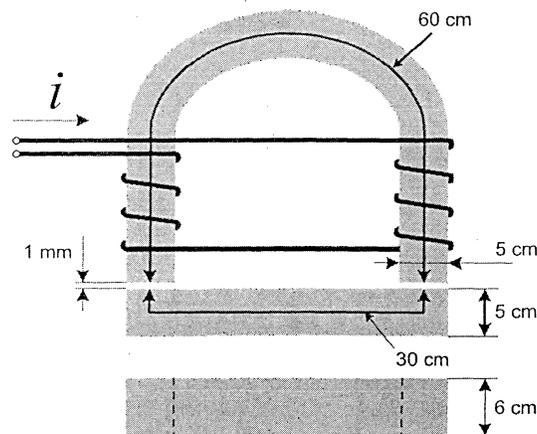


Figure 5: Magnetic core for Question 5

Question 6

A full bridge 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 Hz , 20 V_{RMS}).

- 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.
- Find the peak and the average current in the load.
- Sketch the input and the output voltage if the rectifier diode has on-state voltage drop of 0.5 V .
- Using a $100\ \Omega$ resistance, design an RC low-pass filter (for DC side) that can attenuate a 120 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.