

National Exams December 2013
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: $R_1 = 3\ \Omega$, $R_2 = 6\ \Omega$, $R_3 = 10\ \Omega$, $R_4 = 11\ \Omega$, $R_5 = 12\ \Omega$, $R_6 = 34\ \Omega$, $R_7 = 2\ \Omega$, and $V_s = 28\ \text{V}$. It is observed that $V_7 = 1\ \text{V}$.

- Write Kirchhoff's Current Law (KCL) equations for nodes A, B, and C;
- Write Kirchhoff's Voltage Law (KVL) equations for loops $R_1R_3R_4R_5V_s$ and $R_5R_6R_7$;
- Calculate I_s ;
- Calculate power dissipated in resistor R_1 .

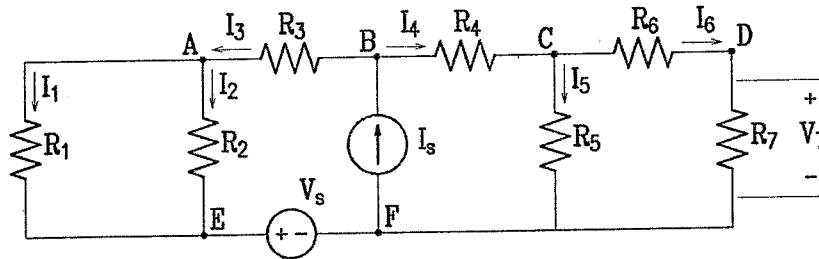


Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 12.5\ \text{k}\Omega$, $R_2 = 22\ \text{k}\Omega$, $R_3 = 50\ \Omega$, $R_4 = 350\ \Omega$, $R_5 = 10\ \text{k}\Omega$, $R_6 = 10\ \text{k}\Omega$, $R_7 = 5\ \text{k}\Omega$, $I_s = 1\ \text{mA}$ and $V_s = 20\ \text{V}$. Determine the following:

- Thevenin equivalent resistance with respect to the load terminals;
- Thevenin equivalent voltage with respect to the load terminals;
- Power transferred to the load if the load resistance is $R_L = 100\ \Omega$.
- Determine the load resistance for the maximum power transfer. Determine the maximum power transferred to the load.

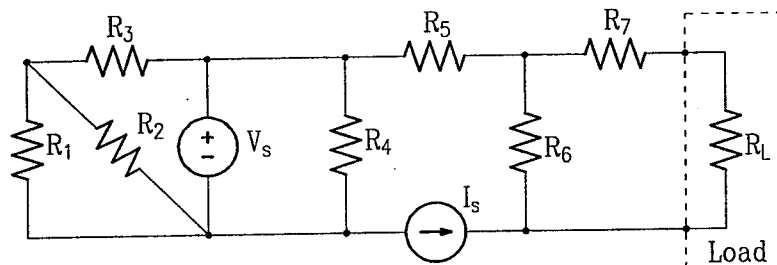


Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3 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, $i_R(t)$.

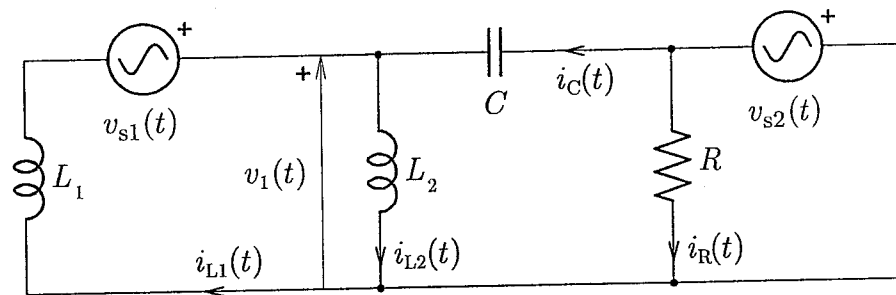


Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 $R_1 = 3 \text{ k}\Omega$, $R_2 = 3 \text{ k}\Omega$, $R_3 = 6 \text{ k}\Omega$, $R_4 = 18 \text{ k}\Omega$, $C_1 = 10 \mu\text{F}$, $C_2 = 3 \mu\text{F}$, $C_3 = 6 \mu\text{F}$, 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 $t = 1 \text{ s}$.
- Plot waveform of the current $i_1(t)$ from $t = -10 \text{ ms}$ to $t = 200 \text{ ms}$;
- What is the total energy stored in all three capacitors at $t = 6 \text{ s}$.

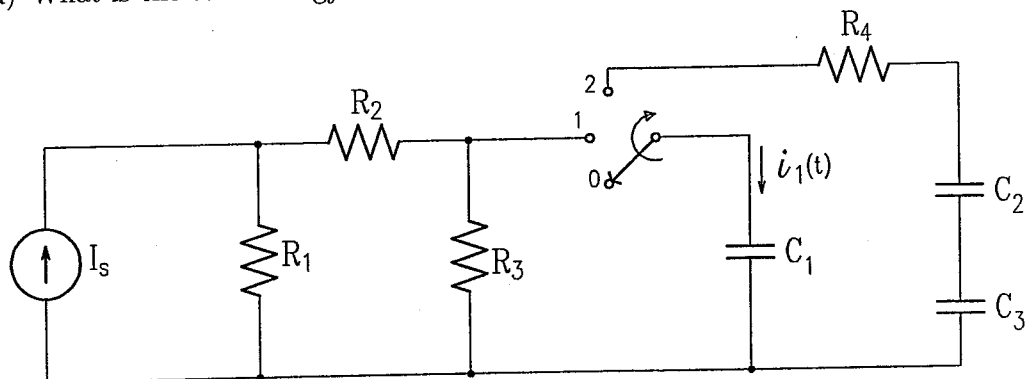


Figure 4: Circuit diagram for Question 4

Question 5

A magnetic core is shown in Figure 5. Consider that the cross section is uniform and equal to 100 mm^2 , relative permeability $\mu_r = 2000$, number of winding turns $N = 100$ and current $I = 1 \text{ A}$ ($\mu_0 = 4\pi \times 10^{-7}$).

- Compute the magnetomotive force.
- Calculate the equivalent reluctance of each part of the magnetic circuit.
- Draw the analog circuit representation of the magnetic circuit from Figure 5.
- Calculate the magnetic flux, flux density and magnetic field intensity in the air gap.

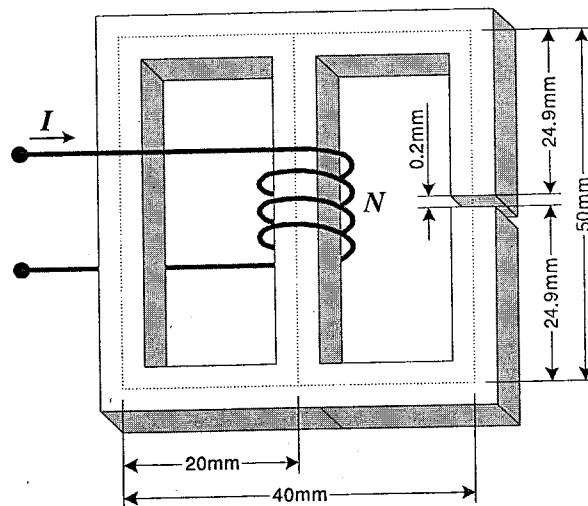


Figure 5: Magnetic core for Question 5

Problem 6

A half-wave 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 Hz , 20 V_{RMS}).

- Draw the rectifier schematic diagram. Sketch the input voltage, the output voltage and the output current. Indicate when the rectifier diode is conducting.
- 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 0.6 V .
- Using a 100Ω 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 for a simple elevator that operates between the first and the second floor only. The following conditions 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.