

National Exams May 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.

Question 1

In the DC circuit of Figure 1 assume the following: $R_1 = 10\ \Omega$, $R_2 = 1\ \Omega$, $R_3 = 2\ \Omega$, $R_4 = 10\ \Omega$, $I_5 = 3\ \text{A}$, and $V_6 = 50\ \text{V}$.

- Write Kirchhoff's current law equations for nodes A, B, and C. Write Kirchhoff's voltage law equations for loops ACBA, ACDA, and ABCDA;
- Using Kirchhoff's laws calculate currents I_1 and I_4 ;
- Calculate voltage V_{BD} ;
- Calculate power dissipated in resistor R_4 ?

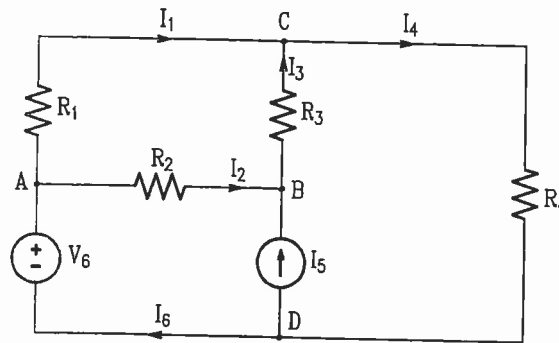


Figure 1: Circuit diagram for Question 1

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 $R_L = 72\ \Omega$.

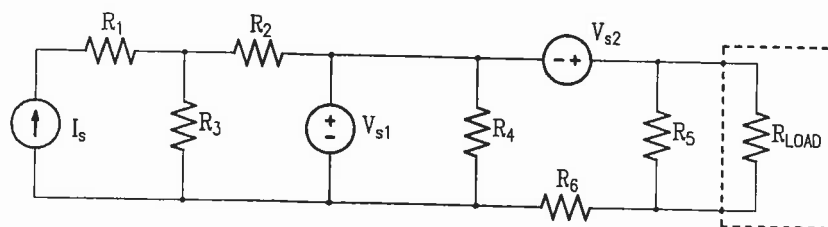


Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3, 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 $V_s(t) = 100 \cos(\omega t)\ \text{V}$.

- Assume that the source frequency is 60 Hz. Calculate the current $i(t)$ and the voltage $v_1(t)$.
- For the source frequency 60 Hz, Calculate active and reactive power supplied by the source.
- Determine the source frequency so that the current $i(t)$ is in phase with the voltage $v_2(t)$. What is this frequency called?
- Determine the source frequency so that the power supplied by the source is zero.

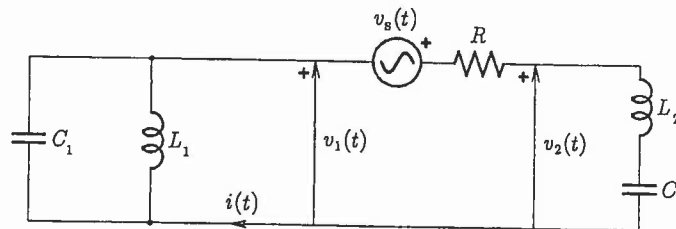


Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 assume the following: $L_1 = 1\ \text{mH}$, $L_2 = 5\ \text{mH}$, $R = 10\ \Omega$, $C = 1\ \mu\text{F}$, $v_{s1}(t) = 20 \cos(120\pi t)\ \text{V}$, and $v_{s2}(t) = 4\ \text{V}$. Two steady-state operating conditions, with switch S open or closed, are possible. Calculate the following steady-state conditions:

- When S open: Current phasor \underline{I}_1 and voltage phasor \underline{V}_1 ;
- When S open: Power dissipated in resistor R ;
- When S closed: Current $i_1(t)$ and voltage $v_1(t)$;
- When S closed: Power generated by the source v_{s2} .

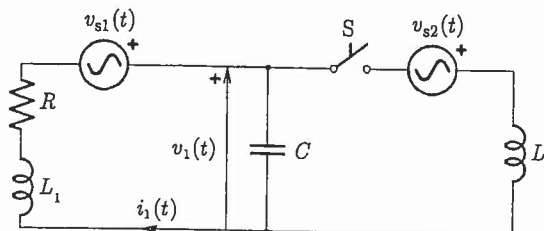


Figure 4: Circuit diagram for Question 4

Question 5

A magnetic core is shown in Figure 5. Relative permeability of the core is $\mu_r = 2000$ ($\mu_0 = 4\pi \times 10^{-7}$ H/m). Number of winding turns is $N = 100$. Assume that the core cross section is uniform and the combined length of all air-gaps is much smaller than the dimensions of the core cross-section. Calculate the following:

- The magnetomotive force in the core if $i = 2$ A.
- The equivalent reluctance of each part of the magnetic circuit.
- The magnetic flux, flux density and magnetic field intensity in each of the the air gaps for $i = 2$ A.
- Inductance of the coil from Figure 5.

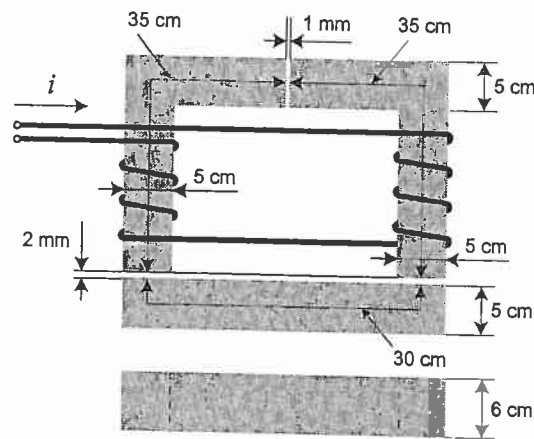


Figure 5: Magnetic core for Question 5

Question 6

A 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 , $50 \text{ V}_{\text{RMS}}$). The solution should use the minimal number of diodes possible.

- What is the minimal number of diodes that have to be used in such a rectifier? Draw the rectifier schematic diagram.
- Sketch the input voltage, the output voltage and the output current.
- Find the peak and the average load current.
- If the load has an inductive component, this kind of rectifier may cause significant overvoltages. Explain why.

Question 7

A logic platform provides control for an elevator. 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) The elevator is on the third floor (1 if yes).
- E) The push button located at the first floor corridor (1 if pressed).
- F) The push button located at the second floor corridor (1 if pressed).
- G) The push button located at the third floor corridor (1 if pressed).
- H) The first floor push button located inside the elevator (1 if pressed).
- I) The second floor push button located inside the elevator (1 if pressed).
- J) The third floor push button located inside the elevator (1 if pressed).
- K) The security card reader for the third floor access (1 if card is swiped).

The controls located at the corridor should be disabled if there is a person inside the elevator. The access to the third floor is restricted. The security card should be swiped before the movement to the third floor is possible. When the elevator is instructed to move, the logic should check if all conditions are met and then initiate the appropriate action, otherwise it should not take any action.

Design the logic circuit that does the following:

- a) Initiates elevator movement one floor up.
- b) Initiates elevator movement one floor down.
- c) Initiates elevator movement two floors up.
- d) Initiates elevator movement two floors down.

Note:

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

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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.