

National Exams May 2014
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: $R_1 = 10\ \Omega$, $R_2 = 10\ \Omega$, $R_3 = 5\ \Omega$, $R_4 = 10\ \Omega$, $R_5 = 100\ \Omega$, $I_s = 9\ \text{A}$, and $V_s = 10\ \text{V}$.

- Write Kirchhoff's Current Law (KCL) equations for nodes B and D;
- Write Kirchhoff's Voltage Law (KVL) equations for loops ACA, ABCA and ADCA;
- Using KCL and KVL equations above calculate voltage V_{ab} ;
- Calculate the power dissipated in resistor R_4 ?

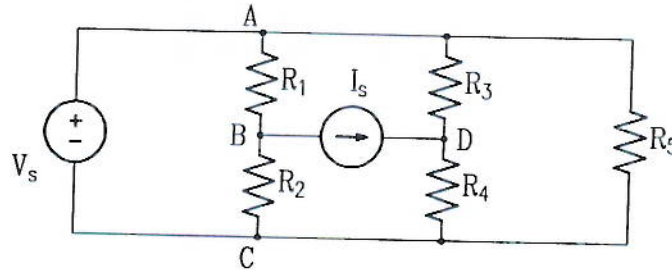


Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 50\ \Omega$, $R_2 = 100\ \Omega$, $R_3 = 50\ \Omega$, $R_4 = 100\ \Omega$, $R_5 = 100\ \Omega$, $R_6 = 20\ \Omega$, $R_7 = 80\ \Omega$, $V_{s1} = 20\ \text{V}$, $I_s = 20\ \text{A}$ and $V_{s2} = 5\ \text{V}$. Determine the following:

- Thevenin equivalent voltage seen by the load;
- Thevenin equivalent resistance seen by the load;
- What is the load resistance corresponding to the maximum power transfer to R_L ?
What is the maximum power transferred to R_L ?
- What is the power transferred to the load, if the load resistance is $R_L = 100\ \Omega$.

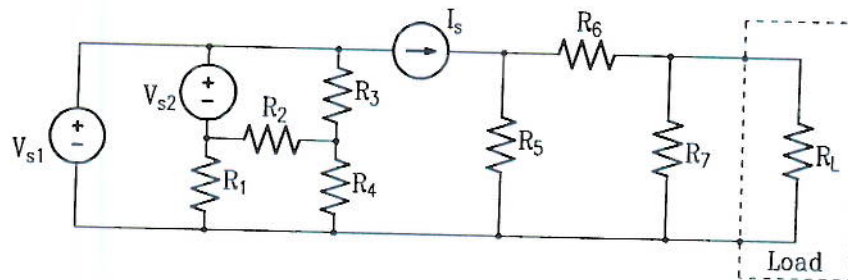


Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3, parameters are: $R = 10\ \Omega$, $L_1 = 10\ \text{mH}$, $L_2 = 0.5\ \text{H}$, $C_1 = 10\ \mu\text{F}$, $C_2 = 200\ \text{pF}$, and $v_s(t) = 100 \cos(\omega t)\ \text{V}$.

- Assume that the source frequency is 60 Hz. Calculate active and reactive power supplied by the source when S is in position 1.
- Determine the source frequency so that the source current amplitude is maximal when S is in position 1. What is this frequency called?
- For the frequency calculated under (b) calculate current $i_1(t)$ and real- and reactive-power supplied by the source.
- When S is in position 2: Determine the source frequency so that the current $i_2(t)$ is zero.

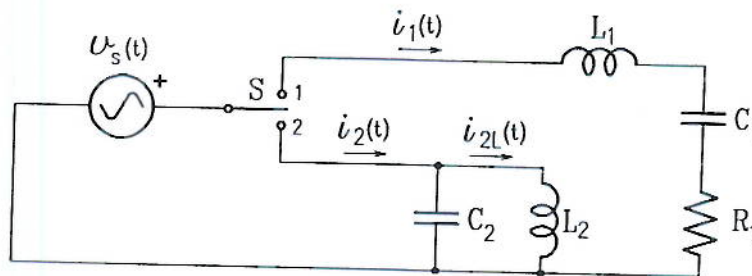


Figure 3: Circuit diagram for Question 3

Question 4

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

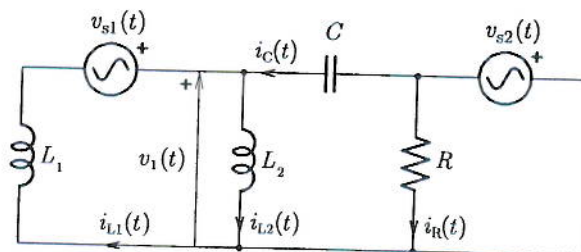


Figure 4: Circuit diagram for Question 4

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.

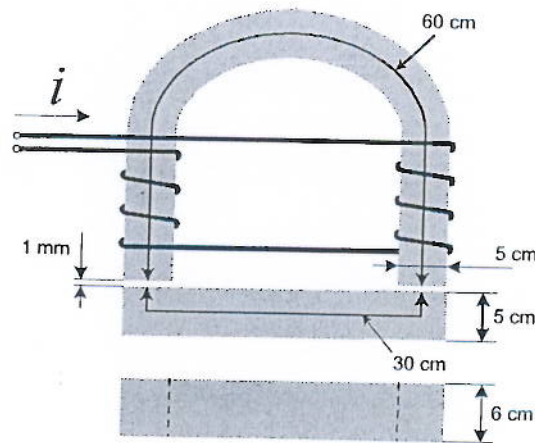


Figure 5: Magnetic core for Question 5

Problem 6

Design a full-wave bridge diode rectifier for a power supply. Rectifier will be supplied by an ideal AC voltage source (60 Hz, 12V_{RMS}). Assume that each diode has an offset voltage of 0.6 V.

- Draw the rectifier schematic diagram. Sketch the input voltage, the output voltage, and also specify which diodes conduct during each half-cycle of the AC side voltage.
- Sketch the output voltage if the load is a 1000Ω resistor in parallel with a $8\mu\text{F}$ capacitor.
- Design an RC low-pass filter (for DC side) that would attenuate a 120-Hz sinusoidal voltage by 20 dB with respect to the DC gain.

Question 7

A logic platform controls a heating and air-conditioning system. To operate, it uses the following sensors:

- A) Time elapsed from the last compressor turn-off instant (1 if the minimal time is exceeded)
- B) Over-temperature (1 if the ambient temperature is higher than t_{HI})
- C) Under-temperature (1 if the ambient temperature is lower than t_{LO})
- D) Heating function switch (1 if ON)
- E) Cooling function switch (1 if ON)
- F) Furnace over-temperature (1 if the furnace temperature is higher than $t_{Furnace}$)

The furnace should be turned on if the heating function switch is in the ON position and the ambient temperature is lower than the set value for heating t_{LO} . The compressor should be turned on if the cooling function switch is in the ON position and the ambient temperature is higher than the set value for cooling t_{HI} . Once the compressor is turned off there is a minimum time delay before it is allowed to turn it on again. This is controlled by the appropriate sensor. Fan should work if the compressor is ON or if the furnace temperature is higher than $t_{Furnace}$.

- a) Design the logic circuit that controls the furnace.
- b) Design the logic circuit that controls the compressor.
- c) Construct the truth table for controlling the fan.
- d) Design the logic circuit that controls the fan.

Note:

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

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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.