National Exams December 2012

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: $R_1 = 1\,\Omega$, $R_2 = 2\,\Omega$, $R_3 = 1\,\Omega$, $R_4 = 5\,\Omega$, $R_5 = 5\,\Omega$, $R_6 = 15\,\Omega$, $V_{s1} = 30\,\text{V}$, $V_{s5} = 25\,\text{V}$, and $I_s = 5\,\text{A}$.

a) Write Kirchhoff's Current Law (KCL) equations for nodes A, B, and C;

b) Write Kirchhoff's Voltage Law (KVL) equations for loops ABDA and ABCA;

c) Calculate the voltage across the resistor R_2;

d) Calculate the current I_2 and the power dissipated in resistor R_2?

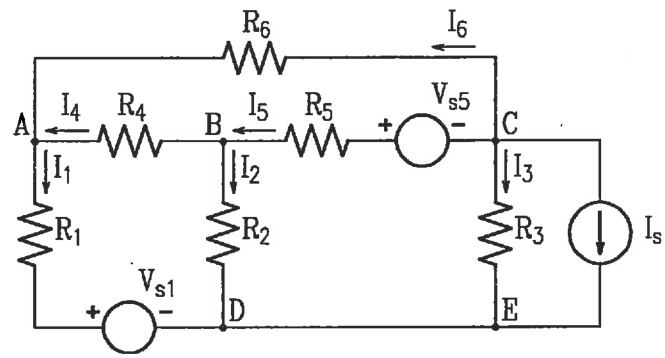

Figure 1: Circuit diagram for Question 1

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:

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

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

c) Power transferred to the load if the load resistance is $R_L = 100\,\Omega$.

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

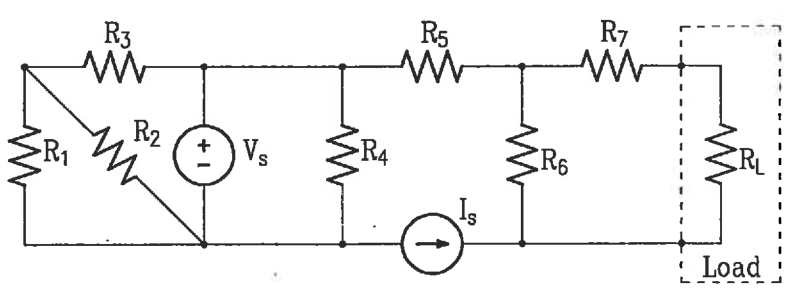

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3, parameters are: $R_1 = 5\,\Omega$, $R_2 = 10\,\Omega$, $L_1 = 10\,\text{mH}$, $L_2 = 5\,\text{H}$, $C_1 = 10\,\mu\text{F}$, $C_2 = 200\,\text{pF}$, and $V_s(t) = 100\cos(\omega t)\,\text{V}$.

a) Assume that the source frequency is 60 Hz. Calculate active and reactive power supplied by the source.

b) Determine the source frequency so that current I_2 is in phase with voltage V_2. What is this frequency called?

c) For the frequency calculated under (b) calculate currents $I_1(t)$ and $I_2(t)$.

d) For the frequency calculated under (b) calculate the reactive power supplied by the source.

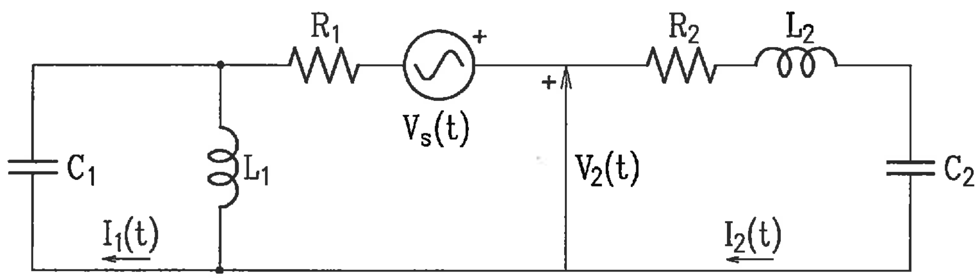

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 $R_1 = 3\,\Omega$, $R_2 = 3\,\Omega$, $R_3 = 6\,\Omega$, $R_4 = 4\,\Omega$, $R_5 = 4\,\Omega$, $R_6 = 8\,\Omega$, $L = 20\,\text{mH}$, 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 at $t = 0_-\,\text{s}$.

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 $t = 25\,\text{ms}$;

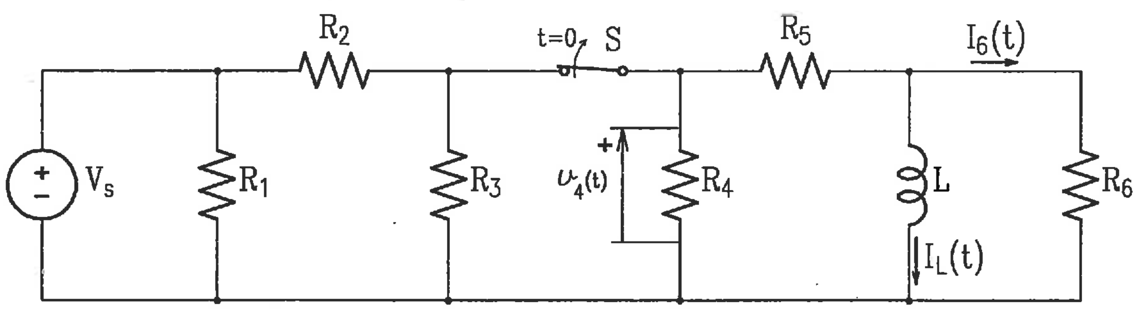

Figure 4: Circuit diagram for Question 4

Question 5

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

a) The magnetomotive force in the core if $i = 1\,\mathrm{A}$.

b) The equivalent reluctance of each part of the magnetic circuit if $x = 0.1\,\mathrm{mm}$.

c) The magnetic flux, flux density and magnetic field intensity in the air gap for $i = 1\,\mathrm{A}$ and $x = 0.1\,\mathrm{mm}$.

d) Inductance of the coil from Figure 5 as a function of air gap length x.

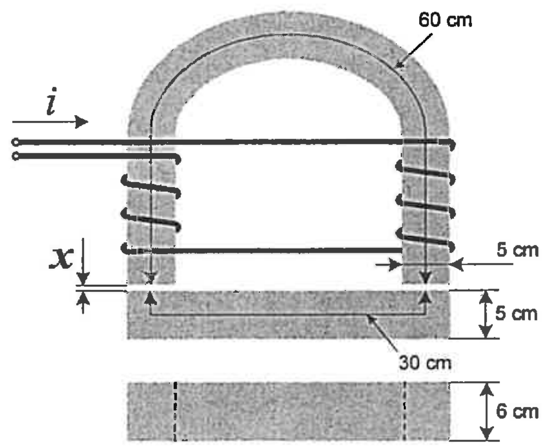

Figure 5: Magnetic core for Question 5

Question 6

A half-wave diode rectifier is used to provide a DC current to a $50\,\mathrm{k\Omega}$ resistive load. Rectifier is supplied by an ideal AC voltage source ($60\,\mathrm{Hz}$, $50\,\mathrm{V_{RMS}}$).

a) Draw the rectifier schematic diagram. Sketch the input voltage, the output voltage and the output current.

b) Find the peak and the average load current.

c) If the load has an inductive component, a simple half-wave rectifier may cause significant overvoltages. Explain why.

d) Suggest the modification to a simple half-wave rectifier circuit to make it suitable for the inductive load.

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.