National Exams December 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 December 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: $R_1 = 3\,\Omega$, $R_2 = 6\,\Omega$, $R_3 = 6\,\Omega$, $R_4 = 8\,\Omega$, $R_5 = 6\,\Omega$, and $V_s = 18\,\text{V}$. It is observed that $I_5 = 2\,\text{A}$.

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

    b) Write Kirchhoff's Voltage Law (KVL) equations for loops $R_1 R_3 R_o$ and $R_1 V_s R_5 R_o$;

    c) Calculate voltage V_{BD} and current I_3 ;

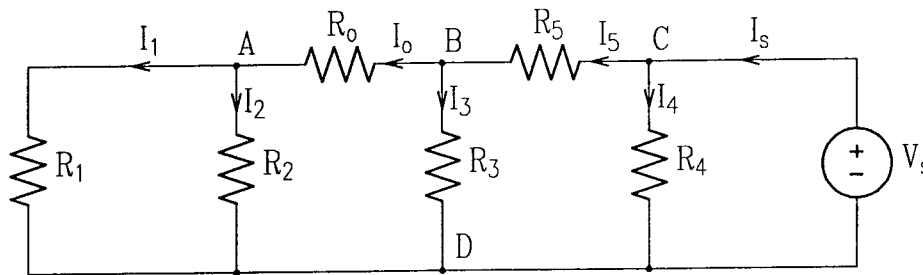   d) Calculate R_o, I_o and the power dissipated in resistor R_o.

Figure 1: Circuit diagram for Question 1

Question 2

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

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

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

    c) Determine the power transferred to the load if the load resistance is $R_L = 72\,\Omega$.

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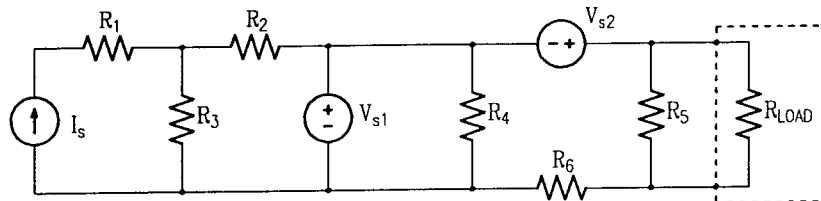

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3, parameters are: $R_1 = 10\,\Omega$, $L_1 = 80\,\text{mH}$, $L_2 = 0.5\,\text{H}$, $C_1 = 100\,\mu\text{F}$, $C_2 = 0.5\,\mu\text{F}$, and $v_s(t) = \sqrt{2} \cdot 100\,\cos(\omega t)\,\text{V}$.

a) Assume that the source frequency is 60 Hz. Calculate active and reactive power supplied by the source when S is in position 1.

b) Determine the source frequency so that the source current amplitude is maximal when S is in position 1. What is this frequency called?

c) For the frequency calculated under (b) calculate current $i_1(t)$ and real- and reactive-power supplied by the source.

d) When S is in position 2: Determine the source frequency so that the current $i_2(t)$ is zero.
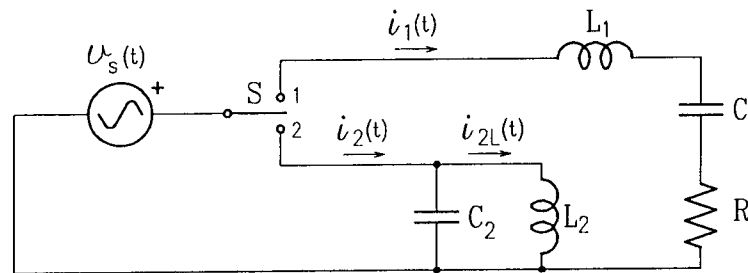

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 assume the following: $L_1 = 160\,\text{mH}$, $L_2 = 80\,\text{mH}$, $R = 2\,\Omega$, $C = 5\,\text{mF}$, $v_{s1}(t) = \sqrt{2} \cdot 10\,\cos(25\,t + \frac{\pi}{4})\,\text{V}$, and $v_{s2}(t) = \sqrt{2} \cdot 8\,\cos(25\,t)\,\text{V}$. Assume that the circuit is in a steady-state operating condition. Calculate the following:

a) Impedances $\underline{Z}_{L1}$, $\underline{Z}_{L2}$, and $\underline{Z}_C$;

b) Voltage phasor $\underline{V}_1$;

c) Current phasors $\underline{I}_{L1}$ and $\underline{I}_{L2}$;

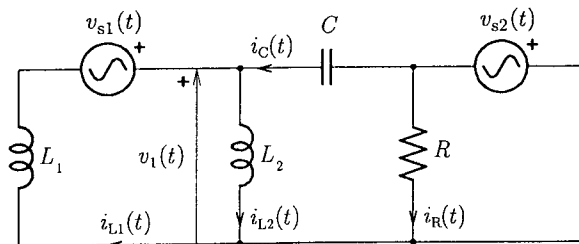d) Resistor current in time-domain, $i_R(t)$.

Figure 4: Circuit diagram for Question 4

Question 5

A magnetic core is shown in Figure 5. Relative permeability of the core is $\mu_r = 2000$ ($\mu_0 = 4\pi \times 10^{-7}\,\text{H/m}$). Total 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:

a) The magnetomotive force in the core if $i = 2\,\text{A}$.

b) The equivalent reluctance of each part of the magnetic circuit.

c) The magnetic flux, flux density and magnetic field intensity in each of the the air gaps for $i = 2\,\text{A}$.

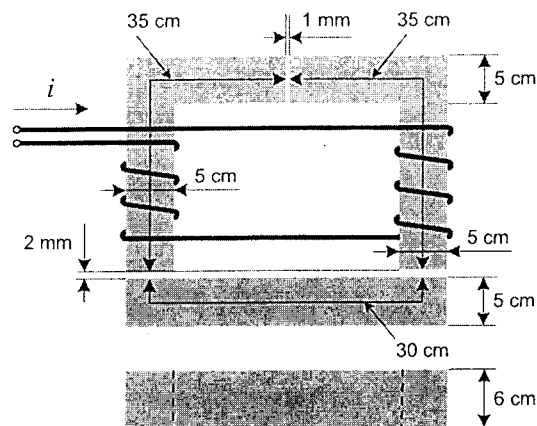d) Inductance of the coil from Figure 5.

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 is supplied by an ideal AC voltage source ($60\,\text{Hz}$, $20\,\text{V}_{RMS}$).

a) Draw the rectifier schematic diagram. Sketch the input voltage, the output voltage and the output current. Indicate when each rectifier diode is conducting.

b) Find the peak and the average current in the load.

c) Sketch the input and the output voltage if each rectifier diode has on-state voltage drop of $0.6\,\text{V}$.

d) Using a $100\,\Omega$ resistance, design an RC low-pass filter (for the DC side) that can attenuate a 60-Hz sinusoidal voltage by $20\,\text{dB}$ with respect to the DC gain.

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.