National Exams December 2017

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.

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

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

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

c) Using KCL and KVL equations above calculate voltage V_{ab};

d) Calculate the power dissipated in resistor R_4?

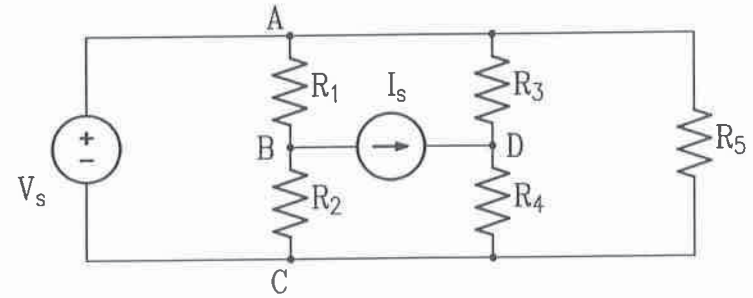

Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 50\,\Omega$, $R_2 = 100\,\Omega$, $R_3 = 50\,\Omega$, $R_4 = 100\,\Omega$, $R_5 = 100\,\Omega$, $R_6 = 20\,\Omega$, $R_7 = 80\,\Omega$, $V_{s1} = 20\,\text{V}$, $I_s = 30\,\text{A}$ and $V_{s2} = 5\,\text{V}$. Determine the following:

a) Thevenin equivalent voltage seen by the load;

b) Thevenin equivalent resistance seen by the load;

c) What is the load resistance corresponding to the maximum power transfer to R_L? What is the maximum power transferred to R_L?

d) What is the power transferred to the load, if the load resistance is $R_L = 100\,\Omega$.

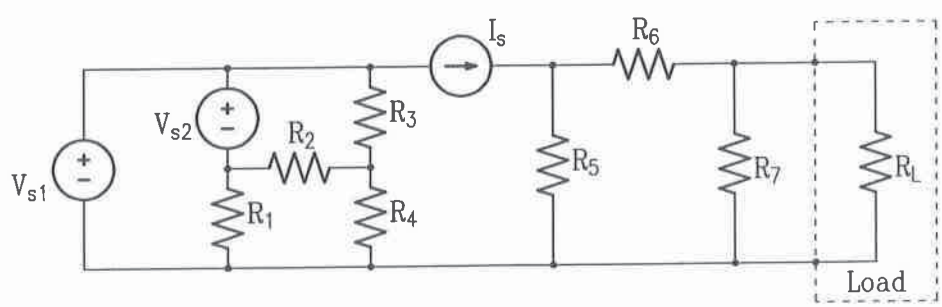

Figure 2: Circuit diagram for Question 2

Question 3

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

a) Assume that the source frequency is 60 Hz and load resistance R_{LOAD} is $100\,\Omega$. Calculate active and reactive power supplied by the source.

b) For case (a): Calculate currents $i_{2L}(t)$ and $i_2(t)$.

c) Assume the infinite load resistance R_{LOAD}. Determine the source frequency so that the source current amplitude is maximal. What is this frequency called?

d) For case (c): Calculate current $i_1(t)$ and real and reactive power supplied by the source.

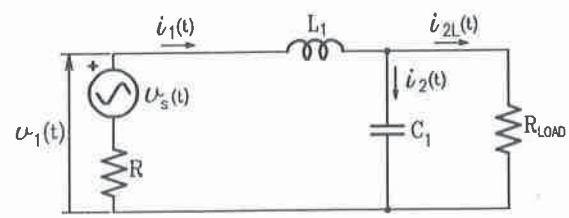

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 two steady-state operating conditions, when switch S is open or closed, are possible. Parameters are $R = 10\,\Omega$, $L = 1\,\text{mH}$, $R_{\text{LOAD}} = 100\,\Omega$, $v_{s1}(t) = 20\ \cos(120\,\pi\, t + \pi/3)$ and $v_{s2}(t) = 10,\cos(120\,\pi\, t)$ V. Calculate the following:

a) When S is closed: Current phasor $\underline{I}_1$ and voltage phasor $\underline{V}_1$;

b) When S is closed: Power consumed by R_{LOAD};

c) When S is open: Currents $I_1(t)$ and $I_2(t)$ and voltage $V_1(t)$;

d) What is the change in power consumed by the load as a result of opening S.

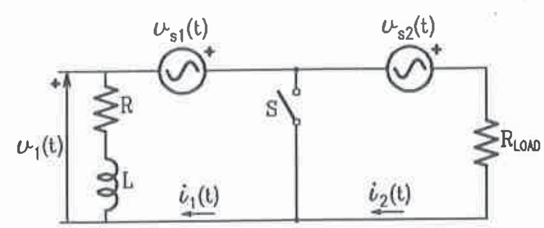

Figure 4: Circuit diagram for Question 4

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 $I = 1A$ ($\mu_0 = 4\pi \times 10^{-7}$).

a) Compute the magnetomotive force.

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

c) Draw the analog circuit representation of the magnetic circuit from Figure 5.

d) Calculate the magnetic flux, flux density and magnetic field intensity in the air gap.

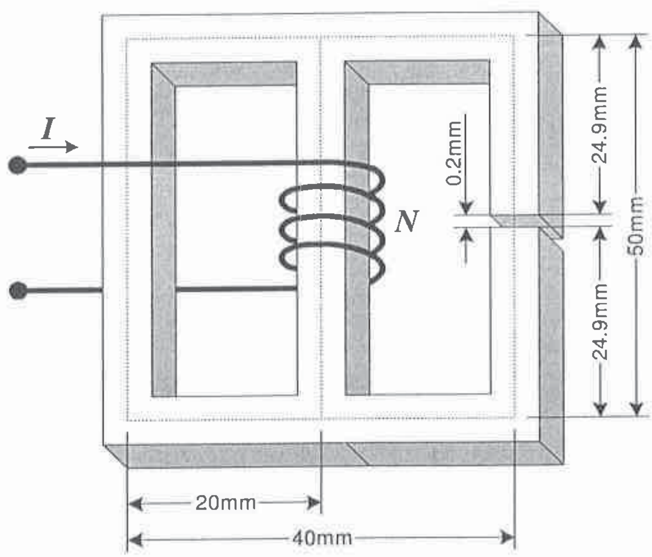

Figure 5: Magnetic core for Question 5

Question 6

A full-wave diode rectifier is used to provide a DC current to a 50 kΩ resistive load. Rectifier is supplied by an ideal AC voltage source (60 Hz, 110 V_{RMS}) and a transformer with the center-tapped secondary (transformer turns-ratio is 110/10/10 V).

a) Draw the rectifier schematic diagram. Sketch the input voltage, the output voltage, the output current, and the current through each of the rectifier diodes.

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

c) Sketch the input and the output voltage waveforms, if the rectifier diode has on-state voltage drop of 0.5 V.

d) Using a 100 Ω 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) The elevator is in motion (1 if yes).

E) Push button located at the first floor corridor (1 if pressed).

F) Push button located at the second floor corridor (1 if pressed).

G) First floor push button located inside the elevator (1 if pressed).

H) Second floor push button located inside the elevator (1 if pressed).

I) 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. The elevator light should be on whenever there is a person in the elevator or the doors are open. The alarm should sound if the elevator is not moving and is between floors.

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.

c) Controls the elevator light.

d) Initiates the alarm.

Note:

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