National Exams December 2015

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.

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

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

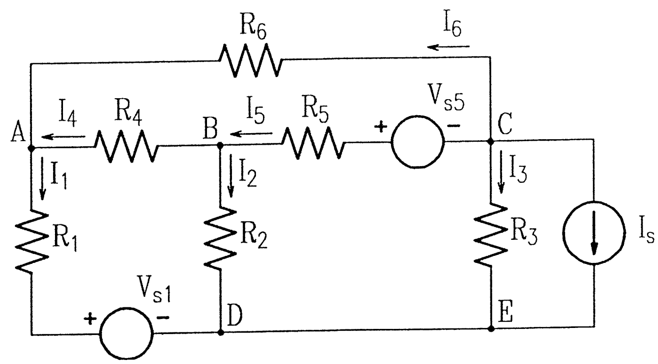

Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 12.5\,\text{M}\Omega$, $R_2 = 22.5\,\text{k}\Omega$, $R_3 = 300\,\text{k}\Omega$, $R_4 = 100\,\text{k}\Omega$, $R_5 = 10\,\text{k}\Omega$, $R_6 = 10\,\text{k}\Omega$, $R_7 = 5\,\text{k}\Omega$, and $V_s = 20\,\text{V}$. Determine the following:

a) Thevenin equivalent resistance seen by the load;

b) Thevenin equivalent voltage seen by the load;

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 power transferred to the load in this case.

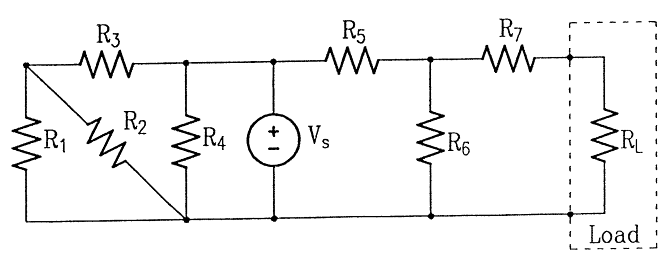

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3 $R_1 = 3\,\Omega$, $R_2 = 3\,\Omega$, $R_3 = 6\,\Omega$, $R_4 = 4\,\Omega$, $R_5 = 4\,\Omega$, $R_6 = 8\,\Omega$, $L = 20\,\text{mH}$, 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 $t = 25\,\text{ms}$;

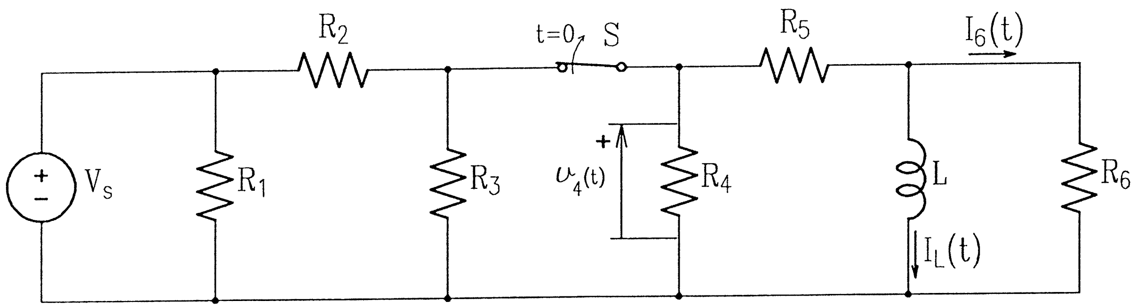

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 assume the following: $L_1 = 160\,\text{mH}$, $L_2 = 80\,\text{mH}$, $R_1 = 5\,\Omega$, $R_2 = 2\,\Omega$, $C = 20\,\text{mF}$, and $v_s(t) = \sqrt{2}\,10\,\cos(100\,t)\,\text{V}$. 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 phasor $\underline{I_1}$;

d) Capacitor current in time-domain.

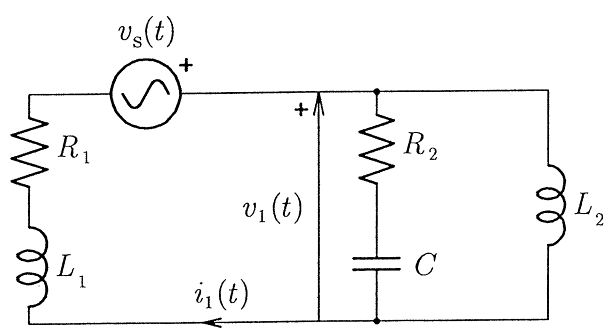

Figure 4: Circuit diagram for Question 4

Question 5

A magnetic core is shown in Figure 5. Assume that the core cross section is uniform and equal to $100\,\text{mm}^2$, relative permeability $\mu_r = 2000$, number of winding turns $N = 100$ and current $I = 1A$ ($\mu_0 = 4\pi \times 10^{-7}\,\text{H/m}$).

a) Calculate 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.

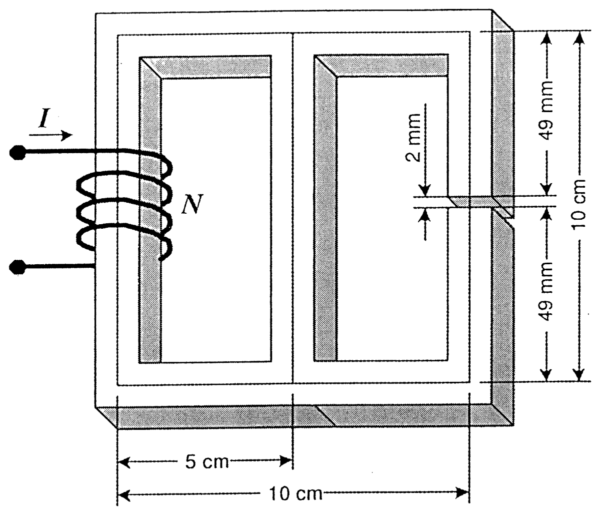

Figure 5: Magnetic core for Question 5

Question 6

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

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 $0.5\,\text{V}$.

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

Question 7

A logic platform controls a two-stage heating and air-conditioning system. It uses the following sensors for operation:

A) Time elapsed from the last compressor turn-off instant (1 if the minimal rest time t_{REST} is exceeded)

B) Time elapsed from the moment the fan started blowing (1 if the Stage 1 time t_{Stage1} is exceeded)

C) Over-temperature (1 if the ambient temperature is higher than t_{HI})

D) Under-temperature (1 if the ambient temperature is lower than t_{LO})

E) Heating function switch (1 if ON)

F) Cooling function switch (1 if ON)

G) 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 on again. The fan should be ON if the compressor is ON or if the furnace temperature is higher than t_{Furnace}. Fan always turns ON at low-speed and continues with low-speed operation until the set time t_{Stage1} is exceeded or desired temperature is reached. If the desired temperature is not reached and the time allocated to Stage 1 expired, the fan switches to high-speed operation.

a) Design the logic circuit that controls the furnace.

b) Design the logic circuit that controls the compressor.

c) Design the logic circuit that sets the fan in low-speed mode.

d) Design the logic circuit that sets the fan in high-speed mode.

Note:

Any gate type can be used to construct the logic circuits.