National Exams Dec 2018

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: $R_1 = 3\,\Omega$, $R_2 = 6\,\Omega$, $R_3 = 10\,\Omega$, $R_4 = 11\,\Omega$, $R_5 = 12\,\Omega$, $R_6 = 34\,\Omega$, $R_7 = 2\,\Omega$,and $V_s = 28\,\text{V}$. It is observed that $V_7 = 1\,\text{V}$.

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

b) Write Kirchhoff's Voltage Law (KVL) equations for loops $R_1R_3R_4R_5V_s$ and $R_5R_6R_7$;

c) Calculate power dissipated in resistor R_7.

d) Calculate I_s;

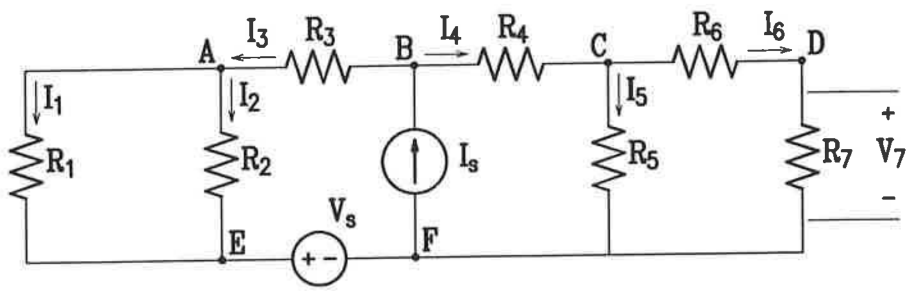

Figure 1: Circuit diagram for Question 1

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:

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 $R_L = 100\,\Omega$.

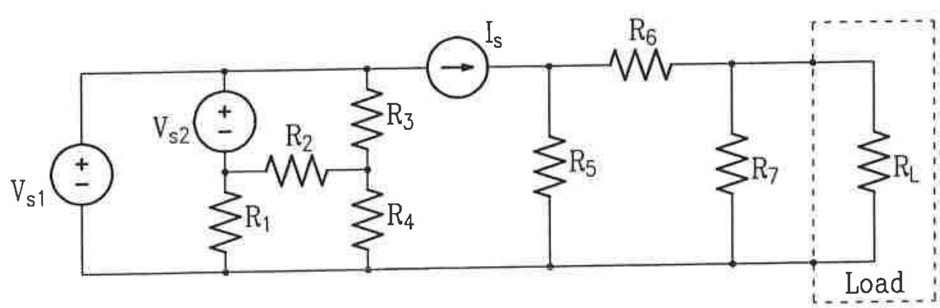

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3 $R_1 = 3\,\Omega$, $R_2 = 3\,\Omega$, $R_3 = 6\,\Omega$, $R_4 = 4\,\Omega$, $R_5 = 4\,\Omega$, $R_6 = 8\,\Omega$, $L = 20\,\text{mH}$, 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 before the switch is opened.

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

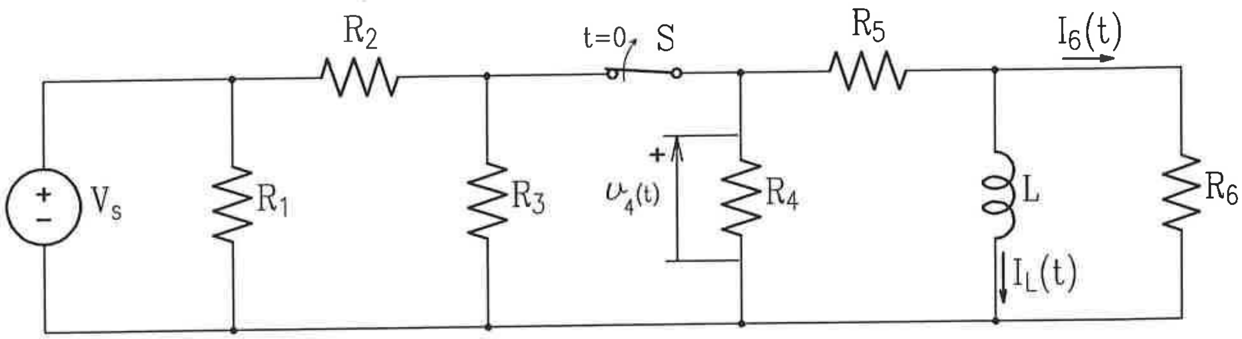

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4, 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.

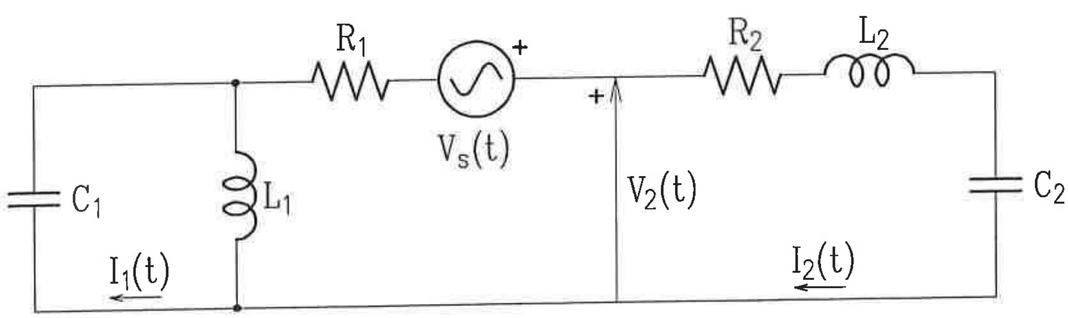

Figure 4: Circuit diagram for Question 4

Question 5

In the circuit of Figure 5 assume the following: $R_{Line} = 2\,\Omega$, $X_{Line} = 2\,\Omega$, $R_{Load} = 6\,\Omega$, $X_{Load} = 4\,\Omega$, $X_C = 100\,\Omega$, $V_s(t) = \sqrt{2}\ 100\ \cos(120\,\pi\,t)$ V. Two steady-state operating conditions, with switch open or closed, are possible. Calculate the following:

a) When the switch is open: Determine the magnitude of the source current and the real power supplied by the source ;

b) When the switch is open: Determine the real power absorbed by the line impedance and the real power absorbed by the load;

c) When the switch is closed: Determine the magnitude of the source current;

d) When the switch is closed: Determine the real power absorbed by the line impedance and the real power absorbed by the load.

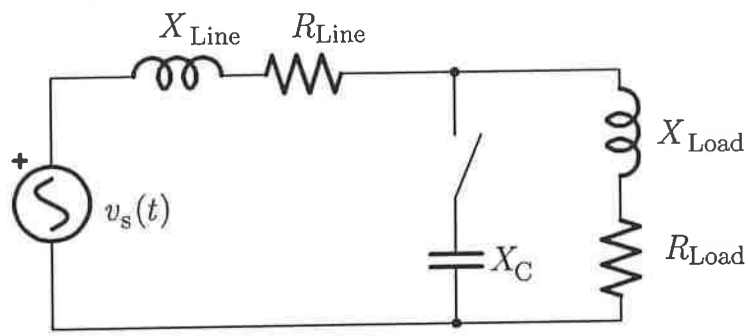

Figure 5: Circuit diagram for Question 5

Question 6

A diode bridge rectifier is used to provide a DC current to a $50\,\text{k}\Omega$ resistive load. Rectifier will be supplied by an ideal AC voltage source (60 Hz, 20 V_{RMS}).

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

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

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

d) Using a $100\,\Omega$ resistance, design an RC low-pass filter (for DC side) that can attenuate a 120 Hz sinusoidal voltage by 20 dB with respect to the DC gain.

Question 7

A magnetic circuit consisting of a fixed horseshoe core and a moveable core element (relay armature) is shown in Figure 6. Consider the relative permeability of the core $\mu_r = 2000$, total number of turns on both legs $N = 1000$, and the current $i = 1\text{A}$.

a) Calculate the total magnetomotive force in both windings.

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

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

d) Calculate the total electromagnetic force acting on the relay armature.

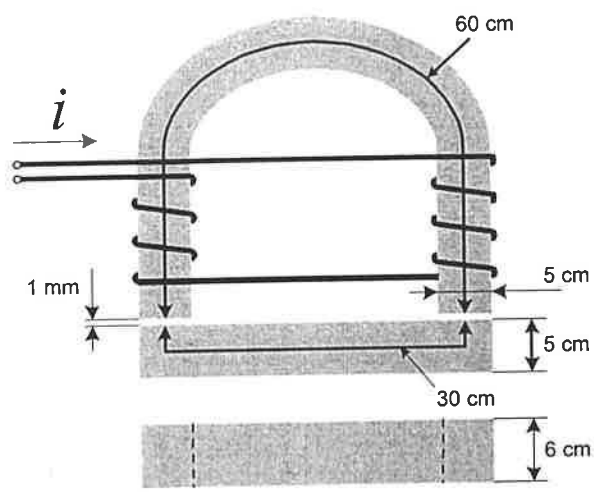

Figure 6: Magnetic core for Question 7