National Exams December 2016

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: $R_1 = 10\,\Omega$, $R_2 = 6\,\Omega$, $R_3 = 3\,\Omega$, $R_4 = 3\,\Omega$, $R_5 = 6\,\Omega$, $I_s = 10\,\text{A}$, and $V_s = 36\,\text{V}$.

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

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

c) Calculate current through the resistor R_1;

d) Calculate power generated by the current source I_s.

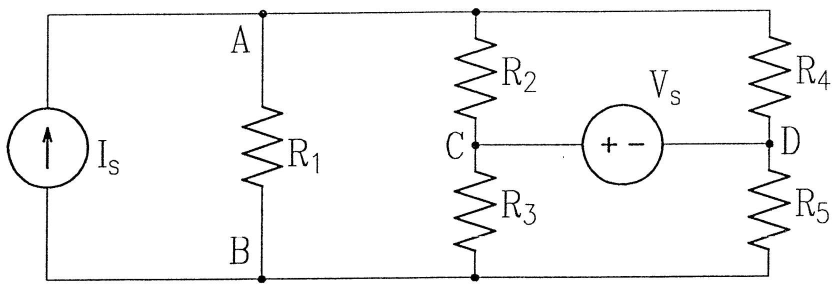

Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 50\,\Omega$, $R_2 = 100\,\Omega$, $R_3 = 50\,\Omega$, $R_4 = 30\,\Omega$, $R_5 = 60\,\Omega$, $R_6 = 10\,\Omega$, $R_7 = 30\,\Omega$, $V_{s1} = 90\,\text{V}$ 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 $R_L = 45\,\Omega$.

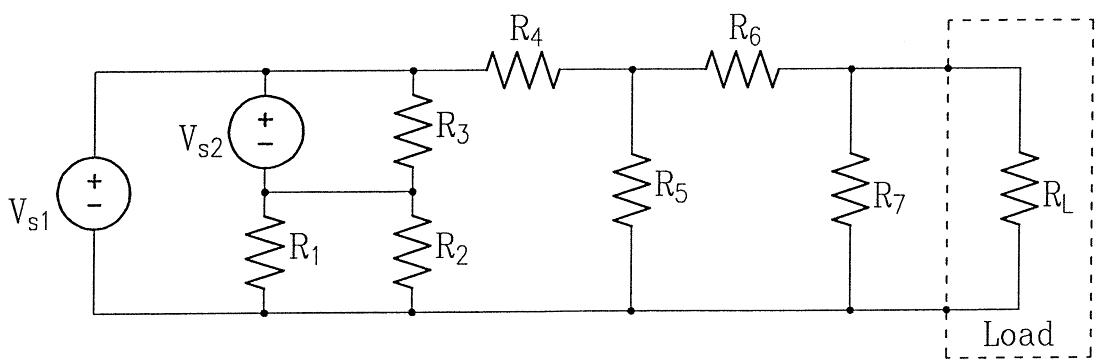

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3 $R_1 = 3\,\mathrm{k\Omega}$, $R_2 = 3\,\mathrm{k\Omega}$, $R_3 = 6\,\mathrm{k\Omega}$, $R_4 = 10\,\Omega$, $C_1 = 4\,\mu\mathrm{F}$, $C_2 = 12\,\mu\mathrm{F}$, $C_3 = 6\,\mu\mathrm{F}$, and $I_s = 200\,\mathrm{mA}$. The switch is in position 0. At $t = 0\,\mathrm{s}$, the switch moves to position 1. At $t = 5\,\mathrm{s}$, the switch moves to position 2. Assume that none of the capacitors has any stored energy at $t = 0\,\mathrm{s}$.

a) Calculate the time constant of the circuit when the switch is in position 1;

b) Calculate the voltage across the capacitor C_1 at $t = 1\,\mathrm{s}$.

c) Calculate the time constant of the circuit when the switch is in position 2;

d) What is the voltage across the capacitor C_1 at $t = 6\,\mathrm{s}$.

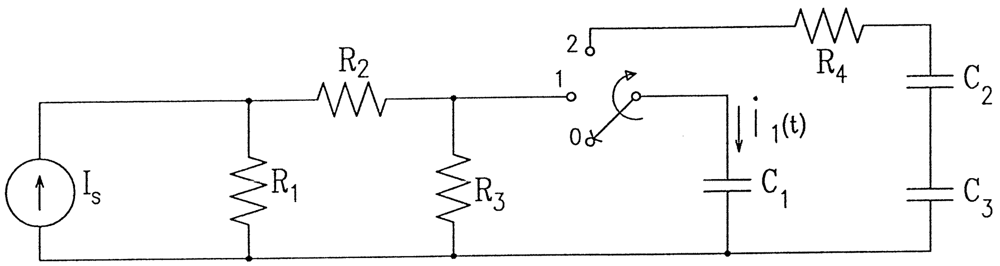

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 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.

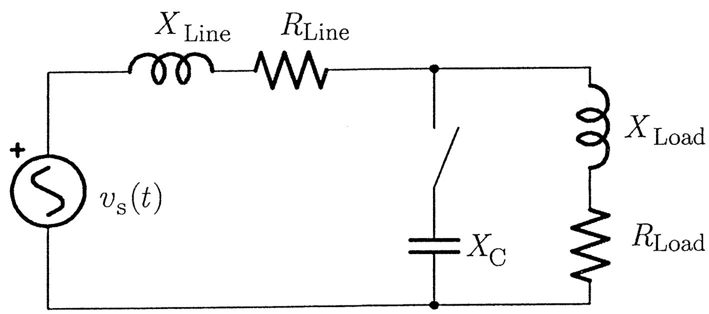

Figure 4: Circuit diagram for Question 4

Question 5

In the circuit of Figure 5, parameters are: $R = 10\,\Omega$, $L_1 = 10\,\text{mH}$, $L_2 = 0.5\,\text{H}$, $C_1 = 10\,\mu\text{F}$, $C_2 = 200\,\text{pF}$, 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 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) determine the active power supplied by the source.

d) When S is in position 2: Determine the source frequency so that the reactive power supplied by the source is zero.

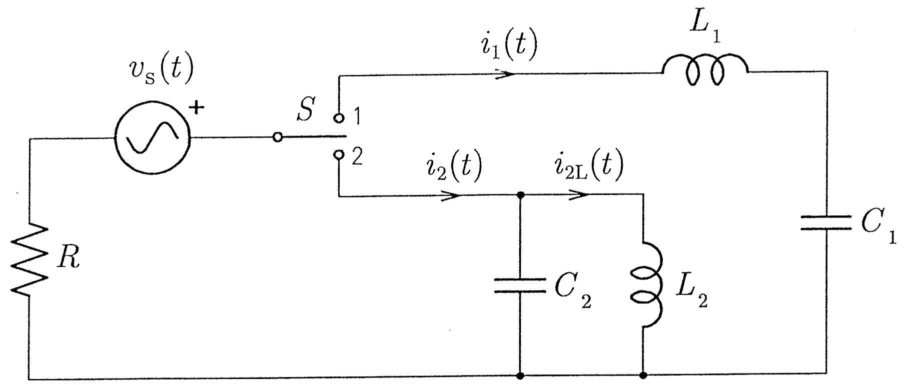

Figure 5: Circuit diagram for Question 5

Question 6

A full-wave bridge 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 (50 Hz, $20\,\text{V}_{\text{RMS}}$).

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, if the rectifier diode has on-state voltage drop of 0.4 V.

d) Using a $50\,\Omega$ resistance, design an RC low-pass filter (for DC side) that can attenuate a 100 Hz sinusoidal voltage by 20 dB with respect to the DC gain.

Question 7

A magnetic core is shown in Figure 6. Consider that the 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) Compute the magnetomotive force.

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

c) Draw the analog circuit representation of the magnetic circuit from Figure 6.

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

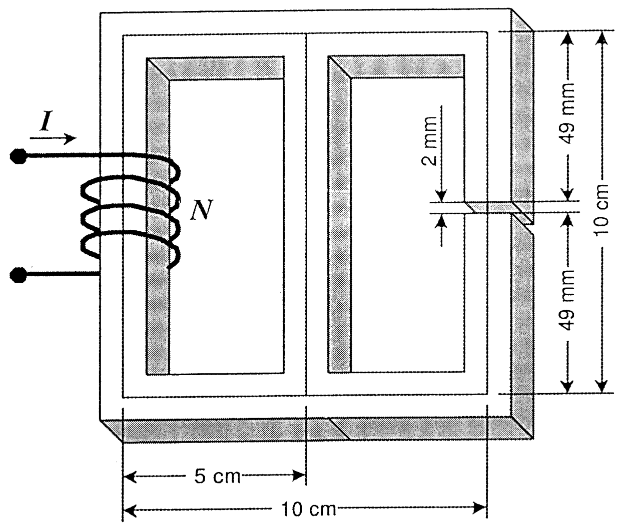

Figure 6: Magnetic core for Question 7