National Exams May 2013

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.
4. All questions are of equal value.

Question 1

In the DC circuit of Figure 1 assume the following: $R_1 = 10\,\Omega$, $R_2 = 7\,\Omega$, $R_3 = 10\,\Omega$, $R_4 = 4\,\Omega$, $R_5 = 1\,\Omega$, and $V_s = 4\,\text{V}$. It is observed that $I_2 = 4\,\text{A}$.

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

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

c) Calculate R_0;

d) Calculate current I_0 and the power dissipated in resistor R_0.

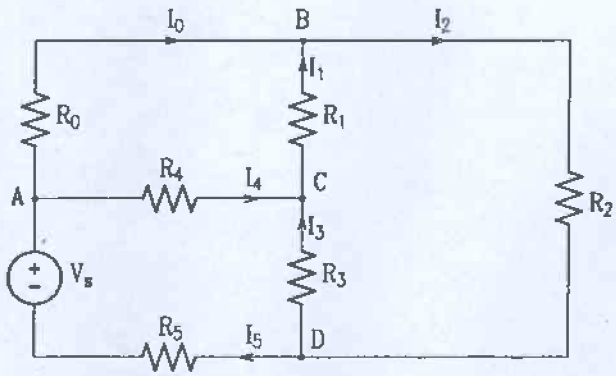

Figure 1: Circuit diagram for Question 1

Question 2

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

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

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

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 maximum power transferred to the load.

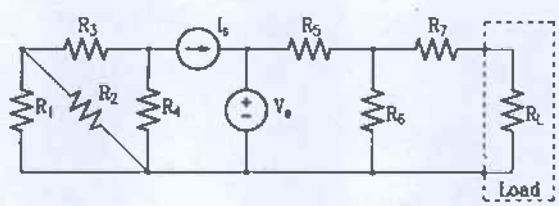

Figure 2: Circuit diagram for Question 2

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

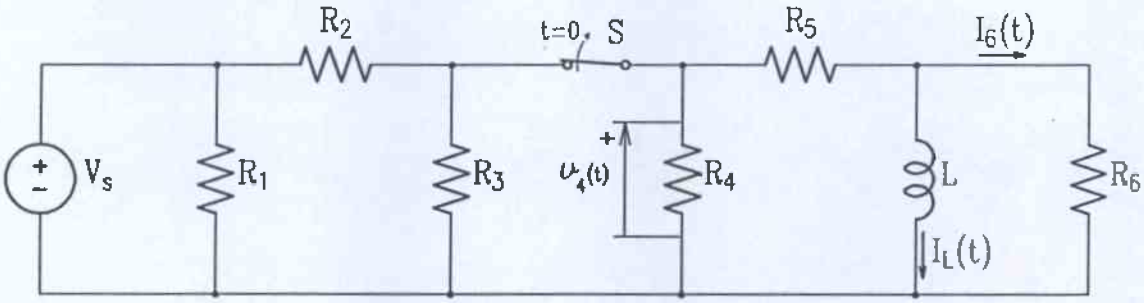

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 assume the following: $L_1 = 160\,\text{mH}$, $L_2 = 80\,\text{mH}$, $R = 4\,\Omega$, $C = 10\,\text{mF}$, $v_{s1}(t) = \sqrt{2}\,10\cos(25\,t + \frac{\pi}{4})\,\text{V}$, and $v_{s2}(t) = 10\cos(25\,t)\,\text{V}$. 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, $i_R(t)$.

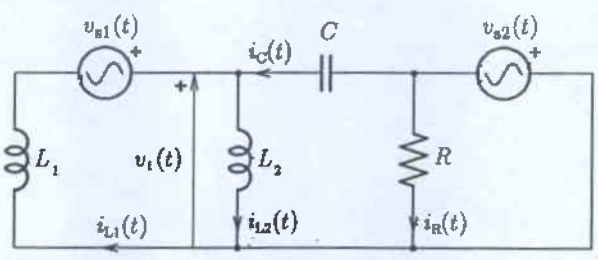

Figure 4: Circuit diagram for Question 4

Question 5

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.

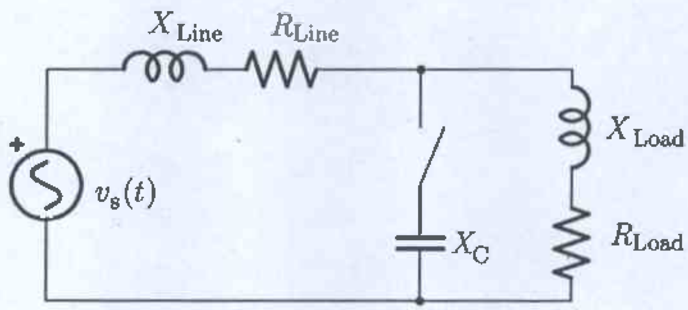

Figure 5: Circuit diagram for Question 5

Problem 6

Design a full-wave bridge diode rectifier for a power supply. Rectifier will be supplied by an ideal AC voltage source (60 Hz, 12 V_{RMS}). Assume that each diode has an offset voltage of 0.6 V.

a) Draw the rectifier schematic diagram. Sketch the input voltage, the output voltage, and also specify which diodes conduct during each half-cycle of the AC side voltage.

b) Sketch the output voltage if the load is a 1000 Ω resistor in parallel with a 8 μF capacitor.

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

Question 7

A magnetic core is shown in Figure 6. Relative permeability of the core is $\mu_r = 2000$ ($\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H/m}$). Number of winding turns is $N = 100$. Assume that the core cross section is uniform and the length of air-gap x is much smaller than the dimensions of the core cross-section. Calculate the following.

a) The magnetomotive force in the core if $i = 1\,\mathrm{A}$.

b) The equivalent reluctance of each part of the magnetic circuit if $x = 0.1\,\mathrm{mm}$.

c) The magnetic flux, flux density and magnetic field intensity in the air gap for $i = 1\,\mathrm{A}$ and $x = 0.1\,\mathrm{mm}$.

d) Inductance of the coil from Figure 6 as a function of air gap length x.

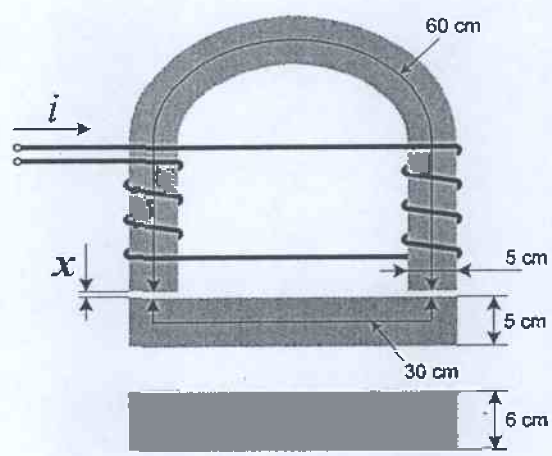

Figure 6: Magnetic core for Question 7