

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 $I_2 = 4\ \text{A}$.

- Write Kirchhoff's Current Law (KCL) equations for nodes A, B, and C;
- Write Kirchhoff's Voltage Law (KVL) equations for loops ABCA, ACDA and BCDB;
- Calculate R_0 ;
- Calculate current I_0 and the power dissipated in resistor R_0 .

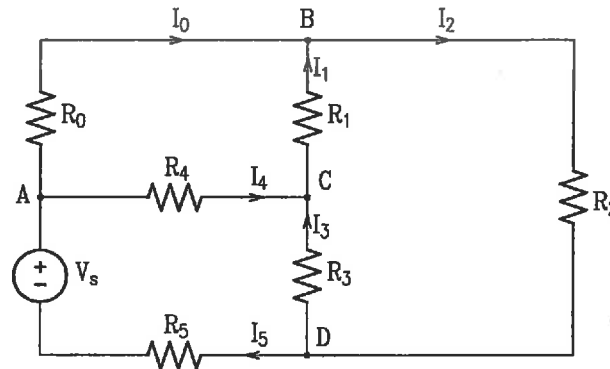


Figure 1: Circuit diagram for Question 1

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:

- Thevenin equivalent resistance with respect to the load terminal;
- Thevenin equivalent voltage with respect to the load terminal;
- Power transferred to the load if the load resistance is $R_L = 100\ \Omega$.
- Determine the load resistance for the maximum power transfer. Determine the maximum power transferred to the load.

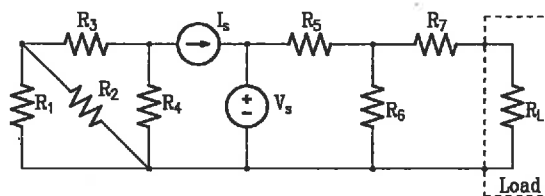


Figure 2: Circuit diagram for Question 2

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.

- Calculate the voltage across the resistor R_4 and the inductor current in steady-state while the switch S is closed.
- What is the energy stored in the inductor before the switch is opened.
- Calculate the time constant of the circuit when the switch is open;
- Plot the current $I_L(t)$ from $t = -5\ \text{ms}$ to $t = 25\ \text{ms}$;

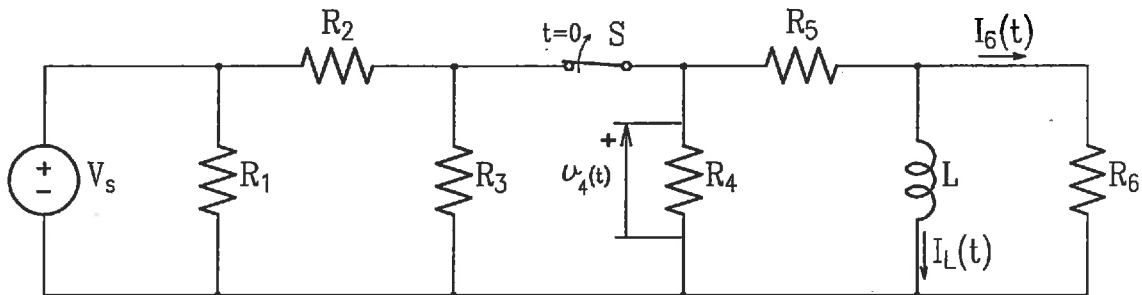


Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 assume the following: $L_1 = 160\ \text{mH}$, $L_2 = 80\ \text{mH}$, $R = 4\ \Omega$, $C = 10\ \text{mF}$, $v_{s1}(t) = \sqrt{2} 10 \cos(25t + \frac{\pi}{4})\ \text{V}$, and $v_{s2}(t) = 10 \cos(25t)\ \text{V}$. Assume that the circuit is in a steady-state operating condition. Calculate the following:

- Impedances Z_{L1} , Z_{L2} , and Z_C ;
- Voltage phasor V_1 ;
- Current phasors I_{L1} and I_{L2} ;
- Resistor current in time-domain, $i_R(t)$.

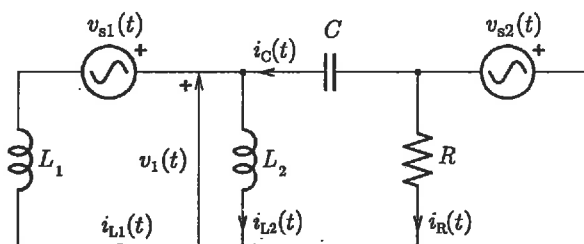


Figure 4: Circuit diagram for Question 4

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:

- When the switch is open: Determine the magnitude of the source current and the real power supplied by the source ;
- When the switch is open: Determine the real power absorbed by the line impedance and the real power absorbed by the load;
- When the switch is closed: Determine the magnitude of the source current;
- When the switch is closed: Determine the real power absorbed by the line impedance and the real power absorbed by the load.

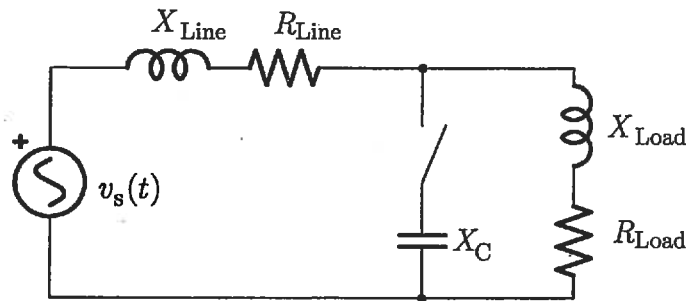


Figure 5: Circuit diagram for Question 5

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.

- 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.
- Sketch the output voltage if the load is a 1000Ω resistor in parallel with a 8μF capacitor.
- Using a 100Ω 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 $\mu_r = 2000$ ($\mu_0 = 4\pi \times 10^{-7}$ 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:

- The magnetomotive force in the core if $i = 1$ A.
- The equivalent reluctance of each part of the magnetic circuit if $x = 0.1$ mm.
- The magnetic flux, flux density and magnetic field intensity in the air gap for $i = 1$ A and $x = 0.1$ mm.
- Inductance of the coil from Figure 6 as a function of air gap length x .

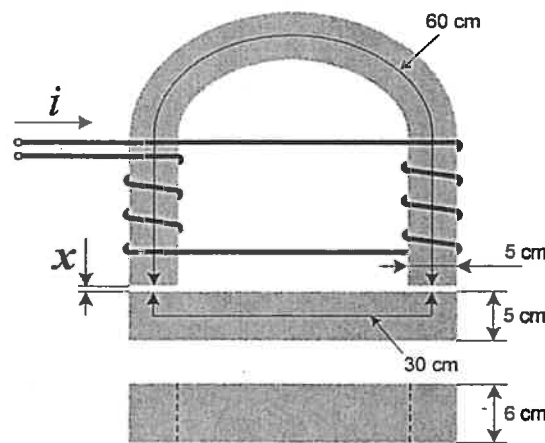


Figure 6: Magnetic core for Question 7

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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.