National Exams December 2010

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.

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: $R_1 = 5\,\Omega$, $R_2 = 6\,\Omega$, $R_3 = 3\,\Omega$, $R_4 = 3\,\Omega$, $R_5 = 6\,\Omega$, $I_s = 2\,\text{A}$, and $V_s = 3\,\text{V}$.

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.

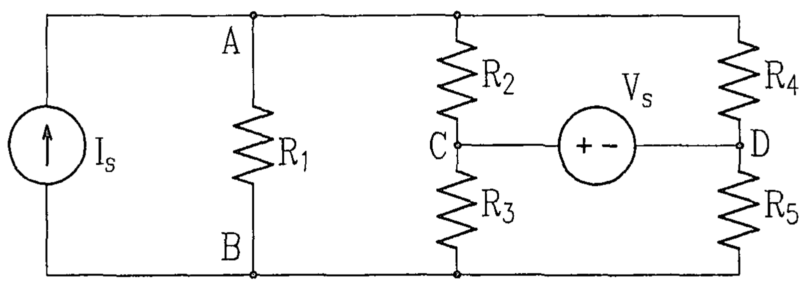

Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 50\,\Omega$, $R_2 = 100\,\Omega$, $R_3 = 50\,\Omega$, $R_4 = 100\,\Omega$, $R_5 = 100\,\Omega$, $R_6 = 40\,\Omega$, $R_7 = 60\,\Omega$, $V_{s1} = 30\,\text{V}$ 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 $R_L = 64\,\Omega$.

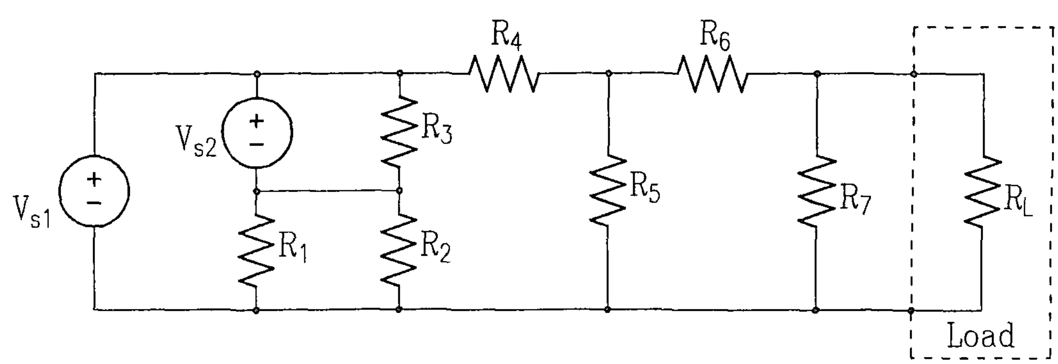

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3 $R_1 = 3\,\text{k}\Omega$, $R_2 = 3\,\text{k}\Omega$, $R_3 = 6\,\text{k}\Omega$, $R_4 = 18\,\text{k}\Omega$, $C_1 = 10\,\mu\text{F}$, $C_2 = 3\,\mu\text{F}$, $C_3 = 6\,\mu\text{F}$, and $I_s = 200\,\text{mA}$. The switch is in position 0. At $t = 0\,\text{s}$, the switch moves to position 1. At $t = 5\,\text{s}$, the switch moves to position 2. Assume that none of the capacitors has any stored energy at $t = 0\,\text{s}$.

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 $t = 1\,\text{s}$.

c) Plot waveform of the current $i_1(t)$ from $t = -10\,\text{ms}$ to $t = 200\,\text{ms}$;

d) What is the total energy stored in all three capacitors at $t = 6\,\text{s}$.

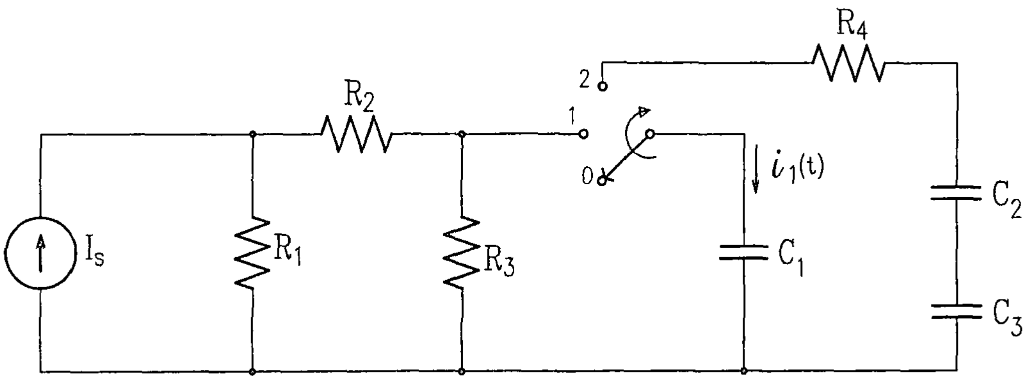

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 assume the following: $L_1 = 160\,\text{mH}$, $L_2 = 80\,\text{mH}$, $R = 2\,\Omega$, $C = 20\,\text{mF}$, $v_{s1}(t) = \sqrt{2}\,10\,\cos(25\,t + \frac{\pi}{4})\,\text{V}$, 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, $i_R(t)$.

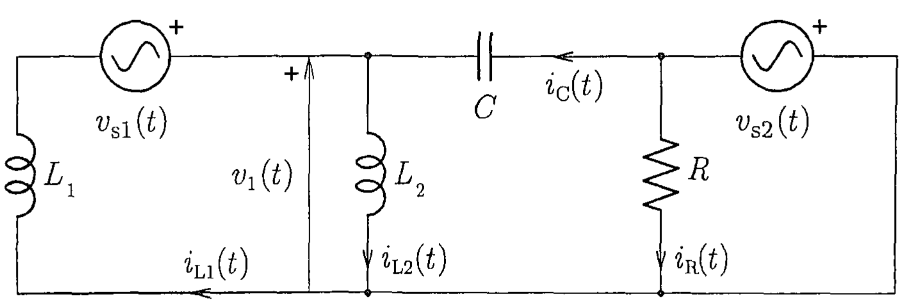

Figure 4: Circuit diagram for Question 4

Question 5

In the circuit of Figure 5, parameters are: $R = 10\,\Omega$, $L_1 = 10\,\text{mH}$, $L_2 = 5\,\text{H}$, $C_1 = 10\,\mu\text{F}$, $C_2 = 200\,\text{pF}$, 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 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 reactive power supplied by the source and the expression for current $i_1(t)$.

d) When S is in position 2: Determine the source frequency so that the reactive power supplied by the source is zero. Determine expressions for currents $i_2(t)$ and $i_{2L}(t)$.

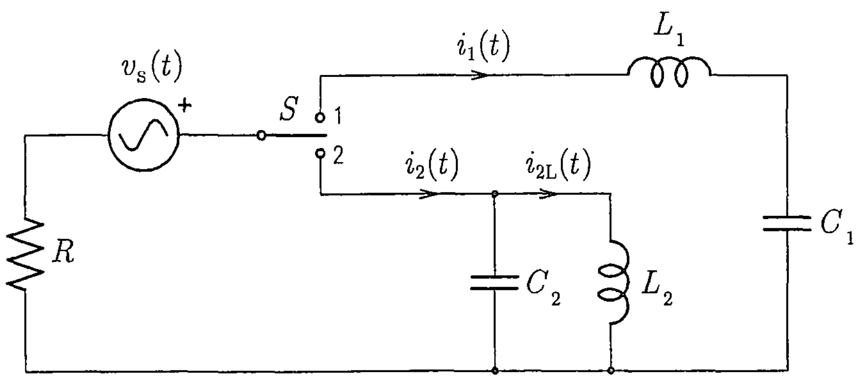

Figure 5: Circuit diagram for Question 5

Question 6

A half-wave diode rectifier is used to provide a DC current to a 50 kΩ resistive load. Rectifier is supplied by an ideal AC voltage source (50 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 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 Ω 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 logic platform provides the wind turbine blade pitch (angle) control. To operate, it uses the following sensors:

A) *Emergency stop* switch (1 if pressed)

B) Limit switch for *Full-speed* position (1 if reached)

C) Limit switch for *Vane* position (1 if reached)

D) Turbine *Ready* signal(1 if ready)

E) Wind speed upper limit (1 if wind speed is too high)

F) Wind speed lower limit (1 if wind speed is too low)

G) Rotor speed limit (1 if rotor speed is too high)

The wind turbine rotor blades should be in *Vane* position when the turbine is not operational and should be in *Full-speed* position under normal operating conditions. Rotor blade pitch is achieved by means of special servo motors that respond to commands:

a) Up (initiate blade movement toward *Full-speed* position)

b) Down (initiate normal blade movement toward *Vane* position)

c) Fast Down (initiate fast blade movement toward *Vane* position)

The *Emergency Stop Condition* is when the wind speed is too high, turbine is not *Ready*, or *Emergency stop* button is pressed. When emergency stop condition is detected blades should move **fast** to *Vane* position.

Rotor speed should never exceed the maximum rotor speed. If the maximum rotor speed limit is reached, the blade should move toward *Vane* position. The blade movement should stop when the rotor speed drops below the speed limit.

If the wind speed is too low, and turbine is ready, blades should move to *Vane* position.

Neglect the changing wind conditions.

a) Design a logic circuit that initiates normal start and brings blades to *Full-speed* position.

b) Design a logic circuit that handles the *Emergency Stop Condition*.

c) Design a logic circuit that assures that the turbine speed does not exceed the speed limit.

d) Design a logic circuit that initiates normal stop due to too low wind speed.

Note:

All kinds of gates could be used to construct the logic circuits.