National Exams May 2015

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 can 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;

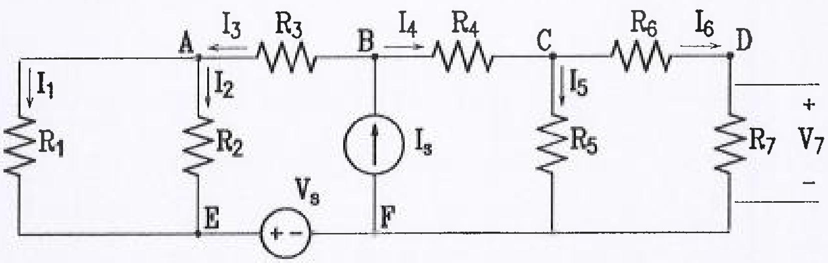

Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 2\,\text{k}\Omega$, $R_2 = 7\,\text{k}\Omega$, $R_3 = 50\,\Omega$, $R_4 = 150\,\Omega$, $I_s = 2\,\text{A}$ 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.

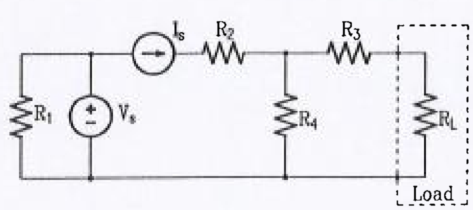

Figure 2: Circuit diagram for Question 2

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

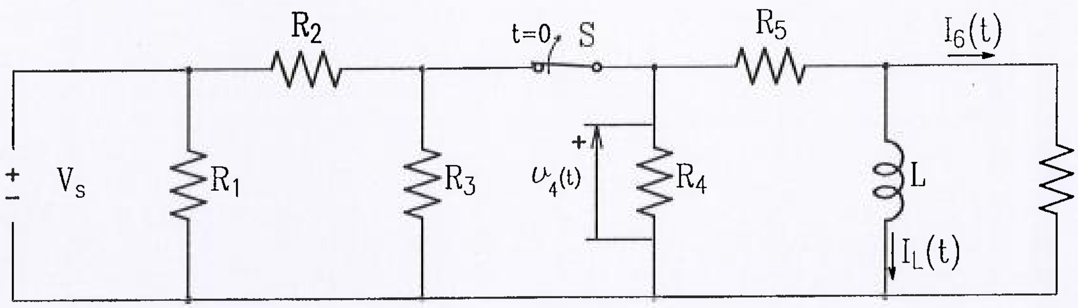

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4, 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.

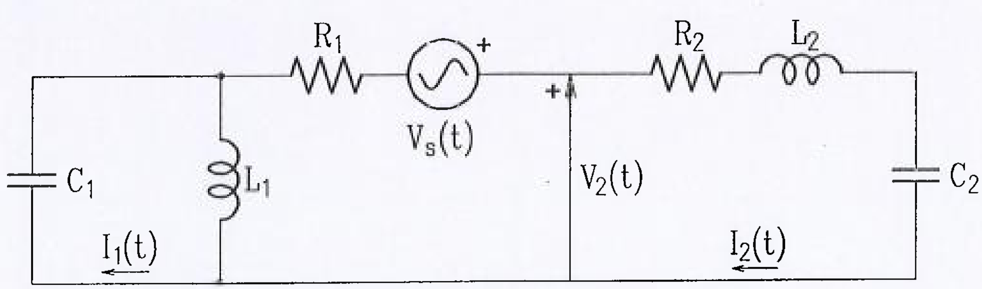

Figure 4: Circuit diagram for Question 4

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.

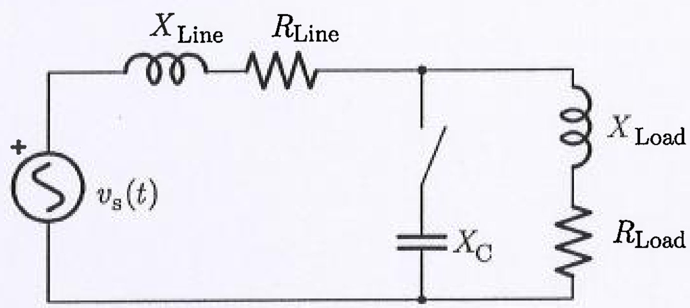

Figure 5: Circuit diagram for Question 5

Question 6

A diode bridge rectifier is used to provide a DC current to a 50 kΩ 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 Ω 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 logic platform provides control of the car alarm, engine start and automatic door lock. The following signals should be considered:

A) Ignition key in place (1 if in place)
B) Ignition activated (1 if activated)
C) Door (1 if all doors are closed)
D) Seat belt (1 if driver's seat belt is engaged)
E) Lights (1 if on)
F) Gear (1 if in Park)
G) Car in motion (1 if in motion)

The alarm should go on if:

- the ignition is activated while any door is open or the driver's seat belt is not engaged;
- the car is in motion and any door is open or driver seat belt is disengaged;
- if the ignition key is removed while the lights are on.

The engine will start if the ignition is activated, while all the doors are closed, the driver's seat belt is engaged, and the gear is in park.

Doors are automatically locked if they are closed and the car is in motion. Doors will be automatically unlocked if the car is not in motion and the ignition key is removed.

Design the logic circuit that:

a) Sounds the alarm;
b) Starts the engine;
c) Automatically locks all doors;
d) Automatically unlocks all doors.

Note:

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