National Exams May 2019

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: $R_1 = 4\,\Omega$, $R_2 = 3\,\Omega$, $R_3 = 6\,\Omega$, $R_4 = 6\,\Omega$, $R_5 = 3\,\Omega$, $I_s = 10\,\text{A}$, and $V_s = 24\,\text{V}$.

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.

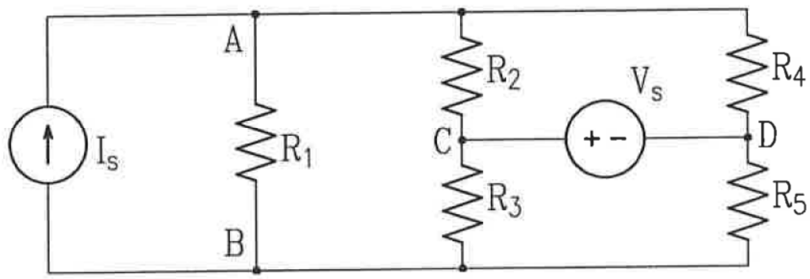

Figure 1: Circuit diagram for Question 1

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 $R_L = 45\,\Omega$.

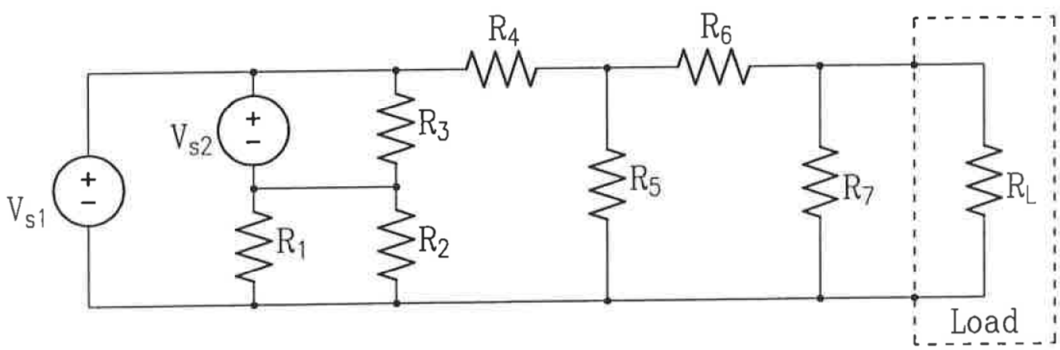

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3 $R_1 = 2\,\mathrm{k\Omega}$, $R_2 = 4\,\mathrm{k\Omega}$, $R_3 = 4\,\mathrm{k\Omega}$, $R_4 = 6\,\mathrm{k\Omega}$, $C = 5\,\mu\mathrm{F}$, and $I_s = 7\,\mathrm{mA}$. The switch S is in position 0 for a long time. At $t = 0\,\mathrm{s}$, the switch moves to position 1.

a) Calculate the voltage across the capacitor at $t \leq 0\,\mathrm{s}$.

b) Calculate the time constant of the transient when the switch moves to position 1;

c) Calculate the voltage across the capacitor at $t = 200\,\mathrm{s}$.

d) Plot the voltage across the capacitor from $t = 0\,\mathrm{ms}$, to $t = 100\,\mathrm{ms}$.

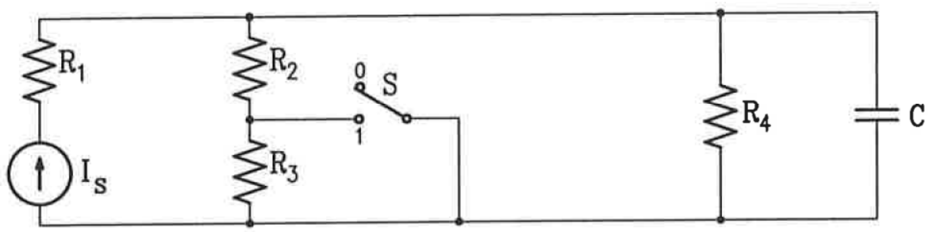

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 assume the following: $R_1 = 600\,\Omega$, $L_1 = 60\,\mathrm{mH}$, $R_2 = 200\,\Omega$, $C = 125\,\mathrm{nF}$, $i_s(t) = 400\cos(20000\,t)\,\mathrm{mA}$. Assume that the circuit is in a steady-state operating condition. Calculate the following:

a) Circuit equivalent in the complex domain;

b) Equivalent impedance seen by the source;

c) Current phasor $\underline{I_c}$;

d) Capacitor current in the time domain.

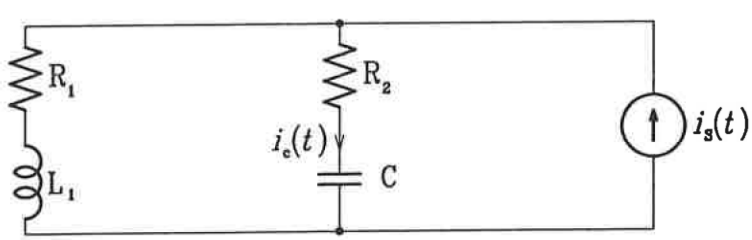

Figure 4: Circuit diagram for Question 4

Question 5

A magnetic circuit consisting of a fixed horseshoe core and a moveable core element (relay armature) is shown in Figure 5. Consider the relative permeability of the core $\mu_r = 2000$, total number of turns on both legs $N = 1000$.

a) Calculate the equivalent reluctance of each part of the magnetic circuit.

b) Calculate the current needed to produce the magnetic flux $\phi = 2\,\text{mWb}$ in the air gap;

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

d) Calculate the total electromagnetic force acting on the relay armature.

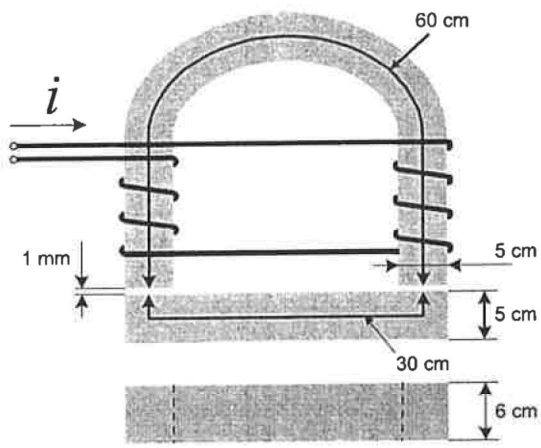

Figure 5: Magnetic core for Question 5

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, $20\,V_{RMS}$).

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 $50\,\Omega$ 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 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.