National Exams December 2011

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: $R_1 = 10\,\Omega$, $R_2 = 10\,\Omega$, $R_3 = 5\,\Omega$, $R_4 = 10\,\Omega$,$I_s = 9\,\text{A}$, and $V_s = 80\,\text{V}$.

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

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

c) Using KCL and KVL equations above calculate voltage V_{ab};

d) Calculate the power dissipated in resistor R_4?

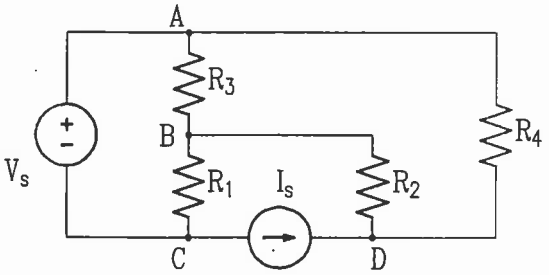

Figure 1: Circuit diagram for Question 1

Question 2

Consider the circuit of Figure 2. Known parameters are: $R_1 = 18\,\Omega$, $R_2 = 32\,\text{k}\Omega$, $R_3 = 10\,\text{k}\Omega$, $R_4 = 10\,\text{k}\Omega$, $R_5 = 5\,\text{k}\Omega$, $I_s = 15\,\text{A}$, and $V_s = 20\,\text{V}$. Determine the following:

a) Thevenin equivalent resistance seen by the load;

b) Thevenin equivalent voltage seen by the load;

c) Power transferred to the load if the load resistance R_{LOAD} is $40\,\Omega$.

d) If the load resistance changes, the power transferred to the load will change accordingly. Determine the maximum load resistance for the maximum power transfer. Determine the maximum power transferred to the load.

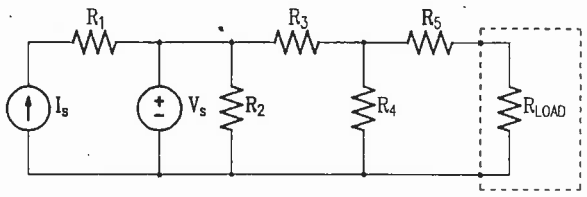

Figure 2: Circuit diagram for Question 2

Question 3

In the circuit of Figure 3, parameters are: $R_1 = 5\,\Omega$, $R_2 = 10\,\Omega$, $L_1 = 10\,\text{mH}$, $L_2 = 2\,\text{mH}$, $C_1 = 4\,\mu\text{F}$, $C_2 = 1\,\mu\text{F}$, $V_{s1}(t) = 10\,\cos(\omega\,t)\,\text{V}$.

a) Determine the source frequency so that current $I_1(t)$ and voltage $V_1(t)$ are in phase.

b) What is this frequency called? Does any other frequency have the same property in the circuit of Figure 3?

c) For the frequency calculated under (a) calculate the voltage across capacitor C_2.

d) For the frequency calculated under (a) calculate active and reactive power supplied by the source.

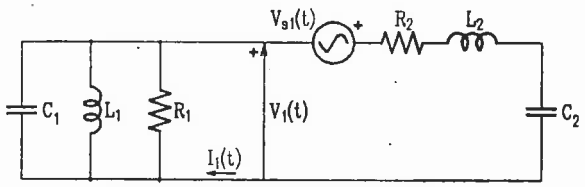

Figure 3: Circuit diagram for Question 3

Question 4

In the circuit of Figure 4 two steady-state operating conditions, when switch S is open or closed, are possible. Parameters are $R = 10\,\Omega$, $L = 5\,\text{mH}$, $R_{\text{LOAD}} = 100\,\Omega$, $v_{s1} = 20\,\cos(120\,\pi\,t)\,\text{V}$, and $I_{s2}(t) = 1\,\text{A}$. Calculate the following:

a) When S is open: Current phasor $\underline{I}_1$ and voltage phasor $\underline{V}_1$;

b) When S is open: Power consumed by R_{LOAD};

c) When S is closed: Currents $I_1(t)$ and $I_2(t)$ and voltage $V_1(t)$;

d) What is the change in power consumed by the load as a result of closing S.

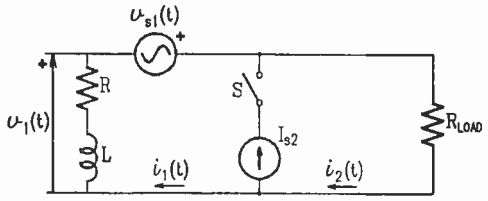

Figure 4: Circuit diagram for Question 4

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 $N = 1000$, and the current $i = 1\text{A}$.

a) Calculate the total magnetomotive force in both windings.

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

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

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

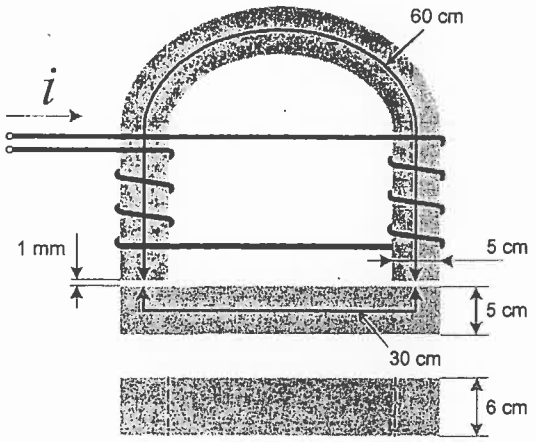

Figure 5: Magnetic core for Question 5

Question 6

A 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 (60 Hz, 50 V_{RMS}).

a) Draw the rectifier schematic diagram. Sketch the input voltage, the output voltage and the output current.

b) Find the peak and the average load current.

c) If the load has an inductive component, a simple half-wave rectifier may cause significant overvoltages. Explain why.

d) Suggest the modification to a simple half-wave rectifier circuit to make it suitable for the inductive load.

Question 7

A logic platform provides control for a plotter pen cradle. The following conditions should be considered:

A) UP arrow button is pressed (1 if yes).

B) DOWN arrow button is pressed (1 if yes).

C) LEFT arrow button is pressed (1 if yes).

D) RIGHT arrow button is pressed (1 if yes).

E) UP area boundary is reached (1 if yes).

F) DOWN area boundary is reached (1 if yes).

G) LEFT area boundary is reached (1 if yes).

H) RIGHT area boundary is reached (1 if yes).

I) RESET button is pressed (1 if yes).

J) RESET indicator is active (1 if yes).

K) EMERGENCY button is pressed (1 if yes).

L) EMERGENCY STOP indicator is active (1 if yes).

One motor provides the cradle movement in the UP-DOWN direction. The other provides the cradle movement in the LEFT-RIGHT direction. Assume that each of the motors has two separate control inputs (one for each direction). Both control inputs should not be set to one at the same time.

When the paper boundary is reached the cradle will not move beyond the boundary in question (for instance, reaching the UP boundary prevents the cradle movement in the UP direction). Reaching UP or DOWN boundary does not affect the LEFT-RIGHT movement and vice versa.

When the RESET button is pressed, all other inputs are ignored, RESET indicator is set, EMERGENCY STOP indicator is cleared, and the cradle moves to the HOME location (a lower left corner of the paper. Once the HOME location is reached, the movement stops and the RESET indicator is cleared.

When the EMERGENCY button is pressed the cradle stops and the EMERGENCY STOP indicator is activated. The cradle will not move until the EMERGENCY STOP indicator is cleared.

Design the logic circuit that does the following:

a) Controls the cradle movement in the UP-DOWN direction.

b) Controls the cradle movement in the LEFT-RIGHT direction.

c) Handles the RESET indicator.

d) Handles the EMERGENCY STOP indicator.

Note:

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