PROFESSIONAL ENGINEERS ONTARIO

National Examinations - May 2013

07-Mec-A5, Electrical & Electronics Engineering

Mechanical Engineering

3 hours duration

Name [print]: Signature:

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 any assumptions made.

[2] Candidates may use one of two calculators, the Casio or Sharp approved models. This is a closed book examination.

[3] This examination consists of the front page and 8 numbered pages.

[4] Any five (5) questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

[5] Each question is of equal value.

[6] Clarity and organization of answers are important.

[7] The candidate is required to sign this examination paper and submit it with the solution booklets.

[8] $\pi = 3.14159$
$1 \text{ hp} = 746 \text{ W}$
$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$

QUESTION 1

Consider the transistor circuit shown in Figure 1. All transistors can be assumed to be identical with a dc current gain β.

Calculate the current transfer ratio for the circuit, I_2 / I_1, as a function of β.

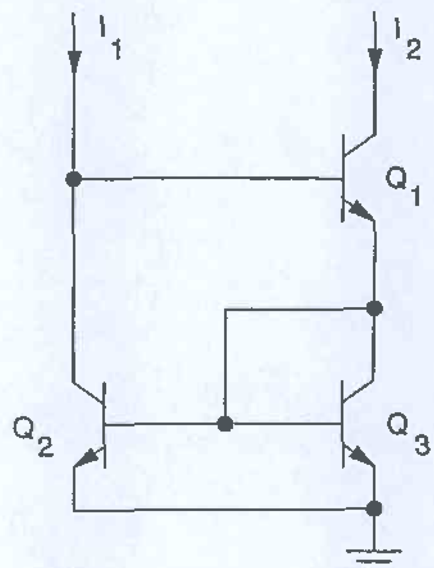

Figure 1 Transistor Circuit

QUESTION 2

This question consists of two parts which are not necessarily related.

Part I

A combinational logic circuit is shown in Figure 2.

[a] Write a general Boolean algebra expression for the output F as a function of the inputs A, B.

[b] Using DeMorgan's theorems and other Boolean identities, simplify the expression obtained in [a]. Is there a single gate which can replace the network shown?

[c] Generate a truth table giving the logic levels at points C, D, E and F for inputs A,B.

Part II

Design a 2-input exclusive or (EOR) gate using only 2-input NOR gates.

[d] Develop the truth table for the gate.

[e] Write a general Boolean algebra expression for the output as a function of the inputs.

[f] Using DeMorgan's theorems and other Boolean identities, modify the expression obtained in [e] to provide a solution which can be implemented with NOR gates.

[g] Draw the circuit diagram for the final gate array.

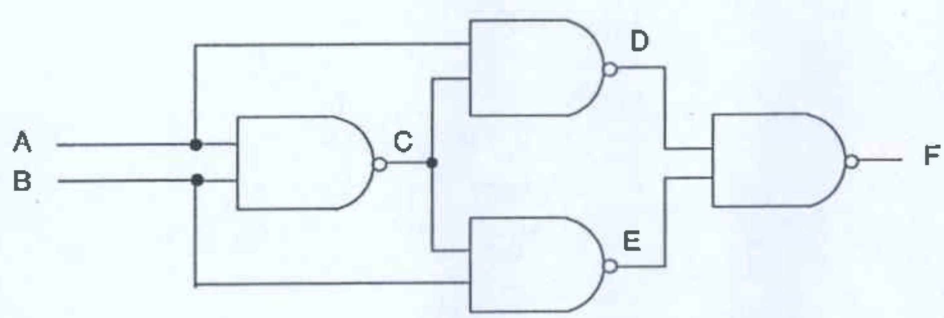

Figure 2 Combinational Logic Circuit

QUESTION 3

A novel type of DC machine is designed using a disc type rotor of effective outer and inner diameters D and d respectively, as shown in Figure 3. A current I_2 is fed radially through the rotor via two ring shaped carbon brushes. The rotor lies in the horizontal plane and is situated in a vertical magnetic field of uniform density, B Tesla. The rotor spins at an angular speed ω rad/s.

[a] Find the magnitude of the emf e generated between the brushes.

[b] Determine the torque that the rotor will be subjected to and find the output horsepower of the machine.

HINT: As a starting point, consider an elemental annulus of radius **r** and radial length **dr**.

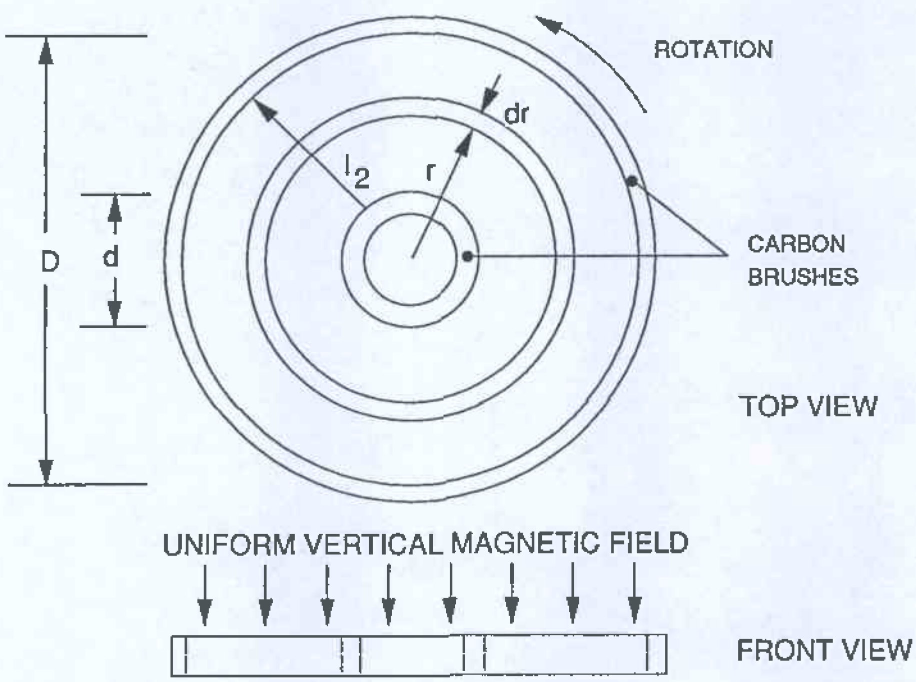

Figure 3 dc Machine

QUESTION 4

An industrial load is represented in Figure 4 by $R = 6\Omega$ and $X_L = 8\Omega$. The load voltage is $250\angle 0^\circ$ V.

[a] Calculate the load current, power, reactive power and power factor.

[b] Calculate the generator voltage V_G required at the input end of the transmission line (represented by the series impedance $Z_T = (1 + j3)\Omega$ and the power lost in transmission P_T.

[c] If capacitor $X_C = 12.5\Omega$ is connected in parallel by closing switch S, calculate I_C, the new load current I, and the new power factor. Show V, I_L, I_C, and I on a phasor diagram.

[d] Calculate the new generator voltage and the new transmission power loss.

[e] What two advantages do you see for improving the power factor by adding a parallel capacitor?

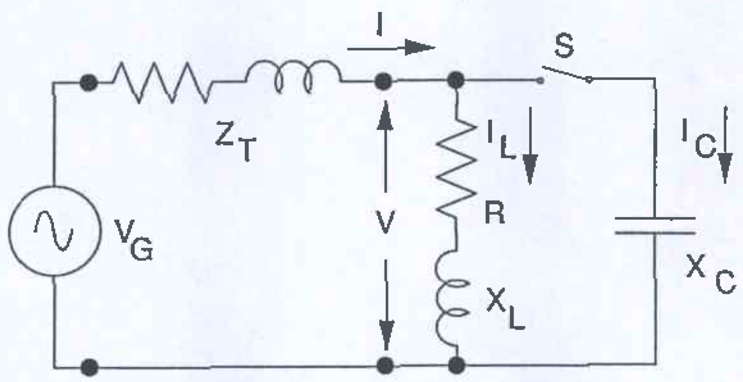

Figure 4 Industrial Load

QUESTION 5

Consider the circuit shown in Figure 5 which has been designed using ideal operational amplifiers (U_1 to U_3) with infinite bandwidth and infinite open loop gain. In the schematic, a, b and c are constants. You will note that U_3 is configured as a basic difference amplifier which has a transfer function given by:

$$E_0 = c\,(e_y - e_x)$$

where e_y and e_x are the potentials at points y and x respectively.

In the derivation of the transfer function for such circuits, one can assume:

[i] Zero differential voltage between the input terminals of the operational amplifier,

[ii] Zero current flows into either input terminal of the operational amplifier.

Applying the principle of superposition, derive an expression for the transfer function of the total circuit [E_0 as a function of E_1, E_2].

Hint: Let $E_2 = 0$, and solve for the potentials at points x and y for input E_1.
Let $E_1 = 0$, and again solve for the potentials at points x and y for input E_2.
Calculate the resultant output E_0 for both E_1 and E_2 inputs.

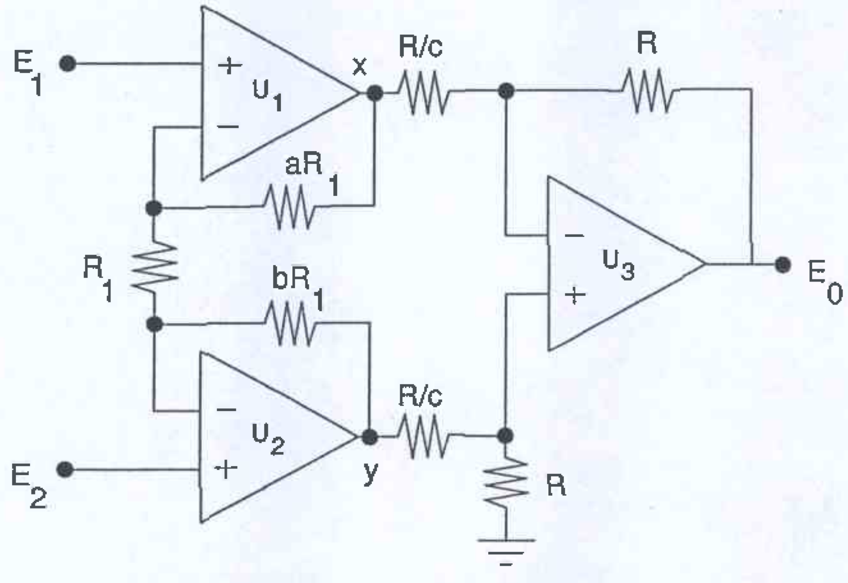

Figure 5 Circuit Schematic

QUESTION 6

Part I

A dc test is performed on a 208-V, six-pole, delta connected, 60Hz induction motor, as shown in Figure 6.

[a] If $V_{DC} = 3.32$ V and $I_{DC} = 3.1$ A, calculate the per phase stator resistance, r_1.

Three phase excitation is applied to the motor which runs with a slip of 3.5%. Find:

[b] The speed of the magnetic field in revolutions per minute.

[c] The speed of the rotor in revolutions per minute.

[d] The electrical frequency of the rotor current.

The load on the motor is now doubled. Calculate:

[e] The speed of the rotor in revolutions per minute.

Part II

You are provided with a graph of the speed-torque characteristic of a three phase wound rotor induction motor. The torque required to drive a pump is $T = K_P n^2$ (K_P is a constant; n is speed in revolutions/second). The induction motor is to be used to drive the pump. Show how you would determine the operating point speed of the system.

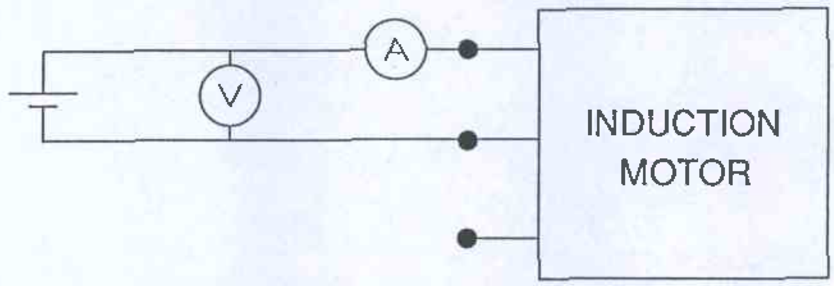

Figure 6 dc Test on Induction Motor

QUESTION 7

Consider the RC circuit shown in Figure 7[a]. The switch S_1 is closed at time t=0 connecting the dc supply V_I to the network.

[a] Derive an expression for the transfer function of the circuit, V_o/V_I, in the time domain.

[b] Sketch the transfer function for a time interval of 5 time constants.

The RC circuit is reconfigured as shown in Figure 7[b]. An ac voltage source of variable frequency v_i is connected to the input.

[c] Derive an expression for the transfer function of the circuit, v_o/v_i, in the frequency domain.

[d] Sketch the magnitude of the transfer function for a frequency range of 4 decades centered at the corner frequency of the circuit.

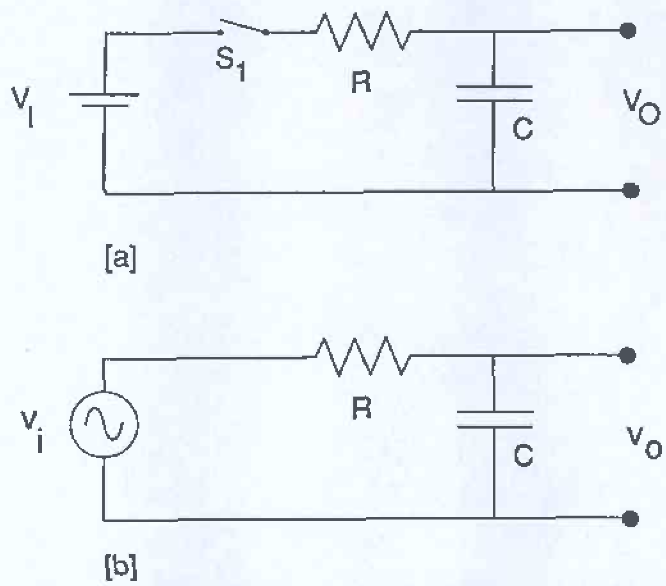

Figure 7 RC Circuit: [a] dc test; [b] ac test

QUESTION 8

Consider the magnetic circuit shown in Figure 8. An ac voltage source $v_1(t)$ is applied to the primary winding, with N_1 turns, which results in a primary current $i_1(t)$. A voltmeter is used to measure the voltage induced in the secondary winding $v_2(t)$. The magnetic circuit has a mean length of L m, a cross sectional area of A m^2 and a relative permeability of μ_R. The primary current is given by:

$$i_1(t) = I_P \sin \omega t$$

where I_P is the peak value of the primary current and ω is the radian frequency of the supply voltage source. Neglect the resistance of the windings, leakage inductances and other losses.

[a] Develop expressions for the primary voltage $v_1(t)$ and the secondary voltage $v_2(t)$ as a function of the current $i_1(t)$.

[b] Develop an expression for the impedance of this circuit as viewed from the primary.

[c] Sketch waveforms for the primary voltage v_{AB} and the secondary voltage v_{XY} showing the magnitudes and phase relations with respect to the primary current $i_1(t)$.

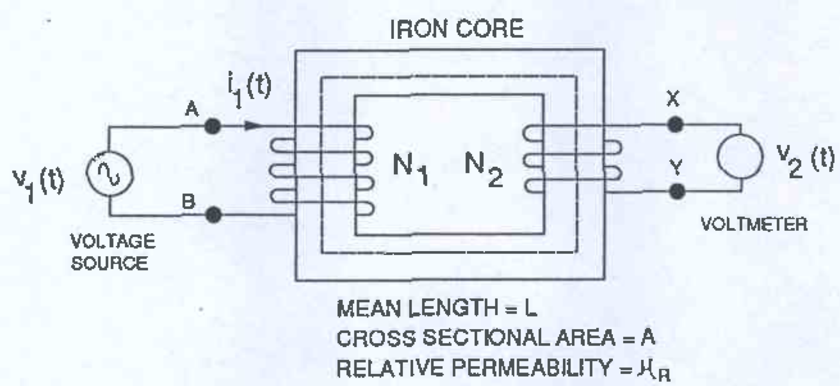

Figure 8 Magnetic Circuit