

PROFESSIONAL ENGINEERS ONTARIO
National Examinations - December 2014
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 hp = 746 W
 $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$

Front Page

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 .

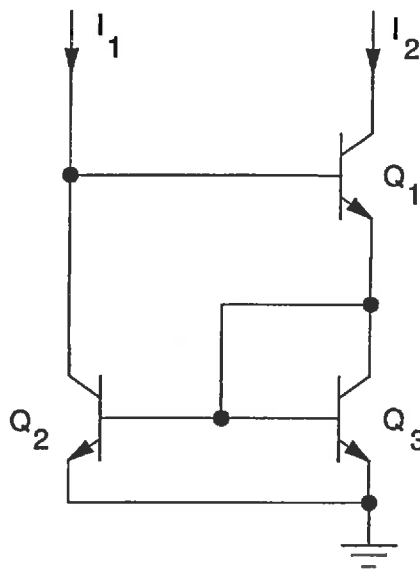


Figure 1 Transistor Circuit

QUESTION 2

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

Part I: Design

Develop the truth table for a 2-input exclusive or gate and write the Boolean algebra expression for the output Y as a function of the inputs A,B.

You are provided with quantity six 2-input nor gates. Design the gate array to implement the 2-input exclusive or function.

Part II: Analysis

A combinational logic circuit is shown in Figure 2.

- Write a general Boolean algebra expression for the output C as a function of the inputs A, B, K_0 , and K_1 .
- Apply DeMorgan's theorems and simplify the expression obtained in [a].
- For each of the 4 possible combinations of K_0 , K_1 , reduce the expression for C to its simplest form.

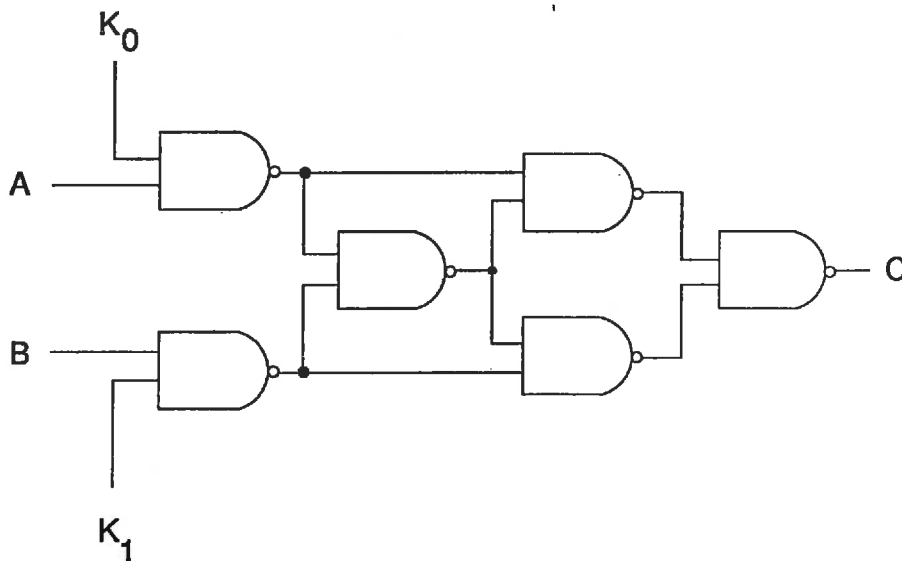


Figure 2 Circuit Schematic

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 .

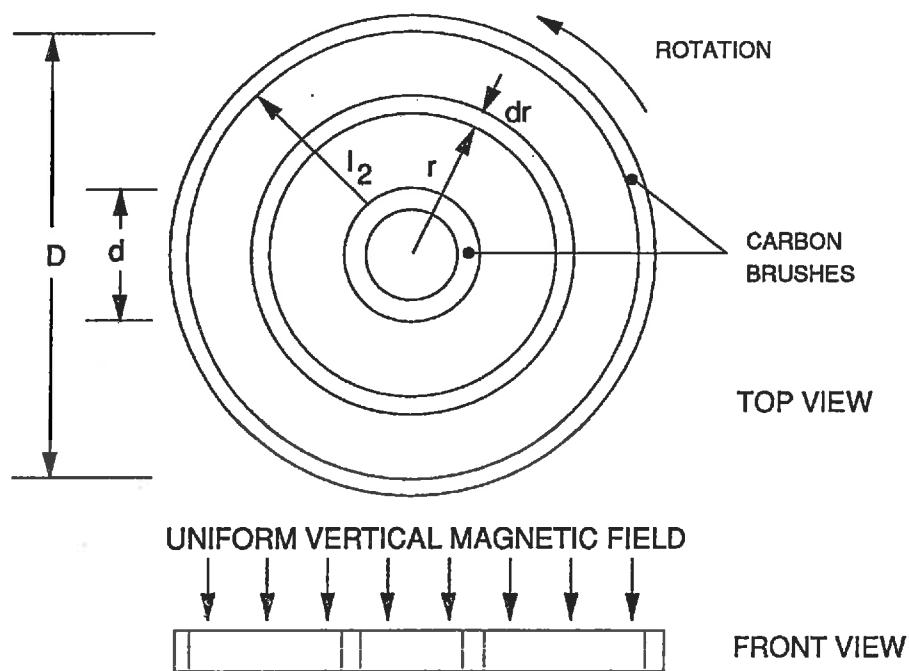


Figure 3 dc Machine

QUESTION 4

Consider the magnetic circuit of a transformer shown in Figure 4. Infinite relative permeability can be assumed for the iron core.

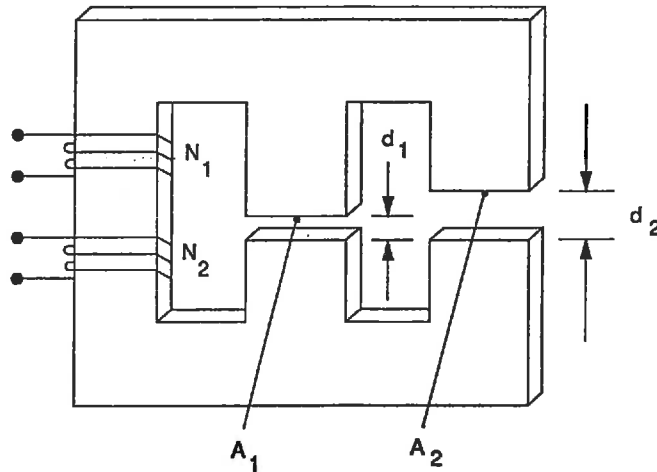


Figure 4 Transformer

The following specifications apply.

L_1	$3.77 \times 10^{-2} \text{ m}$	A_1	0.02 m^2
L_2	$7.54 \times 10^{-2} \text{ m}$	A_2	0.02 m^2
N_1 [primary]	200 turns	N_2 [secondary]	20 turns

When a dc voltage equal to 10 mV is applied to the primary, the measured primary current is 100 mA. When a dc voltage of 0.1 mV is applied to the secondary winding, the measured secondary current is 100 mA.

Assume that leakage inductances and eddy current and hysteresis losses are negligible; consider an operating frequency of 1000 Hz.

- [a] Draw the equivalent circuit of the transformer referred to the primary and calculate component values.
- [b] A transducer with an impedance of 0.078Ω is connected across the secondary of the transformer; an amplifier is connected to the primary. Calculate the output impedance of the amplifier to give maximum power transfer to the load.

QUESTION 5

Consider the circuit shown in Figure 5. Assume an ideal operational amplifier with infinite bandwidth and infinite open loop gain.

- [a] Use the straight line approximation technique to sketch a plot of the magnitude of V_O / V_I in dB versus \log_{10} of frequency for a frequency range of 0.001 Hz to 10 MHz. Clearly indicate all gain levels, corner frequencies and unity gain points. Show calculations of the data used to plot your graph.
- [b] A signal generator is connected to the input of the circuit.
 - [1] A sine wave of frequency 0.01 Hz is selected for input to the circuit. What is the function of the circuit at this frequency? Write an expression for the transfer function of the circuit in the time domain.
 - [2] A sine wave of frequency 1000 Hz is selected for input to the circuit. What is the function of the circuit at this frequency? Write an expression for the transfer function of the circuit in the time domain.
 - [3] A sine wave of frequency 1 MHz is selected for input to the circuit. What is the function of the circuit at this frequency? Write an expression for the transfer function of the circuit in the time domain.

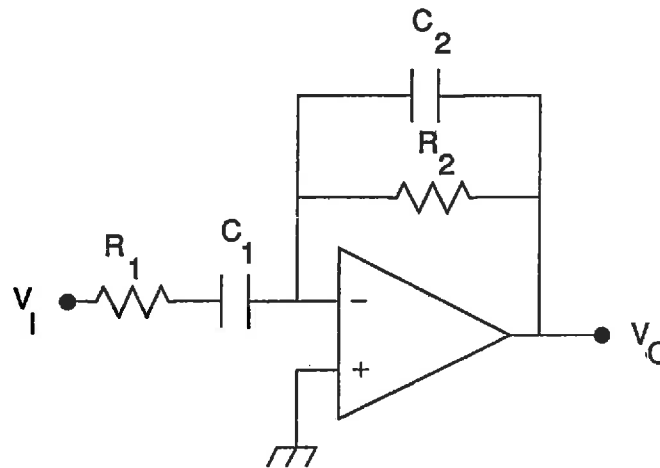


Figure 5 Circuit Schematic

Resistors		Capacitors	
R_1	160 kohm	C_1	1.0 μ F
R_2	16 Mohm	C_2	1 pF
Component List			

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.

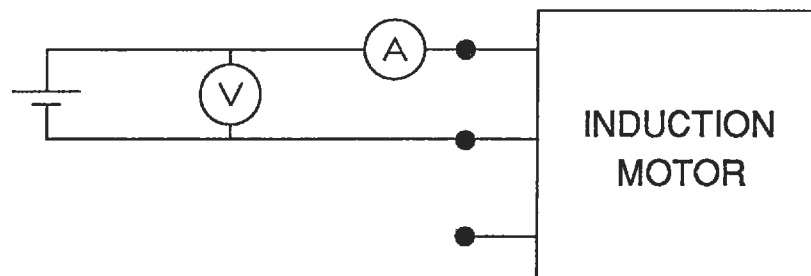


Figure 6 dc Test on Induction Motor

QUESTION 7

Consider the RC circuit shown in Figure 7. The switch S_1 is closed at time $t=0$, connecting the dc supply, V_1 , to the network.

- [a] Derive an expression for the voltage drop across the capacitor C_1 as a function of time.
- [b] Derive an expression for the current delivered to the capacitor C_1 as a function of time.

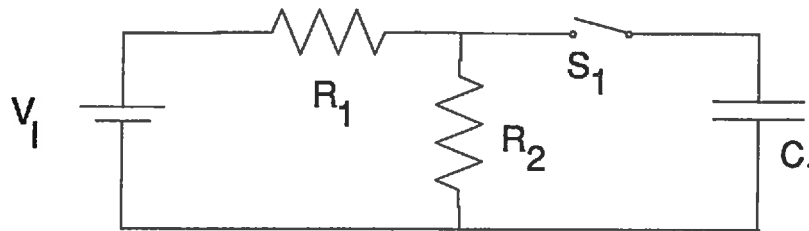


Figure 7 RC Circuit

COMPONENT LIST			
$R_1 = 30 \text{ k}\Omega$	$R_2 = 30 \text{ k}\Omega$	$V_1 = 10 \text{ V}$	$C_1 = 3 \text{ }\mu\text{F}$

QUESTION 8

Part I

Consider the circuit shown in Figure 8a. A one volt (rms) ac voltage source, given by $V = 1 \angle 0^\circ$ is connected to a parallel R-L network. The resistor R has a value of 1Ω ; the impedance of the inductor is $j1\Omega$.

Calculate: [a] the current through R, I_1 ; [b] the current through L, I_2 ; [c] the total current into the network, I_T ; [d] the real power delivered to the load; [e] the system power factor. Note: The currents for parts [a] - [c] should be expressed as phasor quantities, of the form: $I \angle \phi^\circ$.

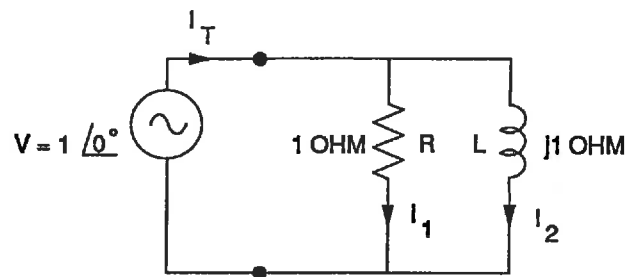


Figure 8a Circuit for Part I

Part II

A capacitor is added in parallel to the inductor as shown in Figure 8b. The impedance of the capacitor is $-j1\Omega$.

Calculate: [a] the current through R, I_1 ; [b] the current through L, I_2 ; [c] the current through C, I_3 ; [d] the total current into the network, I_T ; [e] the real power delivered to the load; [f] the system power factor. Note: The currents for parts [a] - [d] should be expressed as phasor quantities, of the form: $I \angle \phi^\circ$.

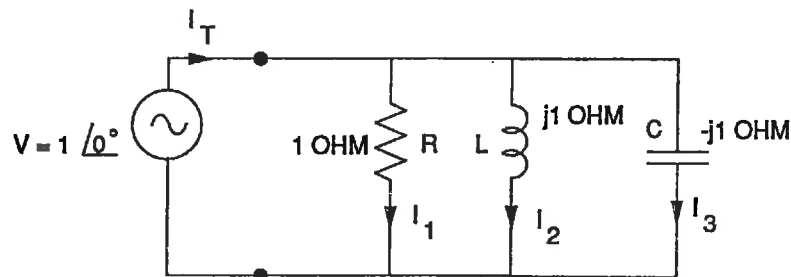


Figure 8b Circuit for Part II