PROFESSIONAL ENGINEERS ONTARIO

National Examinations - May 2015

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 amplifier circuit shown in Figure 1. Assume an average DC current gain $\beta = 100$ for the npn transistor.

[a] Determine the values of R_E and R_C required for an operating point of $I_C = 2$ mA and $V_{CE} = 6$ V.

[b] Sketch the I_C vs V_{CE} characteristic and draw the dc load line.

[c] For $R_L = 3\text{k}\Omega$, draw the ac load line and estimate the output voltage v_o for an input current $i_b = 10 \sin \omega t$ μA.

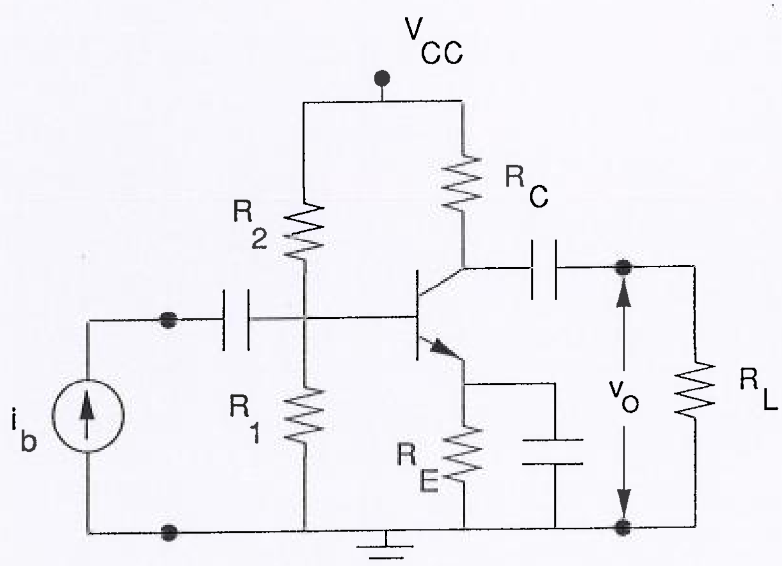

Figure 1 Transistor Circuit

Component List			
$R_1 = 10$ kΩ	$R_2 = 30$ kΩ	$V_{CC} = 15$ V	

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.

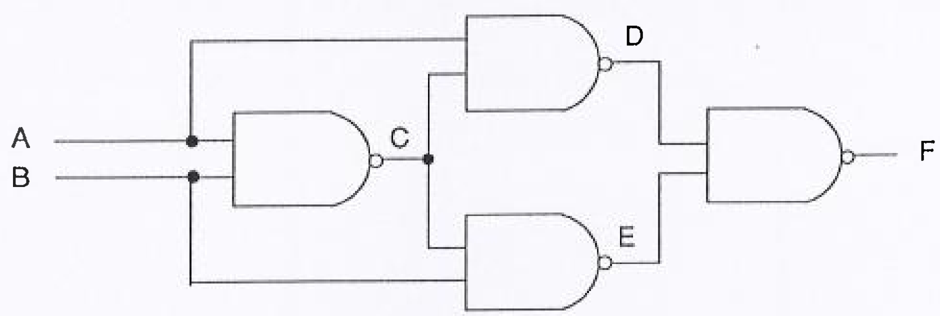

Figure 2 Combinational Logic Circuit

QUESTION 3

A novel type of dc machine can be designed using a spoke-like rotor with current carrying conductors arranged in a radial fashion as shown in Figure 3. Current is fed radially through the rotor spokes via two ring shaped carbon brushes. The rotor lies in the horizontal plane and is situated in a uniform vertical magnetic field.

The rotor has an outer radius $R_2 = 0.2$ m and an inner radius $R_1 = 0.05$ m and consists of 8 conductors. The magnetic flux density B is 0.5 T.

[a] If the rotor runs at a speed of n = 3000 rpm, find the magnitude of the emf e generated between the brushes.

[b] If a total current of 500 A flows radially between the brushes, calculate the torque that the rotor will be subjected to and determine the output horsepower of the machine.

HINT: As a starting point, consider a small radial element of length **dr** located at a distance **r** from the centre of rotation.

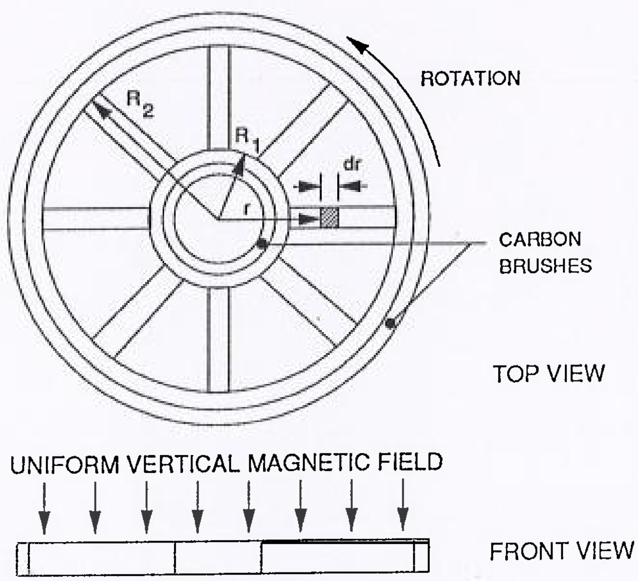

Figure 3 dc Machine

QUESTION 4

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

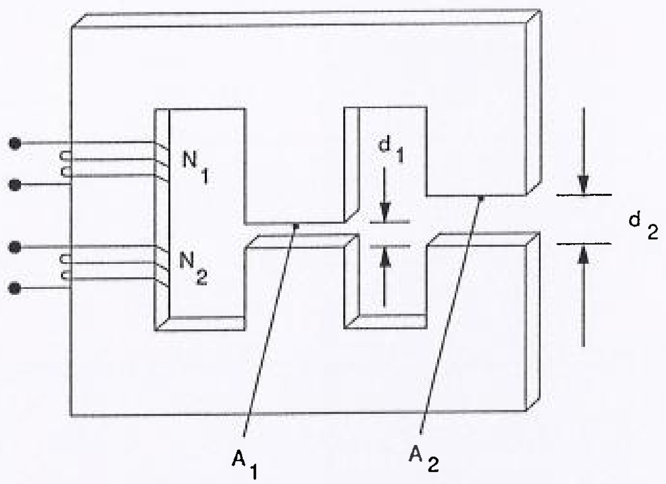

Figure 4 Transformer

The following specifications apply.

L_1	3.77×10^{-2} m	A_1	0.02 m^2
L_2	7.54×10^{-2} 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 0.078 Ω 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.

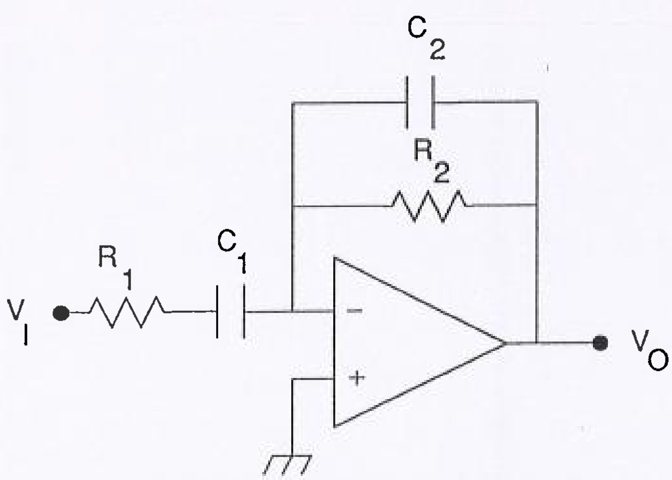

Figure 5 Circuit Schematic

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

QUESTION 6

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

Part I

A 3 phase, 300 hp, 12 pole wound rotor induction motor is operated from a 60 Hz source. The per phase rotor resistance r_2 was measured and found to be 0.04Ω. At full load, the speed of the motor is 582 rpm.

At full load, determine:

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

[b] The slip of the rotor.

[c] The frequency of the rotor currents.

[d] The angular velocity of the stator field with respect to the stator.

[e] The angular velocity of the stator field with respect to the rotor.

[f] The angular velocity of the rotor field with respect to the rotor.

[g] The angular velocity of the rotor field with respect to the stator.

Part II

In the normal operating region of an induction motor, torque is a linear function of slip. A test was performed on a 3 phase, 8 pole squirrel cage induction motor which is operated from a 60 Hz source and it was found that it developed a torque of 3 N.m at a speed of 810 rpm.
The induction motor is used to drive a load which requires a torque which is a linear function of speed. In another test, it was found that the torque required by the load was 0.5 N.m at a speed of 435 rpm.

[a] Sketch the speed-torque characteristics for the motor and load.

[b] Calculate the operating point for the motor-load system.

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.

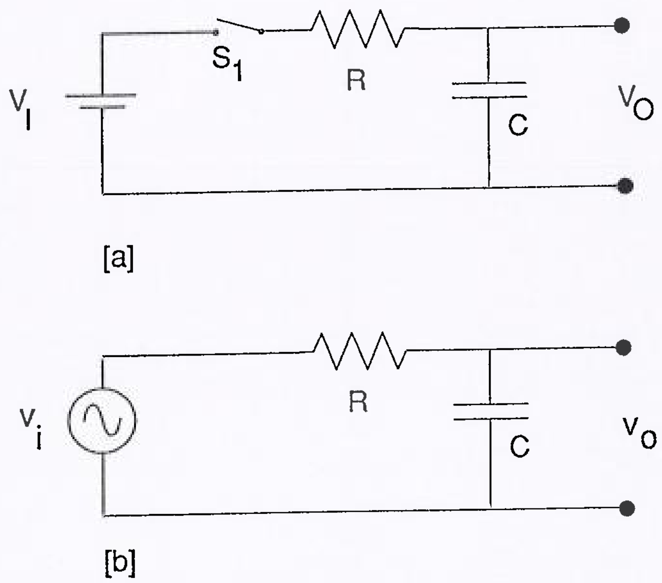

Figure 7 RC Circuit: [a] dc test; [b] ac test

QUESTION 8

An industrial load is represented in Figure 8 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?

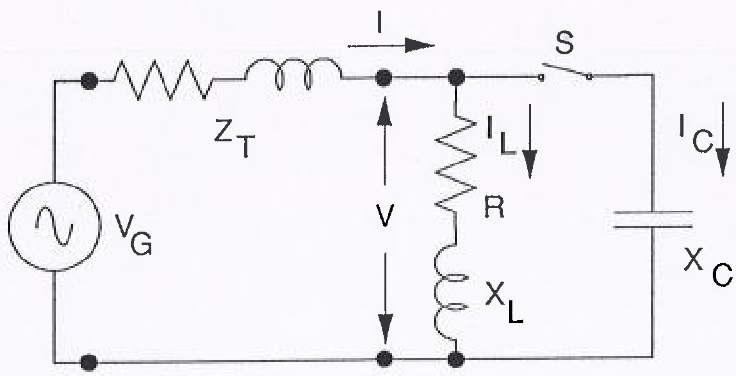

Figure 8 Industrial Load