PROFESSIONAL ENGINEERS ONTARIO

National Examinations - December 2011

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

[4] Each question is of equal value.

[5] Clarity and organization of answers are important.

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

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

QUESTION 1

The silicon transistor in the circuit of Figure 1 has a nominal β of 100; $V_{CC} = 15V$, $R_1 = 10\ k\Omega$ and $R_2 = 30\ k\Omega$. The three capacitors can be considered as ac short circuits.

[a] Specify R_E and R_C to put the operating point at $V_{CE} = 6V$ and $I_C = 2$ mA.

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

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

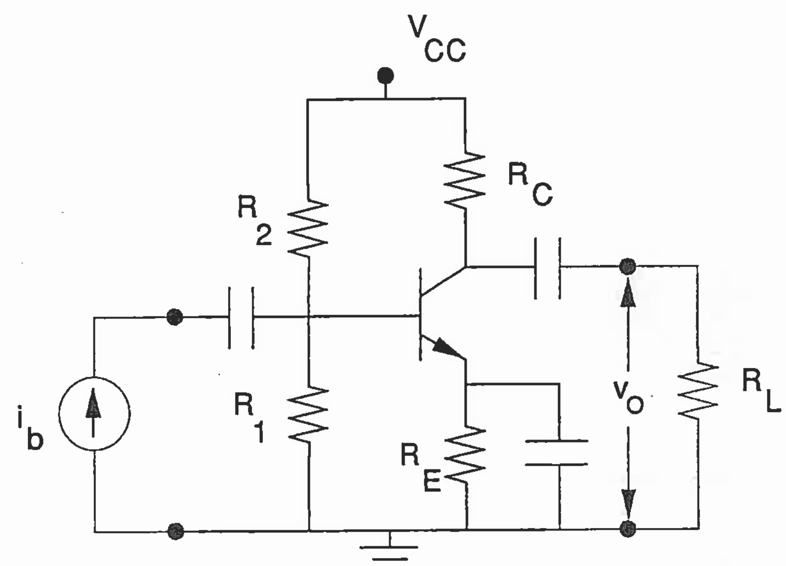

Figure 1 Transistor Circuit

Component List			
$R_1 = 10\ k\Omega$	$R_2 = 30\ k\Omega$	$V_{CC} = 15$ V	

QUESTION 2

Consider the circuit shown in Figure 2. 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.

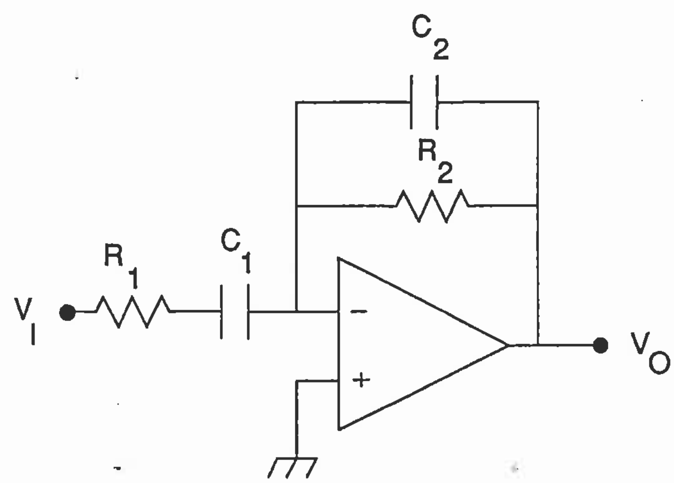

Figure 2 Circuit Schematic

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

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.

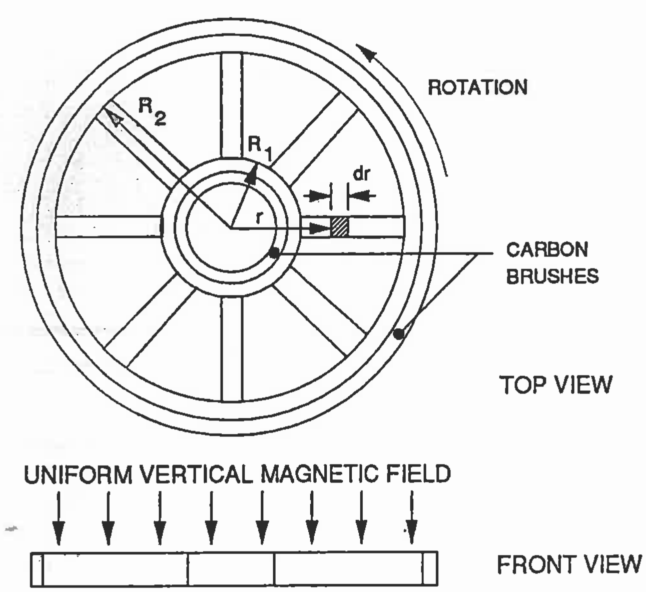

Figure 3 dc Machine

QUESTION 4

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

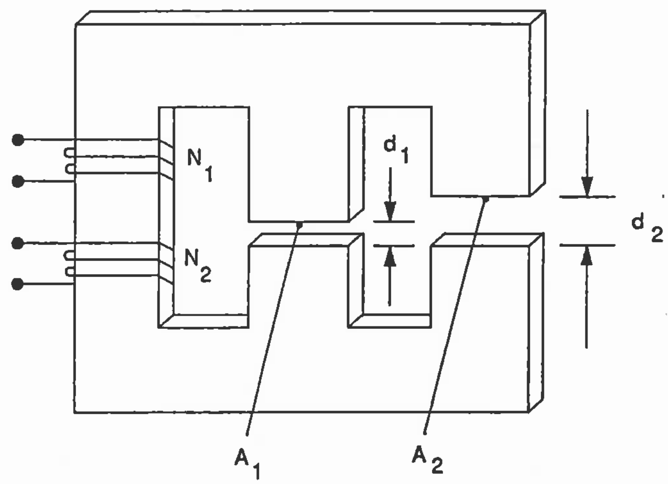

Figure 4 Transformer

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

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 5.

[a] Write a general Boolean algebra expression for the output C as a function of the inputs A, B, K_0, and K_1.

[b] Apply DeMorgan's theorems and simplify the expression obtained in [a].

[c] For each of the 4 possible combinations of K_0, K_1, reduce the expression for C to its simplest form.

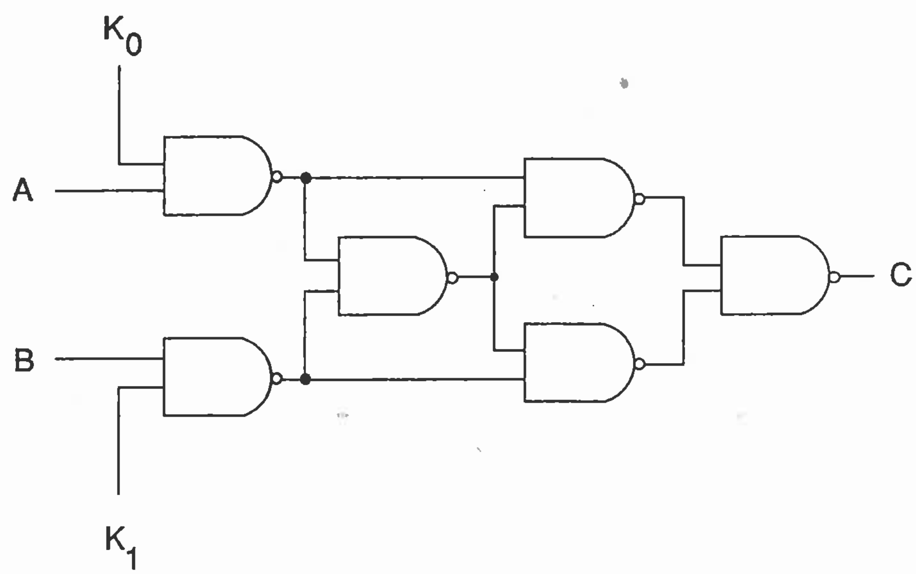

Figure 5 Circuit Schematic

QUESTION 6

Consider the RC circuit shown in Figure 6[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_0/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 6[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.

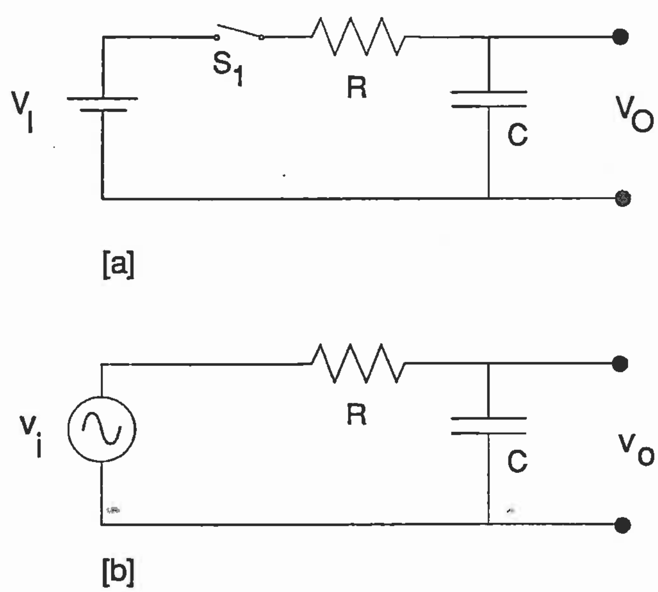

Figure 6 RC Circuit: [a] dc test; [b] ac test

QUESTION 7

A 60 Hz voltage supply is connected to the load shown in Figure 7. Measurements are performed; the voltmeter (V) measures 125V rms, the ammeter (A) measures 5.1A rms and the wattmeter (WM) measures 480W. The load consists of a resistor and inductor in series. Find the following:

[a] Power factor (magnitude and leading or lagging).

[b] Real power.

[c] Apparent power.

[d] Reactive power.

[e] Average stored energy.

[f] Draw a phasor diagram.

[g] Calculate the value of the capacitor which when added in parallel to the load will yield a power factor of unity.

[h] In an industrial application, the addition of capacitor banks is one method considered for the correction of power factor. What type of motor can be used to effect the same power factor correction?

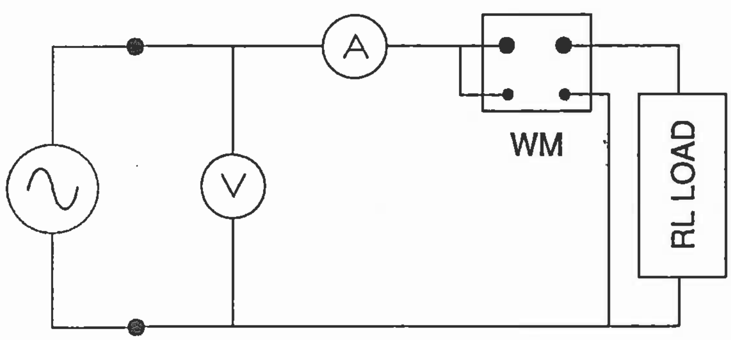

Figure 7 Measurement Setup for RL Circuit

QUESTION 8

The results of no-load and blocked-rotor tests conducted on a three-phase wye-connected induction motor are as follows:

No-load test:

line-to-line voltage: 400V
input power: 1770W
input current: 18.5A
friction and windage loss: 600W

Blocked-rotor test:

line-to-line voltage: 45V
input power: 2700W
input current: 63A

[a] Sketch the equivalent circuit of the induction motor and identify all parameters.

[b] Determine the parameters of the equivalent circuit of the induction motor.