

PROFESSIONAL ENGINEERS ONTARIO
National Examinations - May 2009
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 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 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, $V_{CC} = 15V$, $R_1 = 10\text{ k}\Omega$ and $R_2 = 30\text{ k}\Omega$. The three capacitors can be considered as ac short circuits.

- Specify R_E and R_C to put the operating point at $V_{CE} = 6V$ and $I_C = 2\text{ mA}$.
- Sketch the I_C vs V_{CE} characteristic and draw the dc load line.
- For $R_L = 3\text{ k}\Omega$, draw the ac load line and estimate the output voltage v_o for an input current $i_b = 10 \sin \omega t \mu\text{A}$.

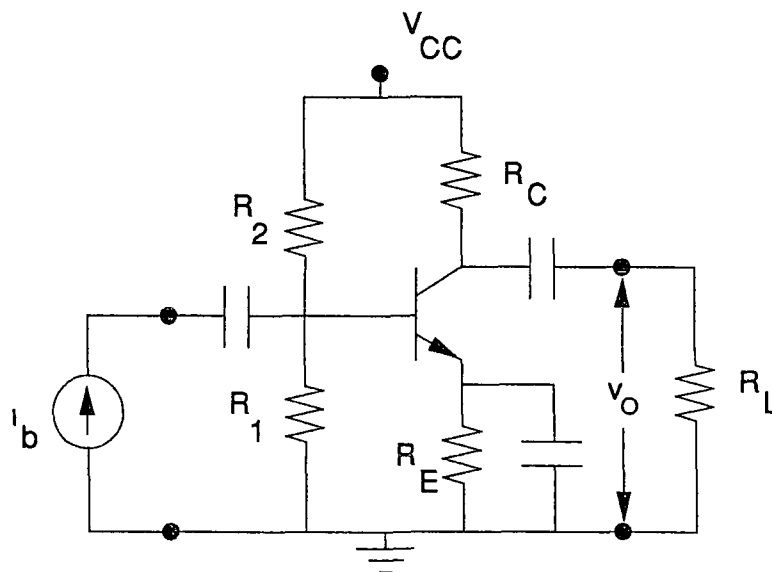


Figure 1 Transistor Circuit

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

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.

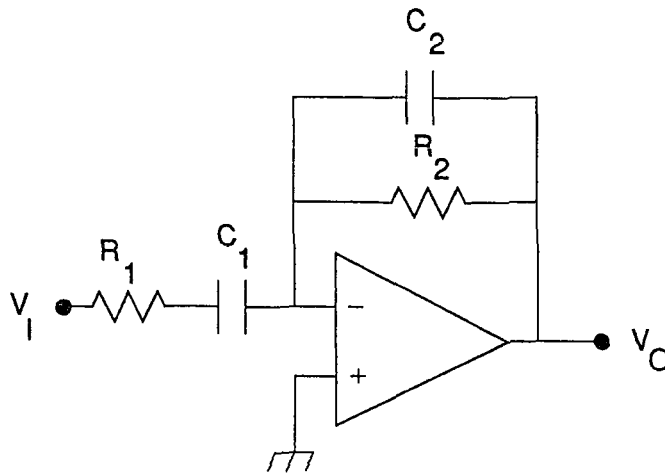


Figure 2 Circuit Schematic

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

QUESTION 3

A linear dc machine consisting of a conducting bar resting on two conducting rails is shown in Figure 3. The magnetic flux density is 1 T, directed into the page, the resistor R is $0.05\ \Omega$, the rail separation is 1 metre, and the battery voltage V_0 is 2 V. Assume negligible friction between the bar and rails.

- [a] Assume that the bar is stationary at time $t=0$ when the switch S_1 is closed. What is the magnitude and direction of the force on the bar at the start? What is the initial current flow? What is speed of the bar assuming that no mechanical load is applied to the bar?
- [b] If the bar is loaded down with a force of 20 N opposite to the direction of motion, determine the new steady state speed. Calculate the power delivered by the battery, the power delivered to the mechanical load and the power lost to heat in the resistance R . What is the efficiency of the machine under these circumstances?
- [c] The loading force in part [b] is removed and a mechanical pulling force of 10 N directed to the right is applied to the bar. In steady state, determine the speed, the power taken from the mechanical source, the power delivered to the battery and the power lost to heat in the resistance R . What is the efficiency of the machine under these circumstances?

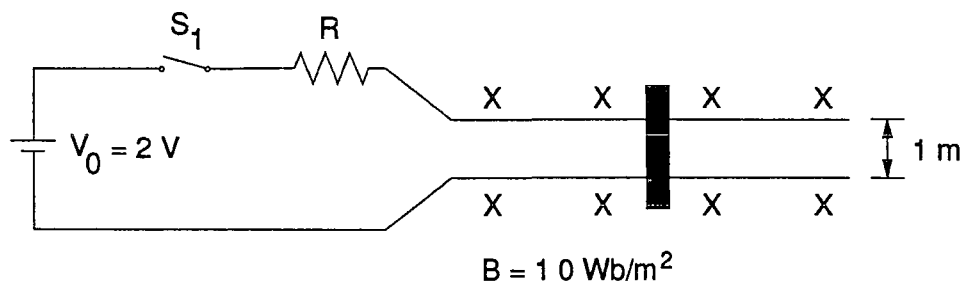


Figure 3 Top View of Linear dc Machine

QUESTION 4

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

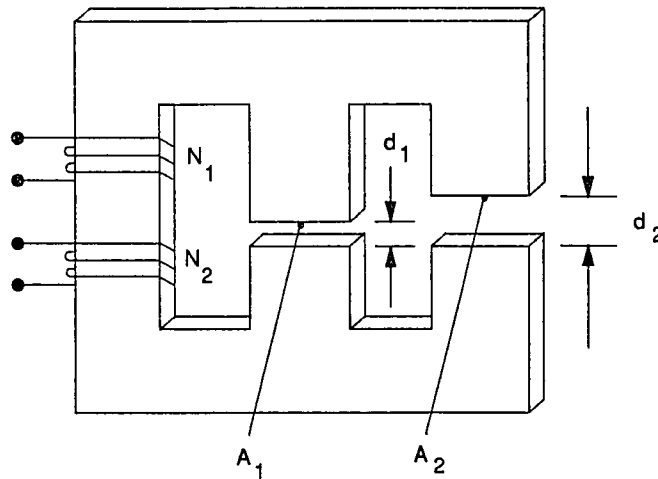


Figure 4 Transformer

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.

- Draw the equivalent circuit of the transformer, referred to the primary and calculate component values.
- 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

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

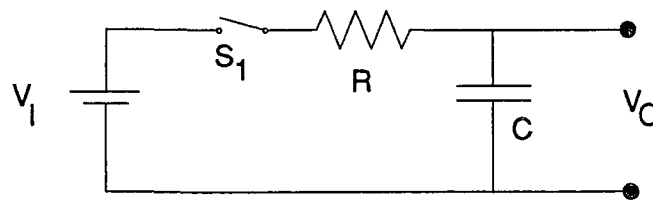
QUESTION 6

Consider the RC circuit shown in Figure 6[a]. The switch S_1 is closed at time $t=0$ connecting the dc supply V_1 to the network

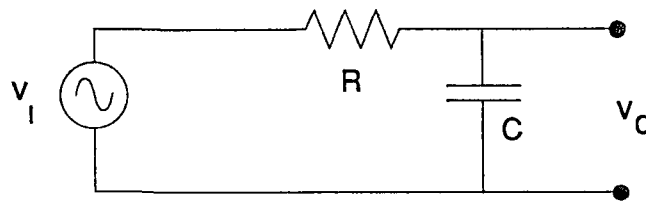
- [a] Derive an expression for the transfer function of the circuit, V_o/V_1 , in the time domain
- [b] Sketch the transfer function for a time interval of 5 time constants

The RC circuit is reconfigured as shown in Figure 6[b]. An ac voltage source of variable frequency v_1 is connected to the input

- [c] Derive an expression for the transfer function of the circuit, v_o/v_1 , 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



[a]



[b]

Figure 6 RC Circuit [a] dc test, [b] ac test

QUESTION 7

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 7

- [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

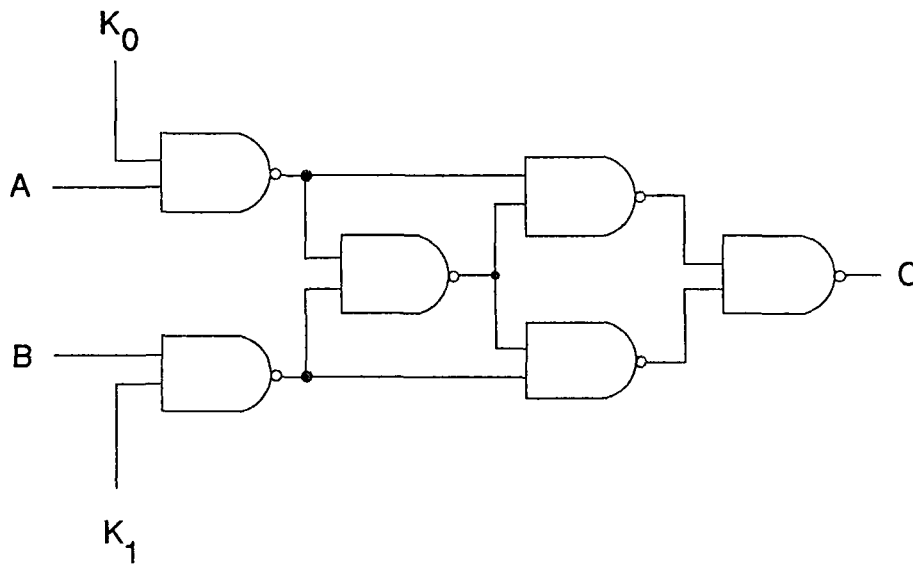


Figure 7 Circuit Schematic

QUESTION 8

A 60 Hz voltage supply is connected to the load shown in Figure 8. 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?

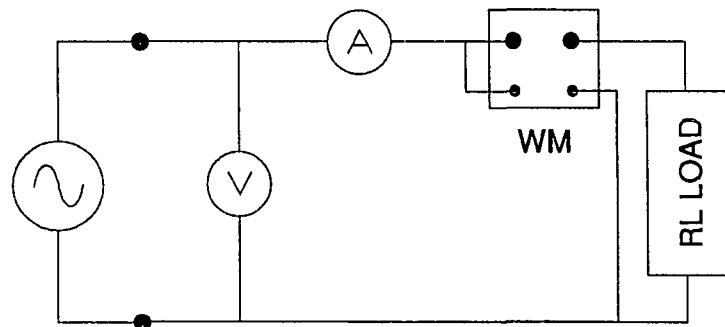


Figure 8 Measurement Setup for RL Circuit