

PROFESSIONAL ENGINEERS ONTARIO

National Examinations - December 2012

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

Front Page

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 $I_C = 2 \text{ mA}$ and $V_{CE} = 6 \text{ V}$.
- [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 $i_b = 10 \sin \omega t \text{ }\mu\text{A}$.

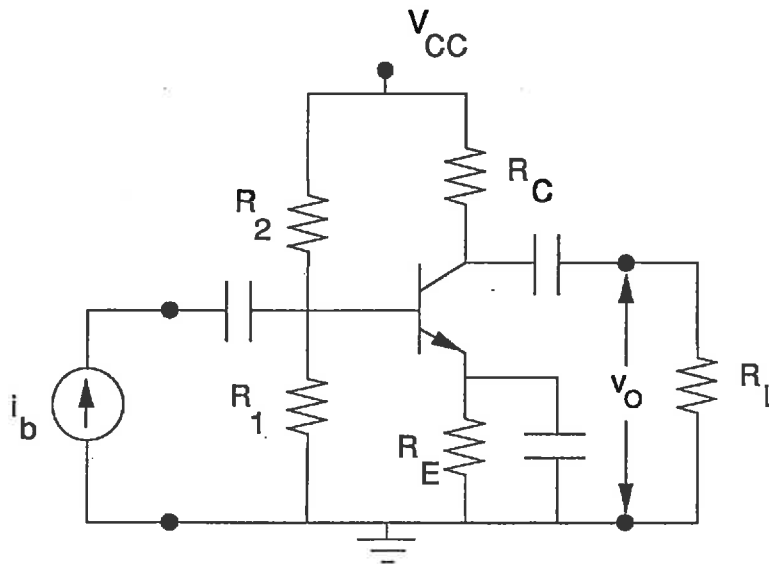


Figure 1 Transistor Circuit

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

QUESTION 2

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.

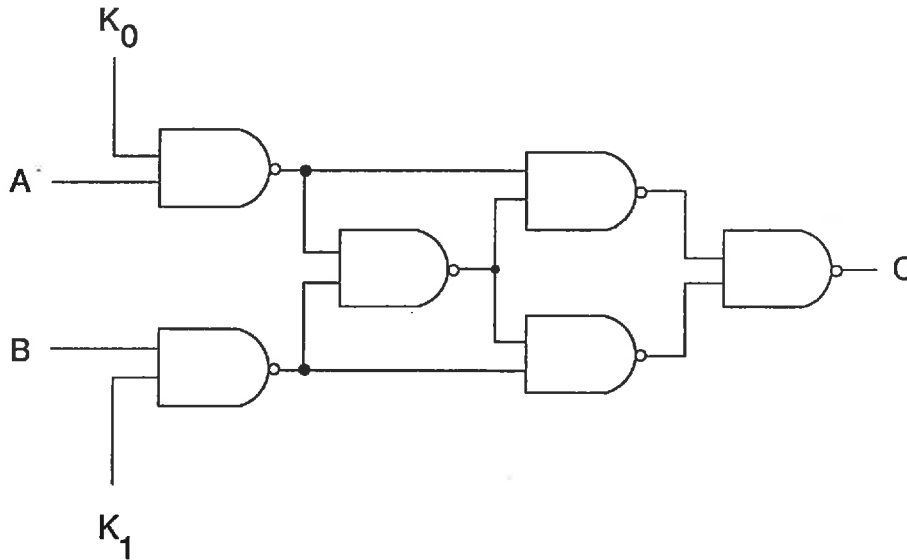


Figure 2 Circuit Schematic

QUESTION 3

A 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 0.05Ω , 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?

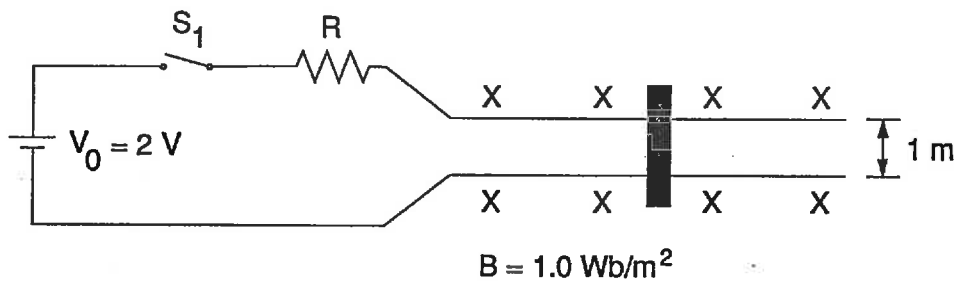
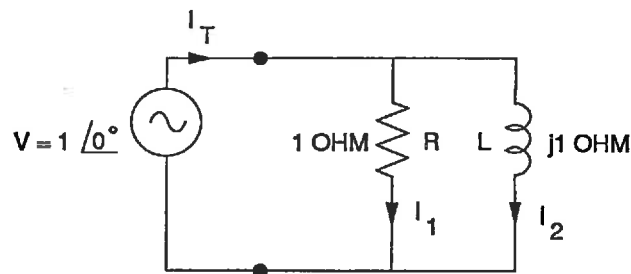


Figure 3 Top View of Linear dc Machine

QUESTION 4**Part I**

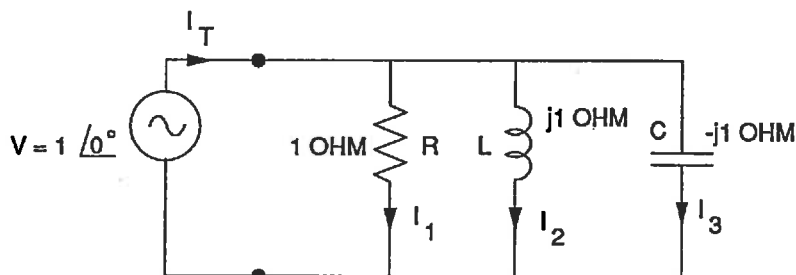
Consider the circuit shown in Figure 4a. A one volt (rms) ac voltage source, given by $V = 1 \angle 0^\circ$ is connected to a parallel R-L network. The resistor R has a value of 1Ω ; the impedance of the inductor is $j1\Omega$.

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 4a Circuit for Part I****Part II**

A capacitor is added in parallel to the inductor as shown in Figure 4b. 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 4b Circuit for Part II**

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.

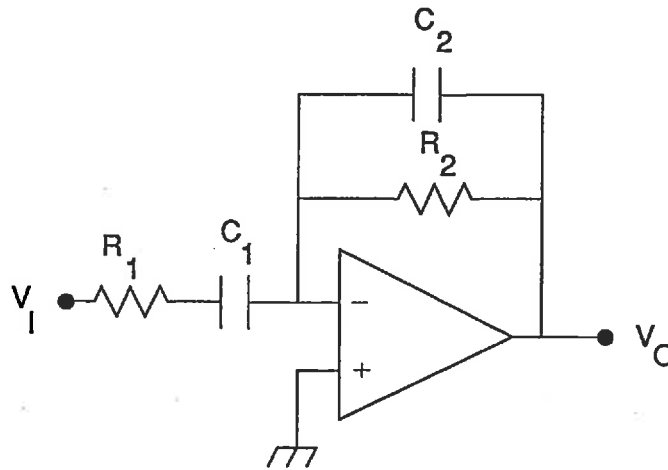


Figure 5 Circuit Schematic

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.

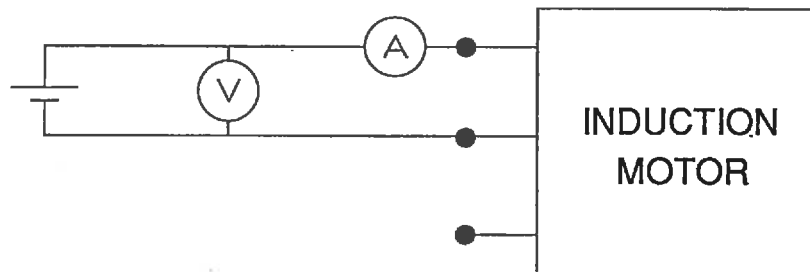


Figure 6 dc Test on Induction Motor

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.

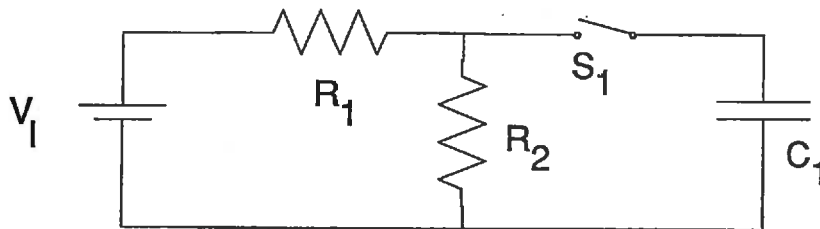


Figure 7 RC Circuit

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

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 m² 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 $i_1(t)$.

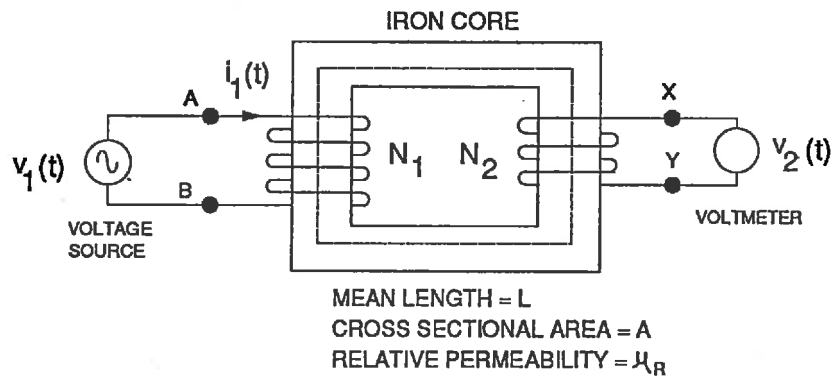


Figure 8 Magnetic Circuit