

PROFESSIONAL ENGINEERS ONTARIO

National Examinations - December 2002

98-Mec-A6, Electrical and 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] All questions are of equal value.
- [5] The candidate is required to sign this examination paper and submit it with the solution booklets.
- [6] $\pi = 3.14159$
 $1 \text{ hp} = 746 \text{ W}$
 $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$

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 .

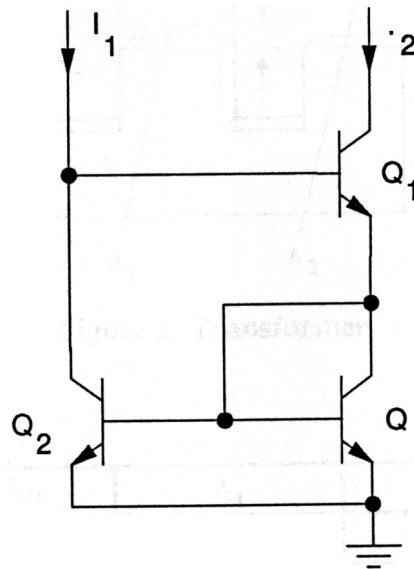


Figure 1 Transistor Circuit

QUESTION 2

Consider the magnetic circuit of a transformer shown in Figure 2. Infinite relative permeability can be assumed for the iron core.

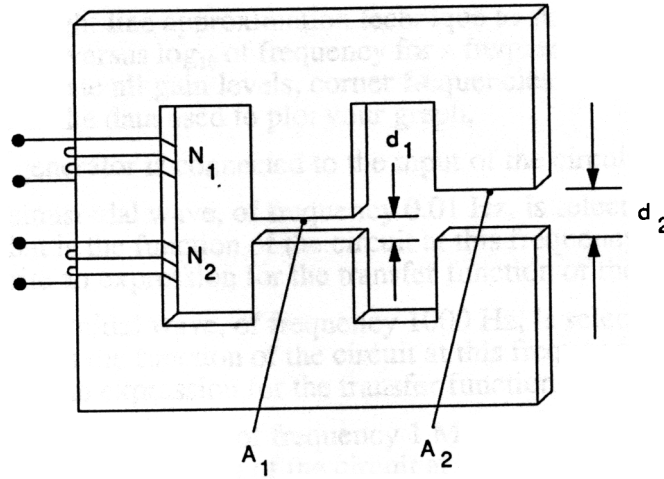


Figure 2 Transformer

The following specifications apply.

d_1	$3.77 \times 10^{-2} \text{ m}$	A_1	0.02 m^2
d_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 3

Consider the circuit shown in Figure 3. 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 sinusoidal 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 sinusoidal 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 sinusoidal 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.

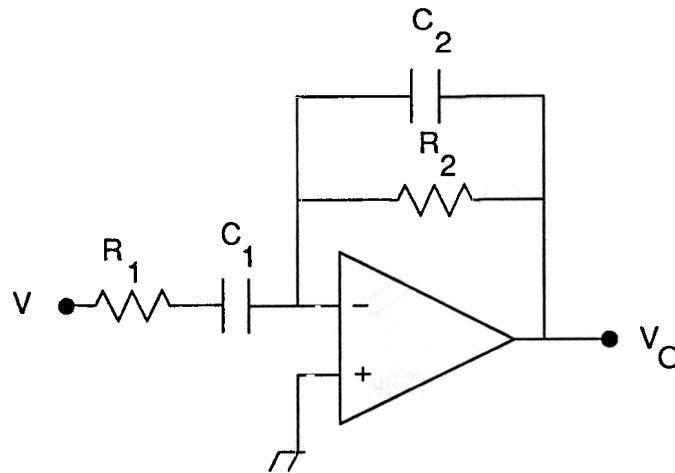


Figure 3 Circuit Schematic

RESISTORS		CAPACITORS	
R_1	160 kohm	C_1	1.0 μ F
R_2	16 Mohm	C_2	1 pF
COMPONENT LIST			

QUESTION 4

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 4. 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 T. 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 .

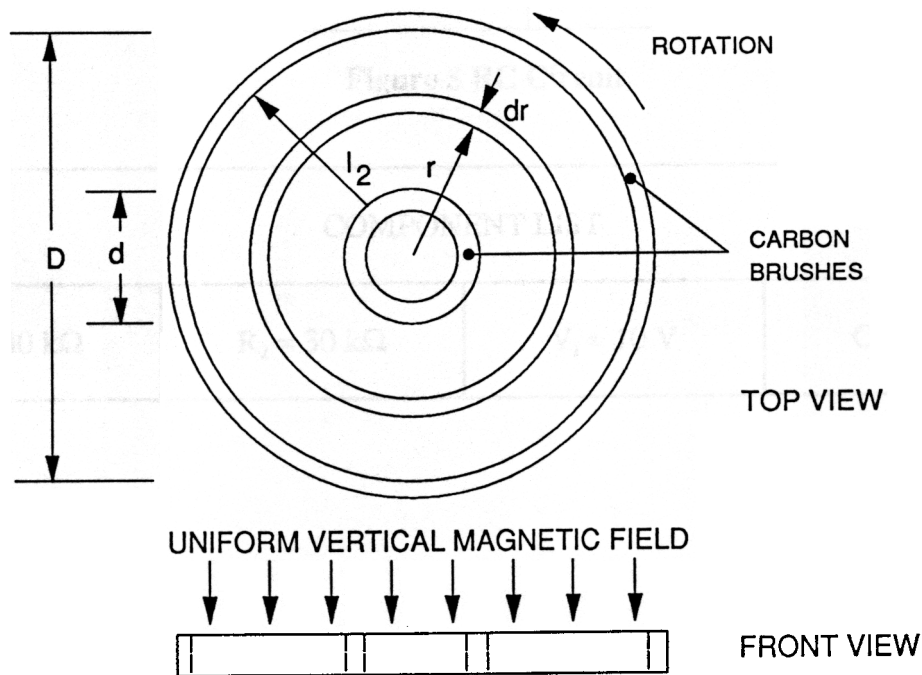


Figure 4 dc Machine

QUESTION 5

Consider the RC circuit shown in Figure 5. 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.

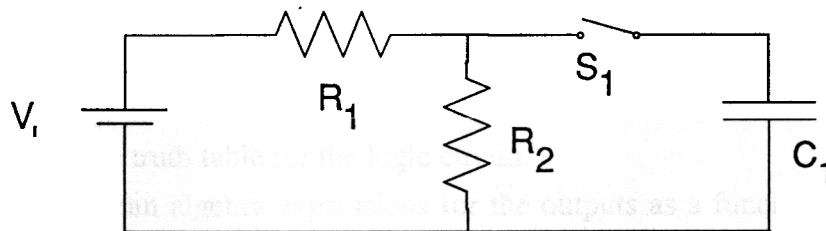


Figure 5 RC Circuit

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 6

Design a combinational logic circuit to meet the following specifications:

Input:
3-bit binary number, CBA
[C = MSB; A = LSB]

Outputs:
X; to be logic 1 for all even number inputs [0,2,4,6]
[zero is to be considered an even number]
Y; to be logic 1 for all odd number inputs [1,3,5,7]

A block diagram of the logic circuit is shown in Figure 6.

- [a] Develop the truth table for the logic circuit.
- [b] Write Boolean algebra expressions for the outputs as a function of the inputs and simplify where possible.
- [c] Design the gate array to implement your design.
Only 2-input NOR gates are available.

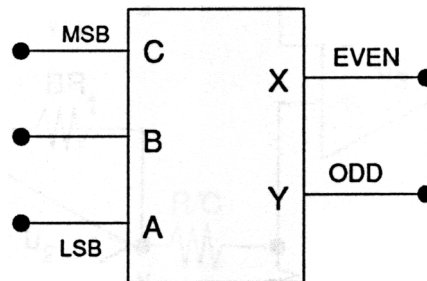


Figure 6 Block Diagram of Combinational Logic Circuit

QUESTION 7

Consider the circuit shown in Figure 7, which has been designed using ideal operational amplifiers, (U_1 to U_3), with infinite bandwidth and infinite open loop gain. In the schematic, A, B and C are constants.

In the derivation of the transfer function for such circuits, one can assume:

- [i] zero differential voltage between the input terminals of the operational amplifier, and
- [ii] zero current flows into either terminal of the operational amplifier.

Applying the principle of superposition, derive an expression for the transfer function of the total circuit [E_0 as a function of E_1, E_2]. It can be assumed that the transfer functions for an inverting amplifier and a non-inverting amplifier are known.

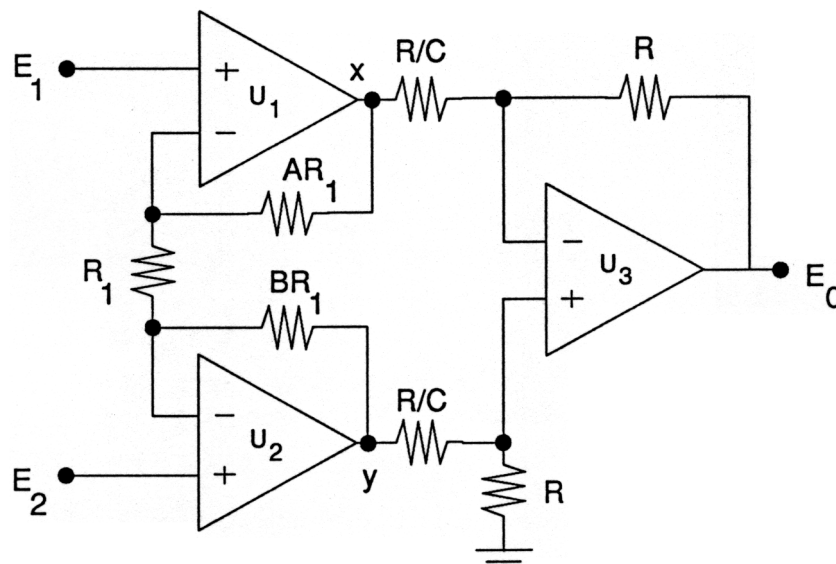


Figure 7 Circuit Schematic

QUESTION 8

A three-phase 220-V 60-Hz Y-connected six pole 10 hp induction motor has the following circuit parameters referred to the stator:

$$R_s = 0.344 \, \Omega$$

$$R'_r = 0.147 \, \Omega$$

$$X_s = 0.498 \, \Omega$$

$$X'_r = 0.224 \, \Omega$$

$$X'_m = 12.6 \, \Omega$$

The rotational losses, including the core losses, amount to 262 W and may be assumed to be constant. For a slip of 2.8%, determine:

- [a] the line current and the power factor
- [b] the shaft torque and output horsepower
- [c] the efficiency