

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering



Study Programme : Bachelor of Technology Honours in Engineering
Name of the Examination : Final Examination
Course Code and Title : DMX4571/MEX4271 - Sensors and Actuators
Academic Year : 2019/20
Date : 30th September 2020
Time : 1330hr – 1630hr
Duration : **3 hours**

WRITE YOUR REGISTRATION NUMBER CLEARLY
WITHIN THE SPACE PROVIDED



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General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Six (6)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. This is a Closed Book Test (CBT).
6. Answers should be in clear hand writing.
7. Do not use Red color pen.

Question 01

- a) Briefly explain what is a sensor. Give an example of a sensor and describe its function. [4 Marks]
- b) List the factors that need to be taken into consideration when selecting a sensor for a particular application. [4 Marks]
- c) Briefly explain what is a displacement sensor and name three sensors which are used for displacement measurement. [4 Marks]
- d) Calculate the number of bits an Analog to Digital Converter (ADC) must have in order to handle a signal with a 96dB dynamic range. [8 Marks]

Question 02

- a) State the Faraday's law of Magnetic Induction. [3 Marks]
- b) Figure Q02 shows a toroidal core with $\mu_r = 10000$, $R = 5\text{cm}$, $r = 1\text{cm}$ and $N = 300$. The current is given by:

$$i(t) = 3\sin(300\pi t)$$

Compute the flux (ϕ) and the flux linkages (λ). Then use Faraday's law of induction to determine the voltage induced in the coil. [7 Marks]

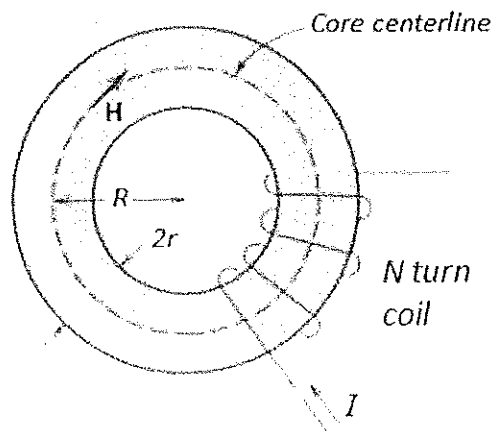


Figure: Q02

- c) Describe the piezo-resistive effect in Silicon devices. [4 Marks]
- d) A quartz piezoelectric crystal having a thickness of 2mm and voltage sensitivity of 0.055 Vm/N is subjected to a pressure of 1.5 MN/m^2 (Mega-newton per Square meter). Calculate the voltage output. If the permittivity of quartz is $40.6 \times 10^{-12} \text{ F/m}$. Calculate its Charge sensitivity. [6 Marks]

Question 03

- a) List the main advantages of the Linear Variable Differential Transformer (LVDT) transducer. [4 Marks]
- b) A slide-wire potentiometer with a length of 100 mm is fabricated by winding wire with a diameter of 0.10 mm around a cylindrical insulating core. Determine the resolution limit of this potentiometer. [4 Marks]
- c) A LVDT under a certain input voltage has specifications which includes the following information:

Range: $\pm 30\text{mm}$; Accuracy: 0.5%; Sensitivity: $5.0(\text{mV/mm})$

When its output is 0.05V,

- i. Calculate the possible value of the linear displacement of its rod. [6 Marks]
- ii. Design and sketch an operational amplifier circuit to amplifier the output voltage by ten times. [6 Marks]

Question 04

- a) Discuss the differences between incremental and absolute rotary encoder. [5 Marks]
- b) A 10-bit Gray code optical encoder is producing the number 0011100101. Determine the indicated angle. [5 Marks]
- c) State three main advantages of Gray code. [4 Marks]

- d) An absolute optical rotary encoder in a certain application must have a resolution of 3° . Determine the number of tracks of this encoder.

[6 Marks]

Question 05

- a) List the three common types of stepper motors. Briefly explain each type.

[5 Marks]

- b) Determine the basic step angle for the following stepper motors.

- i. 6 stator phases - 4 rotor teeth, 3-phase, single stack variable reluctance motor [2 Marks]
- ii. 4 stator phases - 6 rotor teeth, 2-phase, permanent magnet motor [2 Marks]
- iii. 4 stator phases - 5 rotor teeth, 2-phase, hybrid motor [2 Marks]

- c) Consider the single-stack, 3-phase variable reluctance stepper motor shown in Figure Q05. Find the step angle for the following phase-switching sequences.

[9 Marks]

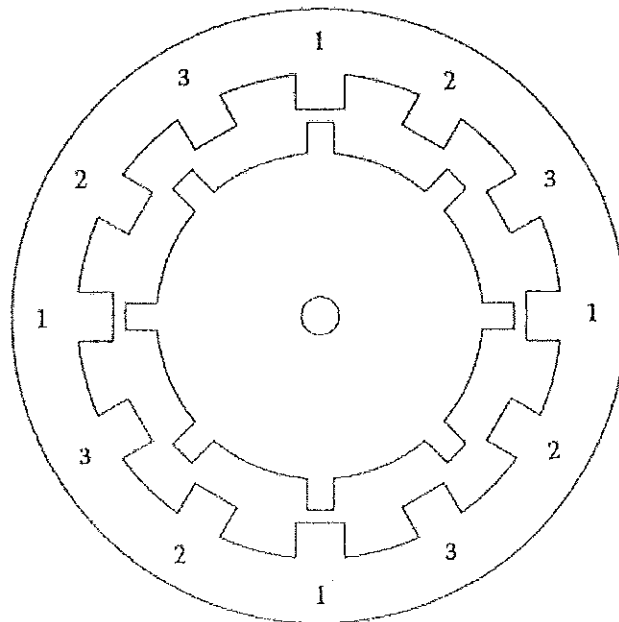


Figure: Q05

Question 06

- a) A shunt DC motor in steady state has the following parameters: $I_s = 300\text{A}$, $V_a = 500\text{V}$, $R_f = 50\Omega$, $R_a = 1\Omega$ and $n = 40\text{r/min}$.

- i. Construct an equivalent circuit for the motor. [3 Marks]
- ii. Calculate the torque for starting the motor. [3 Marks]

- b) A permanent-magnet DC motor has the following parameters:

$$r_a = 8\ \Omega \text{ and } k_v = 0.01\ \text{V} \cdot \text{s/rad}$$

The shaft load torque is approximated as $T_L = K\omega_r$, where $K = 5 \times 10^{-6}\ \text{N.m.s}$. The applied voltage is 6V and $B_m = 0$. Calculate the steady-state rotor speed ω_r in rad/s.

[14 Marks]

Question 07

- a) A 3-phase, 60Hz, 200hp, 2400V, 8 pole, Y-connected synchronous motor has a phase synchronous reactance of 12Ω per phase and negligible resistance. The motor draws 150kW at a power angle of 18 degrees. Determine;

- i. Excitation voltage [3 Marks]
- ii. Line current [2 Marks]
- iii. Power factor [2 Marks]
- iv. Under maximum power condition determine the torque [3 Marks]

- b) A 3-phase induction motor is wound for four poles and is supplied from a 50Hz supply. Calculate;

- i. The synchronous Speed [3 Marks]
- ii. The speed of the rotor when slip is 3% [3 Marks]
- iii. The rotor frequency when speed of rotor is 900rpm [4 Marks]

Question 08

- a) State three main functions of the pneumatic air service unit. [3 Marks]
- b) Draw the graphical symbol and label the ports for a pneumatic four-way, two-position Directional Control Valve (DCV) with pushbutton actuation. [7 Marks]
- c) Design a Pneumatic circuit diagram consisting of a 3/2-way, lever operated, spring return directional control valve to extend a single acting spring return cylinder. The air flow of the cylinder should be controlled and the diagram should include the FRL unit, compressor and other necessary controls. [10 Marks]

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