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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 - Sensors and actuators** /MEX4271
Academic Year	: 2017/18
Date	: 17th January 2019
Time	: 0930-1230hrs
Duration	: **3 hours**

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.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear hand writing.
8. Do not use Red colour pen.

Q1.

An optical encoder is shown in Figure Q1. White and black represents logic 0 and 1 respectively.

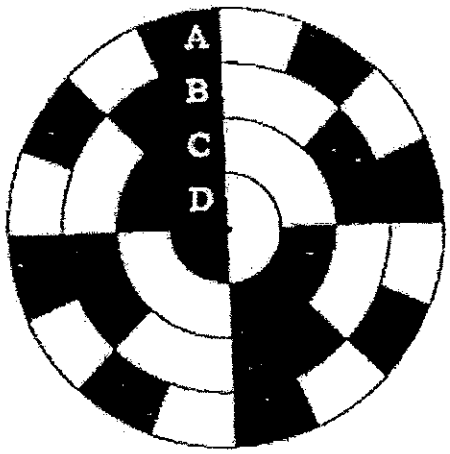

Figure Q1

a) There are two major types of optical encoder. Identify the type of encoder shown in the Figure Q1. [4 marks]
b) Determine the angular resolution of the encoder. [4 marks]
c) Identify whether the encoder shown in the Figure Q1 is gray code or not? [4 marks]
d) Identify an error/issue of this encoder while interfacing with a digital controller. [4 marks]
e) How to improve the resolution of this encoder to 11.25 degrees. Explain. [4 marks]

Q2.

a) Name any three types of temperature sensors. [3 marks]

b) A client want to measure temperature of a metal plate.Long-life and quick response from the sensor are required. What is the best sensor for this application among a thermocouple and an IR temperature sensors. Give reasons for your selection. [5 marks]

c) Briefly explain following static characteristics of the sensors. [6 marks]
   i. Hysteresis error
   ii. Accuracy
   iii. Precision

d) Distinguish between active sensors and passive sensors using suitable examples.[6 marks]

Q3.

An automation process which perform the task of filling empty boxes with trays of chocolates to forward for final wrapping is shown in the Figure Q3.

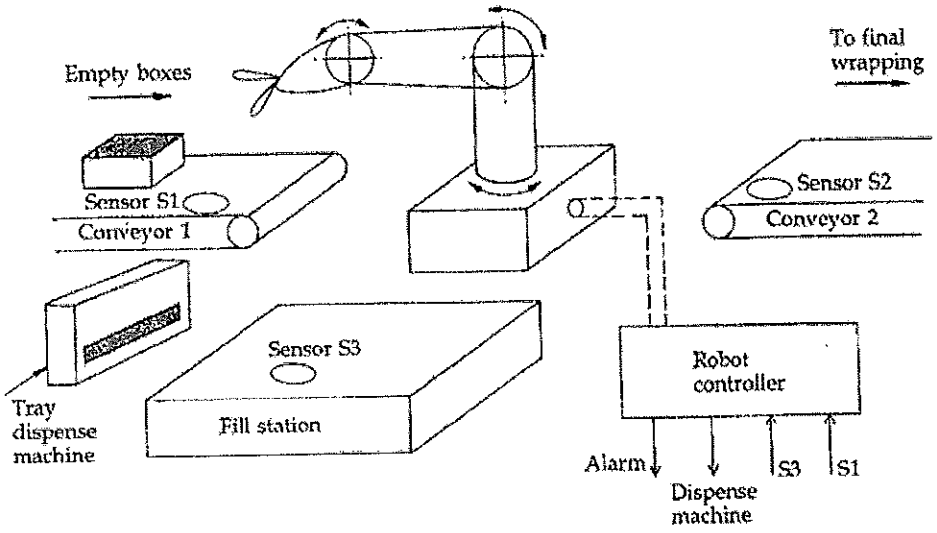

Figure Q3

The conveyor 1 supplied empty boxes for filling. When the sensor S1 senses the presence of an empty box, the robot is signaled and the conveyor 1 stopped.

On receiving a signal from S1, the robot picks up the box and transfers it to the Fill station.

At the Fill station, once the box is in position, the robot operates the Tray dispense machine which lowers a tray chocolates into the box. The robot needs to wait for five seconds for this to happen.

When conveyer 2 starts, conveyor 1 will be restated also to bring in the next empty box. A sensor S3 will confirm the dispensing of a tray to the emoty box. If, after five seconds, a tray is no dispensed, the robot will then return to its home position as shown in Figure Q3 and signal an 'Out of Chocolates' alarm and then stop. An operator will then fill the tray dispenser and restart the system.

The conveyors are controlled by a separate conveyor controller operating from the sensors as required.

a) Indicate the type of sensor which would be most appropriate for sensors S1, S2 and S3. [4 marks]

b) Give a reason/reasons for the choice made in part-(a). [4 marks]

c) What are the other sensor types which will be able to use as S1,S2 and S3 other than your selection in part a. [4 marks]

d) The rotational position of the base of the robot is sensed using a rotary optical encoder which incorporated a gray code.
   i. Explain the main advantage of a Gray code over a pure binary code[4 marks]
   ii. Calculate the resolution of the rotation in degrees, if the Gray code is based on 10 bits. [4 marks]

Q4.

a) Assume you have to design and construct simple load cell using strain gauges for an exhibition to demonstrate the working principle of the strain gauge.
   i. Draw a block diagram of your proposed system.
   ii. Draw a simple circuit diagram. (hint: use Wheatstone bridge, operational amplifiers).

[8 marks]

b) You have to measure linear displacement of a shaft using a LVDT.
   i. Draw a simple circuit diagram for the above application using a LVDT.
   ii. Explain the working principle of the LVDT using an appropriate diagram.
   iii. Draw a graph for displacement vs. output voltage of the LVDT of the above application.

[12 marks]

Q5.

a) An object has to move using a single acting cylinder. The piston rod is to extend when a push button is pressed and return to the start position when the push button is released. Speed of the forward motion should be adjustable. Draw a pneumatic circuit to perform the operation. [8 marks]

b) Draw a hydraulic circuit to operate a single acting cylinder. The piston rod is to extend when a hand-lever valve is operated and return to the start position when the lever is released. [6 marks]

c) What are the main three parts of an air service unit? Briefly explain. [6 marks]

Q6.

a) Single stack three phase variable reluctance stepper motor is illustrated in Figure Q6. Number of rotor teeth(n_r)=8 and number of stator teeth (n_s)=12. If the switching sequence of the phase winding is **1-3-2-1** determine;
   i. the direction of rotation and
   ii. the full step angle.

[4 marks]

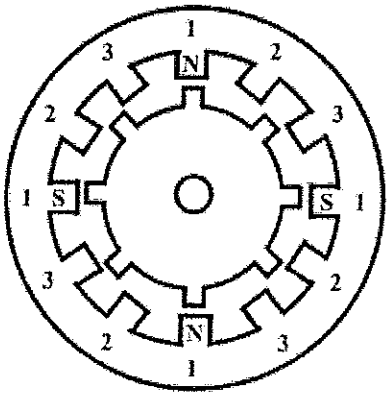

Figure Q6

b) A stepper motor is working in the full step mode and the step angle is 0.9°. Calculate the rotational speed of a stepper motor (in rpm) if stepping rate is 800 steps/sec. [3 marks]

c) Compare and contrast the following types of stepper motors.

i. Permanent magnet

ii. Variable reluctance

iii. Hybrid

[9 marks]

d) Discuss the applicability of solid-state switches and electromechanical switches in the industrial applications. [4 marks]

Q7.

a) A three-phase induction motor is wound for four poles and is supplied from a variable frequency driver with 25 Hz. Calculate;

i. the synchronous speed,

ii. the speed of the rotor when the slip is 3% , and

iii. the rotor frequency when the speed of the rotor is 500 rpm. [8 marks]

b) An induction motor (220Vrms, 60-Hz three phase Y-connected) draws 25A at a power factor of 80% lagging. The total stator copper loss is 300W, the total rotor copper loss is 100W and the rotational loss is 420W for all three phases. Determine, input power, developed power, output power and the efficiency. [12 marks]

Q8.

a) A series-connected dc motor runs at $n_{m1} = 1200$ rpm while driving a load that demands a torque of 12Nm. Neglect the resistances, rotational loss, and saturation effects. Find the power output. Then, find the new speed and output power if the load torque increases to 24 Nm.

[10 marks]

b) A 50-hp shunt – connected dc motor has the magnetization curve shown in Figure Q8-a, and the equivalent circuit diagram is illustrated in Figure Q8-b. The dc supply voltage is $V_T = 240$ V, the armature resistance is $R_A = 0.065\ \Omega$, the field resistance is $R_F = 10\ \Omega$, and the adjustable resistance is $R_{adj} = 14\ \Omega$. At a speed of 1200 rpm, the rotational loss is $P_{rot} = 1450$ W. If this motor drives a hoist that demands a torque of $T_{out} = 250$ Nm independent of speed, determine the motor speed and efficiency.

[10 marks]

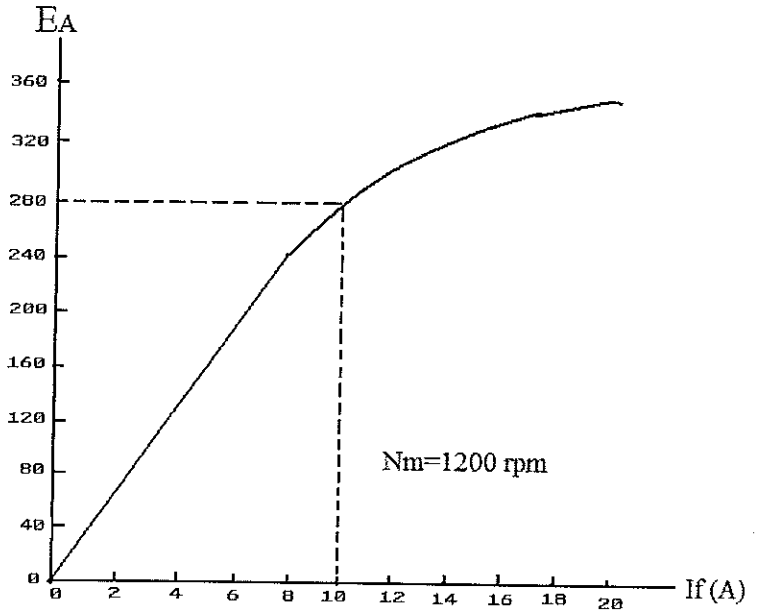

Figure Q8-a

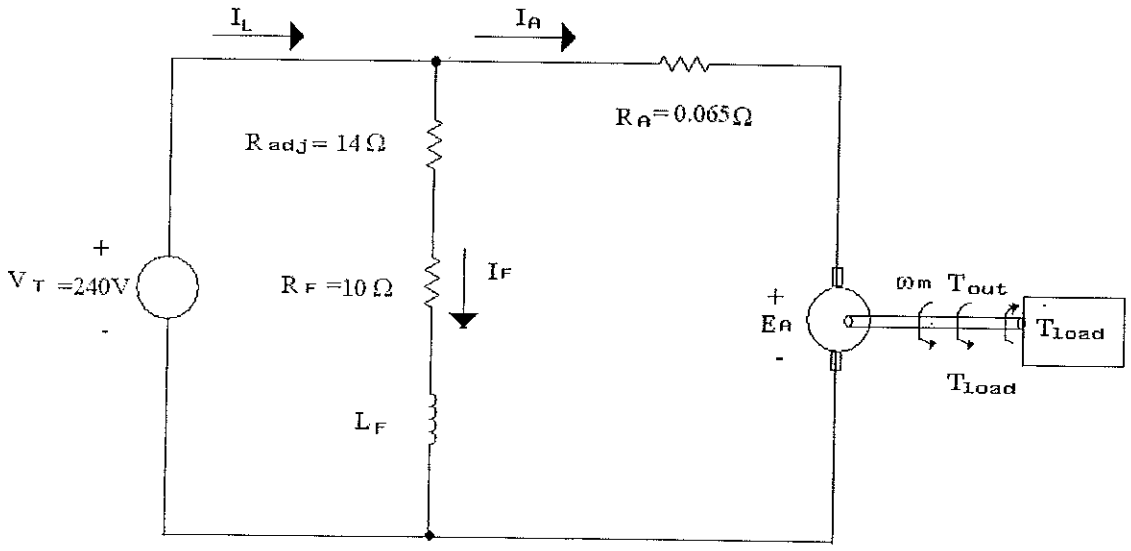

Figure Q8-b

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