NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY

DEPARTMENT OF INDUSTRIAL AND MANUFACTURING ENGINEERING

Master of Engineering Degree Industrial and Manufacturing Engineering

AUTOMATION AND ROBOTICS

TIE 6220

Second Semester Main Examination Paper

May/April 2015

This examination paper consists of 6 pages

Time Allowed: **3 hours**

Total Marks: **100**

Special Requirements: **Calculators**

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INSTRUCTIONS

1. Answer any **five** (5) questions, at least **two** (2) from each Section **A** and **B**.
2. Each question carries 20 marks.
3. The marks allocated to sub-sections of whole questions are indicated on the right hand margin against the subsection.

Section A

Question 1

(a) What is an industrial robot? [2]

(b) What are the four major components of a robot? [4]

(c) The two common methods of classifying robots are by coordinate system and by control method. List four classes for each of the two methods. [8]

(d) The expression for determining payback period that is commonly used for a robot installation is

$$Y = \frac{(P + A + I) - C}{(L + M - O) \times (1 - TR) + D \times TR}$$

Where Y = the payback period; P = price of the robot; A = cost of tooling and fixturing; I = installation cost; C = investment tax credit; L = hourly cost of labour, including fringe benefits; M = hourly savings in the cost of materials; O = cost of running and maintaining the robot; H = number of hours per year per shift; D = annual depreciation assuming an 8-year "tax life"; TR = corporate tax rate.

Exactly, what is payback? [1]

(e) Using some of the parameters given in the expression for payback in (d) above, define 'Return On Investment' (ROI). [5]

Question 2

(a) Discuss the loads typically experienced by a single translational (sliding) joint in an industrial robot. [7]

(b) A control system was being developed for one joint of a rectangular (Cartesian) configuration industrial robot. A proportional and derivative controller was specified. Assuming that the only joint loads were those due to weight and viscous friction, determine, using the final value theorem, the steady-state errors in response to unit step and unit ramp desired positions when the data below apply.

Mass carried by joint	25 kg
Viscous friction coefficient	4.905×10^2 Nsm^{-1}
Proportional gain K_p	2.452×10^5 Nm^{-1}

[13]

Question 3

Arc welding is an important area of application for industrial robots. In most manufacturing welding situations, uncertainties in dimensions of the part, geometry of the joint and the welding process itself require the use of sensors for maintaining welding quality. Several systems use a vision system to measure the geometry of the puddle of the melted metal as shown in Fig Q2. The system uses a constant rate of feeding the wire to be melted.

(a) Calculate the maximum value of K for the system that will result in a stable response. [8]

(b) For K = 6, determine the roots of the characteristic equation. [6]
(c) Estimate the percent overshoot of the system of part (b) when it is subjected to a step input. [6]

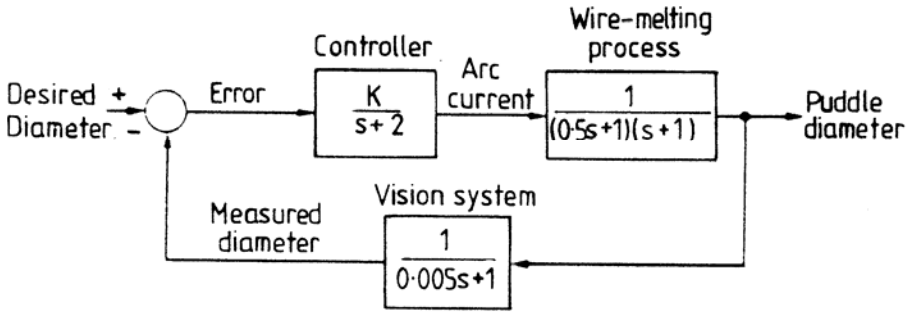

Fig Q3

Question 4

Suppose that the end-effector of a robot is translated by *e* units in X, *f* units in Y, and *g* units in Z. Then

$$A = Trans(e, f, g) = \begin{bmatrix} 1 & 0 & 0 & e \\ 0 & 1 & 0 & f \\ 0 & 0 & 1 & g \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

If $V = 25\hat{i} + 10\hat{j} + 20\hat{k}$, determine the following:

(a) Translation by 8 units in X, 5 units in Y, and 1 unit in Z, [5]
(b) Rotation about X through 30°, [5]
(c) Rotation about Y through 45°, [5]
(d) Rotation about Z through 60°. [5]

SECTION B

Question 5

a)

i) With aid of diagrams describe the construction and operation of an optical tactile sensor. [4]
ii) You work at a factory which manufactures a variety of products made of powder, plastics, glass and wood. You have been tasked to design a counter for finished products which can be used over greater distances. Which proximity sensor are you going to use? [2]

iii) Describe with aid of diagram the operation of the proximity sensor you selected in Question 5 (ii) [4]

b)

i) Show with aid of diagrams and how a conductive elastomer tactile sensor can be used to improve a the grip of an object with an irregular shape on a robotic gripper [6]

ii) What limitations do elastomer tactile sensor has? [4]

Question 6

a) Discuss the steps in the implementation of the SRI vision system. [10]

b) Seven foundry castings shown in Figure Q6 are to be analysed using the SRI vision system using perimeter of figure, square root of the area, total hole area, minimum radius, maximum radius, average radius and compactness. Develop the decision tree for the system to use in the image analysis. [5]

c) Show using an appropriate example how an image can be expanded and shrunk. [5]

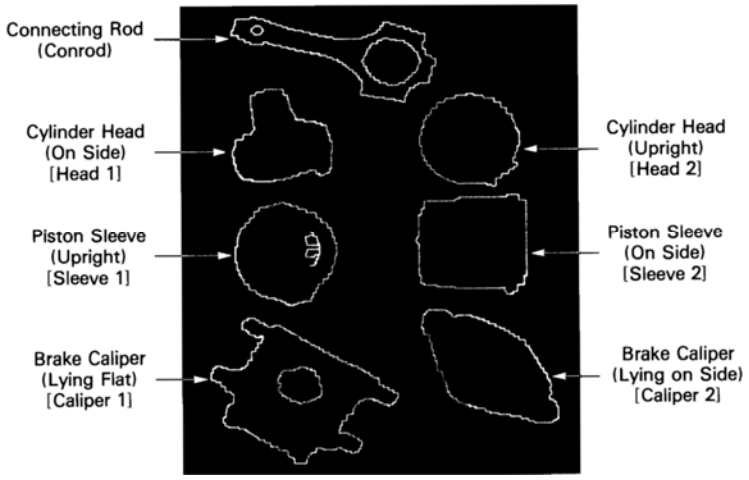

Figure Q6 Foundry castings

Question 7

a) With aid of diagrams describe the principle of operation of the Inductosyn. [5]

b) Besides being used as a position sensor a Linear Variable Differential Transformer can be used to monitor acceleration. Discuss using aid of diagrams and the crucial formulas how this can be achieved. [5]

c) Show how the motor current can be used to monitor the force exerted by a gripper [5]

d) Figure Q7 show an image of an object detected by a robot.

i. Determine the chain vector for the image using point (2,1) as the starting point [2]

ii. Using the Sobel operator determine the local intensity gradient at point marked A [3]

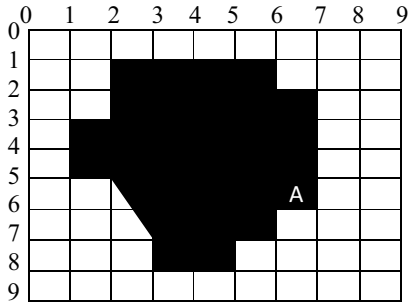

Figure Q7 Image

Question 8

a)

i) Describe the stages of assembly for peg-in-hole type process. [5]

ii) Your company manufactures a reticle assembly shown in Figure Q8. Due to increase of demand for the products you boss has suggested that the company invests in robotic assembly. Suggest design changes that you will make on the component suitable for robotic assembly. [5]

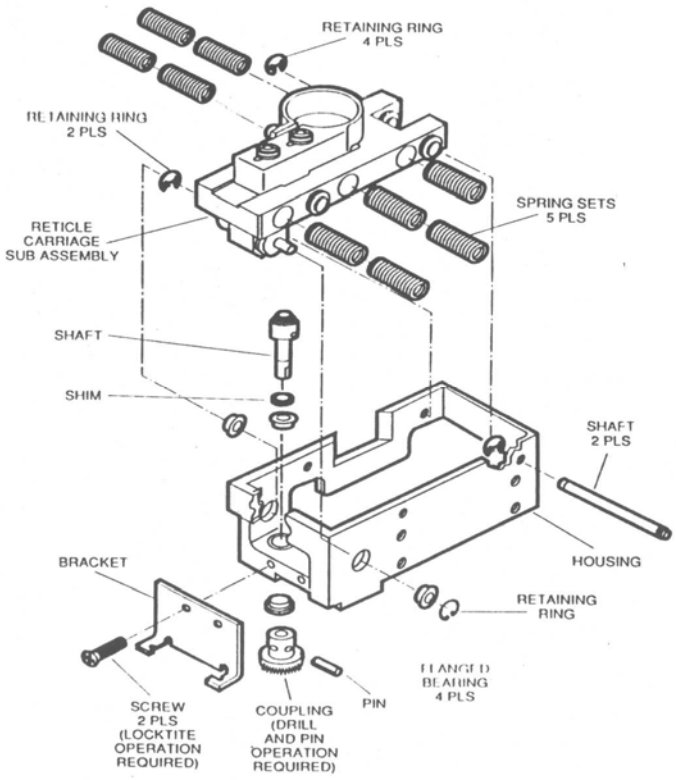

Figure 8 Reticle assembly

a) An absolute encoder can be used to control movement of a robotic arm.

   i) Show the principle of operation of an absolute encoder. [5]

   ii) It is difficult to use a potentiometer as a position sensor because of severe reliability problems caused by electrical noise. Show how a potentiometer and an incremental encoder can be used to calibrate a robot. [5]

END OF EXAMINATION