NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF INDUSTRIAL TECHNOLOGY
DEPARTMENT OF INDUSTRIAL AND MANUFACTURING ENGINEERING

Degree of Master of Engineering

Automation and Robotics TIE 6220

MAY 2011 EXAMINATIONS

INSTRUCTIONS TO CANDIDATES

Answer FIVE questions. Each question carries 20 marks and the marks allocated to sub-sections of whole questions are indicated on the right hand margin against the sub-section.

Time allowed: 3 hours

Q1(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]

Q2 Figure Q1 shows a plan view of a two-joint articulated arm operating close to a conveyor. The arm is initially adjusted so that the first joint takes an angle $\theta_1 = \frac{\pi}{4}$ and the second joint an angle $\theta_2(t=0) = \frac{\pi}{2}$. Joint one then remains in this position whilst joint two can be considered to perfectly follow a ramp command:

$$\theta_2 = \theta_2(t=0) - \alpha t .$$

Simultaneously the component on the conveyor moves from a start position x_0, y_0, perfectly following a further ramp command:

$$y = y_0 - \beta t .$$

Assuming that the component on the conveyor and the end-effector on the outer end of link 2 can both be considered as points, determine, using homogeneous transforms

whether the two will collide. You may neglect any collision between arm and component – examine only the end-effector and component. [20]

Data $\alpha = 0.3927$ rads^{-1}
$\beta = 0.3885$ ms^{-1}
$x_0 = 2.0$ m
$y_0 = 1.8385$ m
$\ell_1 = 1.5$ m
$\ell_2 = 1.016$ m

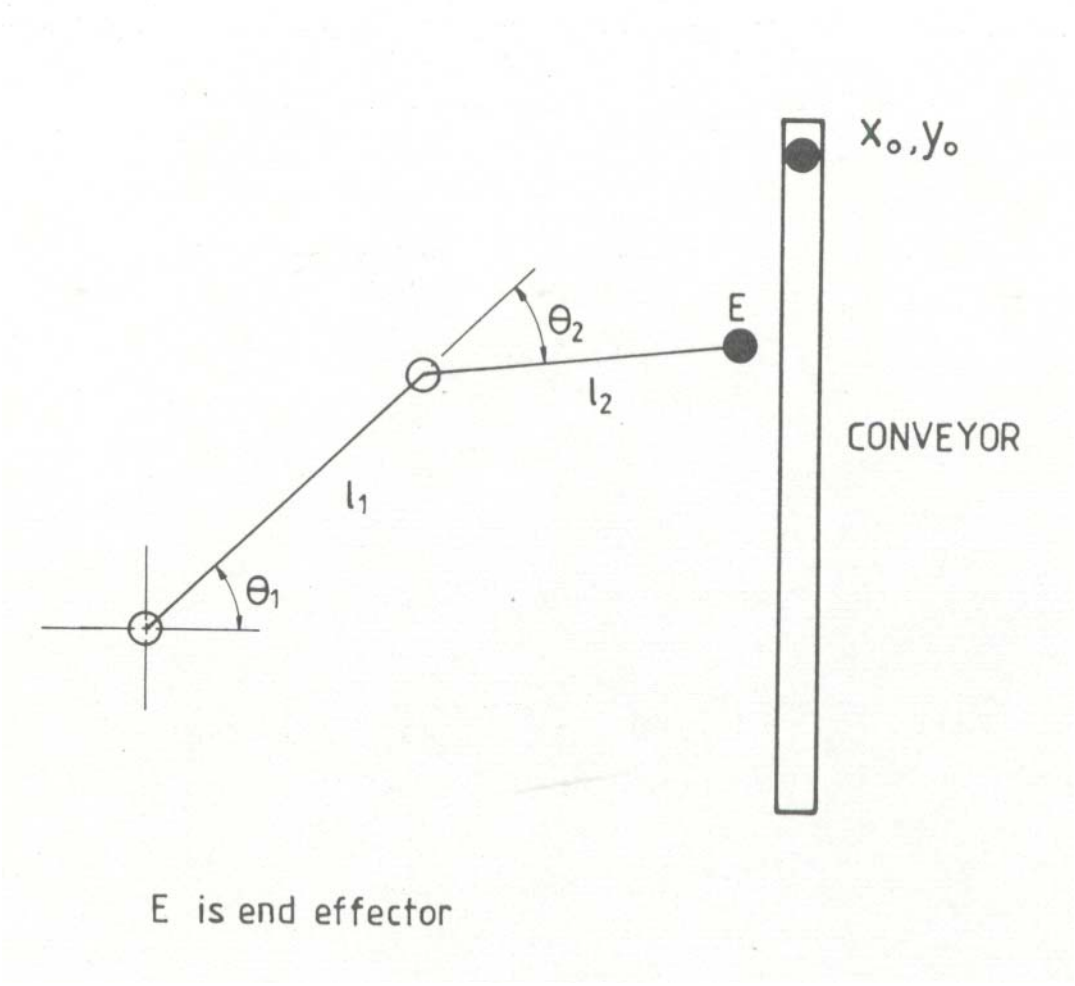

Fig Q1

Q3. (i) Discuss the concept 'Degrees of Freedom (DOF) in relation to the design of industrial robots. The answer should include reference to: sources of DOF, reasons for more than six apparent DOFs and the number of DOF required for different tasks. [10]

(ii) A robot joint having a single rotational DOF is to be controlled by a model-based controller. Friction in the joint follows a Coulomb law and a mass attached to the arm causes gravitational torque to be applied to the joint. Describe fully a control system suitable for a step input command, including in your description a block diagram of the controller. What requirement applies to ensure critical damping? [10]

Q4. (a) Describe with aid of diagrams the principle of operation of the following Opto-electronic sensors:

i) Break beam. [2]
ii) Diffuse. [2]
iii) Focused. [2]

(b) Describe the principle of operation of a Vidicon television tube. [5]

(c) NUST wants to install doors which automatically open when a person approaches the entrance at its library.
   i) Which type of proximity sensors would you recommend for NUST? [2]
   ii) Justify your choice of the proximity sensor. [3]

(d) Why is through illumination not the most practical of all the methods of illumination for use in a manufacturing environment? [2]

(e) Your company wants to install a robot system which will inspect the quality of products produced, as they will be moving on the conveyer belt. The company engineer decided to utilize stroboscopic illumination but all the products inspected by the robot were rejected. Explain why the products were rejected and suggest the type of illumination that has to be combined with stroboscopic illumination to give the correct results. [2]

Q5 (a). Draw neat and annotated sketches of the following types of robot joint configurations:

(i) Rectangular [4]
(ii) Cylindrical [4]
(iii) Spherical [4]
(iv) Articulated (Revolute) [4]

Indicate the directions of movement about and along the axes and the number of degrees of freedom in each case.

(b) What does the term SCARA stand for? Suggest two cases/applications where this type of robot can be used. [4]

Q6 (a) Describe the three transport concepts used in automated assembly. [9]

(b) Describe the principle of operation of a Remote Center Compliant (RCC) device [3]

(c) Badly designed parts can cause significant feeding and orientation problems. Explain, when designing parts for automated assembly, how you deal with the following:
   i) Symmetrical parts. [2]
   ii) Non-functional features. [2]

(d) Your company manufactures a product which uses fasteners given in Figure Q6 shown below. Due to the increase in demand of the product your company has decided to invest in robotic assembly of the products. Suggest design

changes that you will make on the fasterners to make it suitable for robotic assembly. [4]

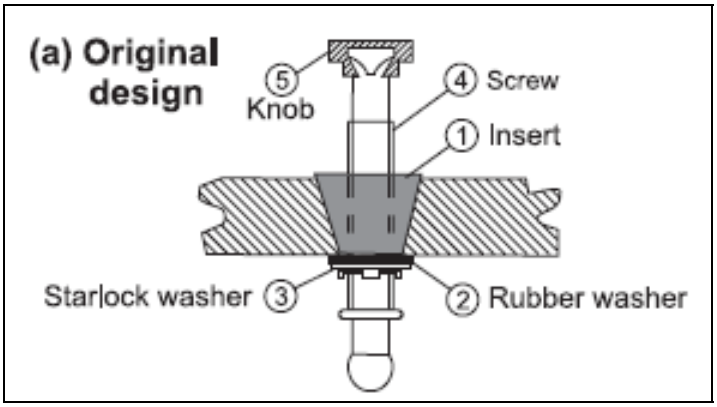

Figure Q6

Q7 Safety is of paramount importance in the operation of robots.

(a) Give reasons why safety measures should be imposed for using robots. [9]

(b) Give a list of guidelines that that can help remove the hazardous situations to robot personnel, factory workers and the robot itself. [11]

Q8. (a) Define 'Pay Back Period' in relation to the purchase and installation of a robot. [6]

(b) A robot used for machine loading is priced at $46 000.00. The special gripper required for it costs $5 000.00 and the sensors cost $1 000.00. The feeder costs $30 000.00. There are no layout charges. The robot will replace one operator whose rate is $16.00 per hour including fringe benefits. The operator works 250 days a year, 8 hours a day. No production increase or quality improvements are anticipated. What is the payback period for one-shift and two-shift operations? [14]

END OF EXAMINATION