MANUFACTURING ENGINEERING TRIPOS PART I

Monday 27 April 2009 9 to 12

Paper P2

ORGANISATION AND CONTROL OF MANUFACTURING SYSTEMS

*Answer not more than **four** questions of which not more than **one** may be taken from each section **A, B, C** and **D**.*

*Answers to sections **A, B, C** and **D** must appear in four separate booklets.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments.

STATIONERY REQUIREMENTS	SPECIAL REQUIREMENTS
8 page answer booklet x 4	Engineering Data Book
Rough work pad	CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

Version 4

SECTION A

*Answer **one** question from this section.*

1 (a) A Programmable Logic Controller (PLC) is commonly used for control and coordination of automated production cell operations, and ladder logic is a standard approach for producing control instructions for PLCs. Using an example, explain how a timer is generated in ladder logic code. [20%]

(b) Figure 1 shows an operation controlled by a PLC. The conveyor transports parts to a work-in-progress (WIP) tray. The conveyor should start running as soon as the optical sensor *I1* detects a part, and the operator presses a momentary manual push button. The PLC uses a counter triggered by optical sensor *I2* to keep track of the number of parts in the WIP tray. There is a material handling robot to transport the tray to the next operation. Once there are 10 drilled parts in the WIP tray the conveyor stops, the robot transports the tray to the next operation, and the counter is reset.

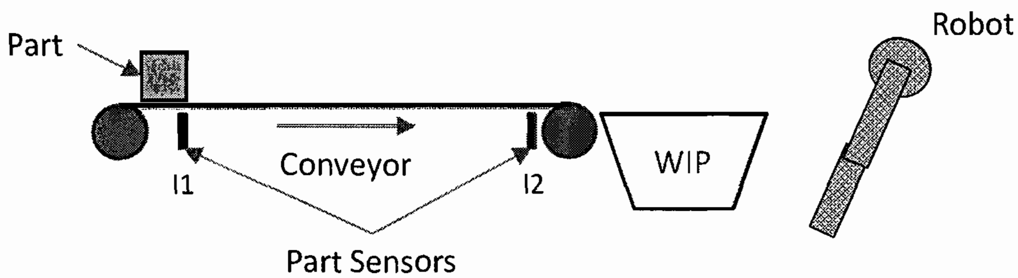

Fig. 1

The inputs to the operation are:

I1: Part sensor 1 activated
I2: Part sensor 2 activated
I3: Momentary contact push button to start conveyor

The outputs from the operation are:

O1: Conveyor motor
O2: Robot

Generate a ladder logic code for this production operation. Also provide an explanation for each rung of the ladder you generate. [50%]

(c) Petri Net modelling provides one approach for generating ladder logic code for an automated production cell. For the operation represented by the Petri Net model given in Figure 2, generate a ladder logic code for the Petri Net. Also provide an explanation for each rung of the ladder you generate. [30%]

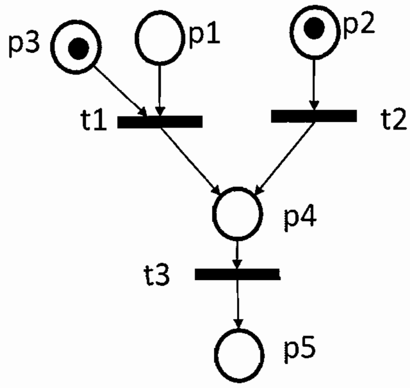

Fig. 2

2 (a) Explain the advantages and limitations of CNC control in machining operations. [20%]

(b) Describe three categories of positional disruption that might occur in machine tools? For each of these categories, explain clearly why the effects of these cannot be eliminated by better design alone. [30%]

(c) A machine tool is to be equipped with a simple, proportional negative feedback controller with gain K_p which acts on the error between desired and actual tool position. The behaviour of the machine tool is represented by its transfer function $G(s)$ as follows:

$$G(s) = \frac{0.9}{(s+2)(s+5)}$$

(i) Sketch the closed-loop system and write the expression for the steady-state error of the machine tool. Determine the gain of the feedback controller that will result in a 1% steady-state error in tool position. [30%]

(ii) What are the implications of the gain value calculated in part (i)? How can you further decrease the steady-state error? [20%]

SECTION B

*Answer **one** question from this section.*

3 TruckParts Ltd. produces a range of transmissions for trucks. The demand for its main product is 500 units per month. The fixed cost of setting up the machine that produces the transmission is £5,000, and the value of each transmission is £4,000. The company uses an annual interest rate of 10% to account for the cost of capital, and estimates that it costs another £500 to store one part in the warehouse for one year.

(a) State the basic assumptions underpinning the Economic Batch Quantity (EBQ) model, and derive the mathematical formula. Calculate the EBQ for the transmission. [30%]

(b) Outline the main advantages and key problems associated with the EBQ model. [30%]

(c) As part of a general review of inventory management policies for its purchased parts, the Operations Manager conducts an ABC-analysis of all parts currently stored. What general ordering policies would you recommend for A-parts, B-parts, and C-parts? Justify your answer. [25%]

(d) Explain the "two-bin" system, and outline its main advantages. [15%]

4 You are the operations manager of CamBike Ltd, a bike manufacturing company. The bike manufacturing process has four main stages: frame welding, painting, assembly, and packing. The total processing times is 8 hours 10 minutes per bike. A shift has 7.5 hours, and the factory is running for two shifts per day. Each month has 20 working days. The average demand is 14,400 units per month. Current work-in-progress (WIP) inventory levels for all production stages combined are at 480 units.

(a) What general functions does inventory have in a manufacturing system? [30%]

(b) In the case of CamBike, how much could you reduce the inventory level in percent, if you reduced the WIP level to the minimum level? Justify your approach. [30%]

(c) The marketing department at CamBike found that sales are very seasonal, with exponential growth periods leading up to the summer months. Currently, customer demand is forecast using a simple exponential smoothing model to predict its future sales. Is this appropriate? Justify your answer, and give at least one alternative approach to forecasting the demand for bikes. [30%]

(d) The marketing department at CamBike is concerned about development of the UK bike market over the next five years. You have been tasked with developing a forecasting model. What economic indicators would you consider in your analysis? [10%]

SECTION C

*Answer **one** question from this section.*

5 (a) Discuss reasons why the theoretical capacity of a manufacturing process may be impossible to achieve in practice. [20%]

(b) CeeBalls Ltd manufactures red and white coloured cricket balls for the UK market in a factory with four machines A, B, C and D. White coloured balls follow route A-B-D and red-coloured balls follow route A-C-D. Production is organised so that whenever a batch of one type of balls is made, an identical sized batch of the other type of balls is always made immediately afterwards. Data on process times and setup times are given in Table 1.

Machine	Process time (seconds)	Setup time (minutes)
A	30	10
B	60	15
C	80	5
D	20	7

Table 1

(i) Draw a process-flow diagram for this process. [10%]

(ii) Calculate the long-run capacity in terms of pairs of balls (one white and one red) produced each hour and identify the bottleneck of this process for a batch size of 10, and for a batch size of 100. [25%]

(iii) Discuss the implications of the difference between the results in (ii) for the two batch sizes. [15%]

(c) CeeBalls Ltd faces high demand during summer months and low demand during winter. Discuss three options available to CeeBalls Ltd for coping with such variation in demand, and the implications of choosing each of the options. [30%]

6 (a) Explain the differences between Just-in-Time (JIT) and Materials Requirements Planning (MRP) approaches to production planning and control. Discuss the situations under which it would be appropriate to adopt each approach. [30%]

(b) A widget manufacturer needs to deliver widgets as per Table 2. The widget is assembled from a number of components and sub-assemblies as per the bill of materials shown in Figure 3. The current stock, lot sizing rules, lead times and scheduled receipts (which arrive at the beginning of the week) are shown in Table 3.

(i) Construct the MRP records for the widget as well as its constituent parts A, B, and C for these 6 weeks. [40%]

(ii) Discuss the implications of implementing JIT practices in this company? [30%]

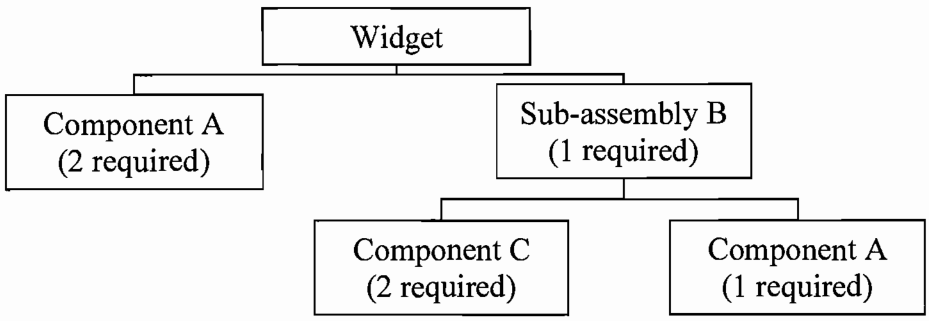

Fig. 3

Week	1	2	3	4	5	6
Demand	100	0	100	150	0	100

Table 2

	Current stock	Lead-time	EOQ	Scheduled receipts
Widget	100	1 week	125	None
Component A	500	1 week	Lot-for-Lot	500 in week 2
Sub-assembly B	50	2 weeks	300	75 in week 2
Component C	1000	1 week	Lot-for-Lot	None

Table 3

SECTION D

*Answer **one** question from this section.*

7 A company with annual sales of £2,400,000 operating 50 weeks per year holds average inventory of raw materials, work in progress and finished goods as shown in Table 4.

		Inventory level	Unit price (£)
Raw material	R1	2000	0.5
	R2	1400	4
	R3	800	7
	R4	600	12
	R5	400	16
	R6	200	20
Work in Progress	W1	90	70
	W2	80	140
	W3	160	180
Finished Goods	F1	70	1200
	F2	140	1600

Table 4: Average inventory levels and unit prices

(a) Calculate the weeks of supply and the inventory turns for this company. [30%]

(b) Discuss why it is impossible to meet all supply objectives at the same time within the enterprise and across the supply chain. [50%]

(c) Explain why it may be difficult for manufacturers to reduce their inventory levels in a recession. [20%]

8 (a) Discuss, with examples, the importance of standards in business-to-business transactions. [25%]

(b) Discuss the advantages and disadvantages of internet-based sales transactions compared to Electronic Data Interchange (EDI). [25%]

(c) Why does EDI continue to account for more than 80% of business-to-business transactions? . [25%]

(d) Explain the types of goods that may be particularly suited to internet-based purchasing and describe four alternative types of marketplace that may be used for such transactions. [25%]

END OF PAPER