MANUFACTURING ENGINEERING TRIPOS PART I

Monday 30 April 2007 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 6

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SECTION A

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

1 (a) Static deflection, dynamic deflection and thermal distortion are all disturbances that can significantly affect the performance of a machine tool.

(i) For each of these types of disturbance, identify approaches in the design of the machine tool that can help to reduce the source of the problem and its effects.

(ii) Why is design on its own insufficient for ensuring the machine tool is able to perform effectively in the face of such disruptions? [40%]

(b) The deflection behaviour of a machine tool can be represented by a multiplicative series of second order systems. Its transfer function, $G(j\omega)$, is given by

$$G(j\omega) = \prod_{i=1}^{4} G_i(j\omega) = \prod_{i=1}^{4} \frac{{\omega_{ni}}^2}{-\omega^2 + 2c_i\omega_{ni}j\omega + {\omega_{ni}}^2}$$

where, for each of the second order systems, $G_i(j\omega)$, the parameter c_i, $i = 1,...,4$ represents the damping factor, and ω_{ni}, $i = 1,...,4$ represents the natural frequency. Deflection analysis of the machine tool is to be done by considering $G_1(j\omega)$ only. For the lowest frequency mode, $G_1(j\omega)$, $c_1 = 0.25$ and $\omega_{n1} = 200rad/s$. In seeking to use cheaper materials, a 20% reduction in material stiffness is being considered.

(i) Explain how this stiffness change will impact on the natural frequency of $G_1(j\omega)$.

(ii) By considering a closed negative feedback loop around $G_1(j\omega)$ with a simple feedback gain K, determine the value of K which will restore the original natural frequency.

(iii) How would you amend the feedback in order to also ensure that the damping factor of $G_1(j\omega)$ is not altered by this feedback? [60%]

2 (a) Petri Net modelling provides one approach for generating Ladder Logic code for an automated production cell.

(i) Under what circumstances is this approach most advantageous?

(ii) When is Petri Net modelling likely to be inappropriate? [20%]

(b) The material flow for a production cell for joining two metal components together is represented by the simple Petri Net in Figure 1.

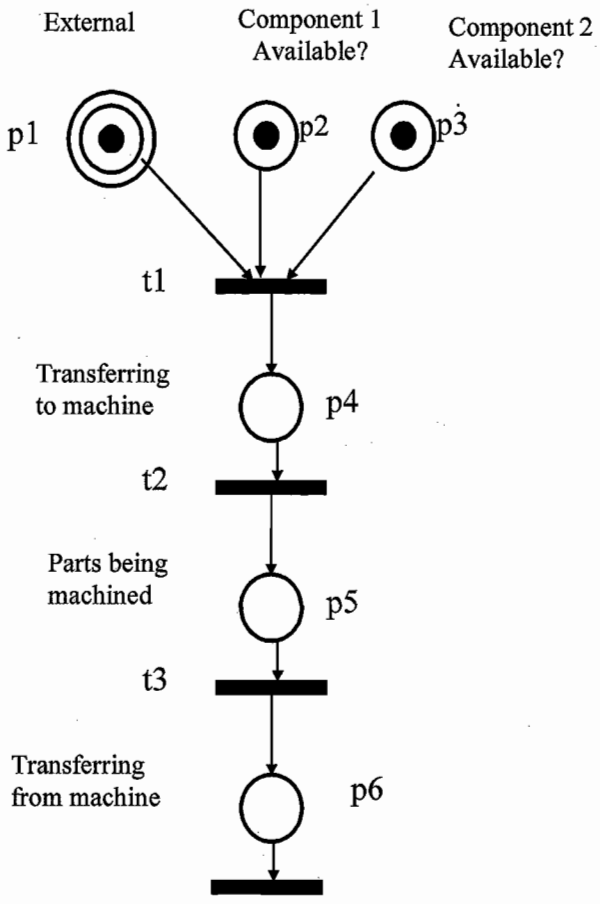

Figure 1

Redraw and extend this Petri Net to include the availability of the following additional resources:

(i) Machine tool: The machine tool is shared between more than one production cell. Ensure that the availability of the machine tool is guaranteed both during machining and also while parts are being transferred to the machine.

(ii) Material handling robot: the robot is used to transfer parts to and from the machine.

(iii) Finished goods storage: production is executed in batches of 10 parts and the robot removes parts to a finished goods store which has a capacity of 10 places available. Production must be stopped when this store is full and is only recommenced when the completed batch is collected.

In each case, clearly explain the reason for the introduction of each new place, transition and arc. Also state the current marking of the Petri Net you have generated. [60%]

(c) The extended Petri Net developed in part (b) is to be converted into fully operational ladder-logic code for a Programmable Logic Controller (PLC). Briefly outline the key steps that need to be followed. [20%]

SECTION B

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

3 (a) The total cost of inventory is typically given by the cost equation

$$C = C_o \frac{D}{Q} + C_h \frac{Q}{2}$$

where

D – demand,
Q – order quantity,
C_o – ordering cost,
C_h – holding cost.

(i) State the basic assumptions underpinning this model.

(ii) Derive a mathematical formula for Q^*, the Economic Order Quantity (EOQ), and the resulting optimal cost C^*. [30%]

(b) A company produces service parts for photocopiers. The demand for the parts is 30 units per month and the fixed cost of ordering raw material is £1,000 regardless of the order size. The value of each part is £500. The company uses an annual interest rate of 10% to account for the cost of capital, and a further 15% for the annual cost of storage.

(i) Calculate the EOQ, Q^*, and the resulting total cost, C^*, for the company.

(ii) Comment on any practical issues which might lead to variations in the actual quantity ordered. [30%]

(c) Assume that the actual order quantity is not $Q = Q^*$ but rather $Q = Q^*(1+\Delta Q)$. Then let the resulting total cost C be given not by $C = C^*$ but by $C = C^*(1+\Delta C)$.

(i) Develop an expression for the ratio $\Delta C/\Delta Q$ in terms of D, C_o *and* C_h for small values of ΔQ (i.e., $\Delta Q << 1$). State any approximations you make.

(ii) Comment on the robustness of EOQ in terms of the impact that small changes in order quantity have on cost. [40%]

4 (a) A manufacturer of sunshades operates an assembly line with ten separate tasks, A-J. The table below gives the duration of each task, and the immediate preceding operations of each task. The company works 8.5 hours per day, with two 15-minute breaks per day.

Task	Duration(minutes)	Preceding Operations
A	3	-
B	5	-
C	1	B
D	7	A,C
E	5	D
F	8	C,E
G	4	F
H	2	F
I	2	G,H
J	1	I

(i) Draw a process diagram for this assembly operation.

(ii) Justifying your approach, balance this line for a daily demand of 60 units and show the tasks to be completed by each worker.

(iii) Determine the minimum number of stations as well as the balancing loss for your solution.

(iv) The company is asked to increase daily demand by 10%. Discuss the implications of this increase. [50%]

(b) The firm has observed that sales are very seasonal, with many more sunshades being sold over the summer months than during winter. The marketing department would like to introduce a method to forecast sales more accurately, and is proposing to use simple exponential smoothing.

(i) What value of α, the smoothing constant, should be used? Justify your answer.

(ii) Could moving average smoothing be used as an alternative? Justify your answer.

(iii) In the light of the observed seasonality, would there be a better option than using either moving average smoothing or simple exponential smoothing? [50%]

SECTION C

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

5 (a) Many different dispatching rules can be used to determine the sequence in which orders are released to assembly stations.

(i) Define what is meant by a dispatching rule and specifically describe the key features of Earliest Due Date (EDD), First Input, First Output (FIFO) and Least Changeover Cost (LCC) dispatching rules.

(ii) Under what circumstances might each dispatching rule be used? Justify your answer. [30%]

(b) A factory assembles industrial heating systems. The factory manager has decided to move from the current FIFO dispatching approach to an EDD approach. The factory has currently orders (1, 2, 3, 4, 5) to be made on two assembly stations (A, B). Timing and sequence data (in days) are given in the table below:

Product	Due Time	Release Time	Sequence	Process Time at A	Process Time at B
1	150	0	A-B	30	20
2	130	20	B-A	30	40
3	120	40	B-A	30	10
4	110	40	A-B	40	30
5	90	60	B-A	10	20

(i) Determine average lateness and the number of late orders for both the current and proposed dispatching approaches.

(ii) Evaluate the factory manager's decision, noting whether there is any other data you would require to fully review this decision. [50%]

(c) A factory study indicates that some product changeovers are significantly less costly than all other product changeovers. Under what circumstances should the manager consider an LCC approach to dispatching as a further option? [20%]

6 Small company B has been assembling and supplying a limited range of simple sub-assemblies for a computer manufacturer A for several years. The computer manufacturer is located nearby and company B has established an office within the site to organise deliveries and monitor any issues that arise. In turn, suppliers, C_1, C_2, etc., for B are local and well known to B. Because of stringent time pressures and cost constraints, B has deployed a JIT approach to its business – both in terms of production planning and supplier management. This approach has worked well and B has been able to consistently meet the expectations of its customer, A.

(a) Why has the JIT approach worked well for Company B? State any assumptions you make. [50%]

(b) Because of its success, Company B has been asked to increase its range of subassemblies. Additionally, computer manufacturer A is increasingly producing highly customised orders which is leading to greater and more frequent variations in many of the subassemblies.

(i) What are the challenges that B faces under these new circumstances?

(ii) Would you continue with the same JIT approach (for both production planning and supplier management) or would you develop an alternative approach? Justify you answer. [50%]

SECTION D

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

7 The implementation of information systems can be characterised as a multi-stage process comprising initiation, adoption, adaptation, acceptance, routinisation and infusion.

(a) Briefly outline the activities involved in each stage. [20%]

(b) Describe some of the potential issues that may be experienced in implementing large-scale information systems such as Enterprise Resource Planning systems in manufacturing organisations. [20%]

(c) Discuss the advantages and disadvantages of different implementation and customisation strategies in a manufacturing organisation in more detail. [30%]

(d) What factors may influence a manufacturing organisation's choice of implementation or customisation strategy? [30%]

8 (a) Discuss the strengths and weaknesses of simulation, optimisation and heuristics as methods of solving allocation problems such as distribution in manufacturing organisations. [15%]

(b) A manufacturer operates distribution centres, X, Y and Z. Each has a capacity of 400 units of finished product. These are supplied from factories A, B and C, with a production capacity of 50, 40 and 30 units respectively. The transportation cost per unit between the factories and the distribution centres are:

	Distribution Centre X	Distribution Centre Y	Distribution Centre Z
Factory A	7	8	2
Factory B	5	4	6
Factory C	3	6	9

(i) Formulate the linear programming problem to minimise transport costs. [15%]

(ii) Set out the initial NorthWest Corner allocation and show that this is not an optimal solution. [50%]

(iii) What is the cost saving from the first improved NorthWest corner allocation compared with the initial NorthWest corner allocation? [20%]

END OF PAPER