MANUFACTURING ENGINEERING TRIPOS PART I

Monday 1 May 2006 9.00 to 12.00

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.*

STATIONERY REQUIREMENTS
8 page Answer book x 4
Rough Work Pad

SPECIAL REQUIREMENTS
Engineering Data Book
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

SECTION A

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

1 Computer Numerical Control (CNC) programming of machine tools is commonplace in most automated production environments today.

(a) Discuss the main benefits that have been achieved through the introduction of CNC programming compared to manual methods used previously. Under what circumstances might manual approaches still be used? [30%]

(b) You have been asked to evaluate and automate a simple machining operation that is performed on a stand-alone, three-axis machine tool. The machining operation cuts a slot recess into a mechanical mating face on a valve casting to accommodate a sealing gasket. A section of the G–Code programme proposed to control the operation of the machine tool is given in Fig. 1 and a table of typical commands provided in Fig. 2.

N5	G90 G21
N10	G00 X110 Y50 Z-25
N15	M03 S3000
N20	G01 Z-30 F20
N25	G02 X100 Y60 R10 F20
N30	G01 X100 Y140 F20
N35	G02 X110 Y150 R10 F20
N40	G01 X190 Y150 F20
N45	G02 X200 Y140 R10 F20
N50	G01 X200 Y60 F20
N55	G02 X190 Y50 R10 F20
N60	G01 X110 Y50 F20
N65	G01 Z-25 F20

Fig. 1 G-Code for Machining of Valve Casting

(cont.

Command	Description
G00	Position in rapid
G01	Linear interpolation
G02	Circular interpolation (CW)
G03	Circular interpolation (CCW)
G21	Metric
G90	Absolute Positioning
G91	Incremental Positioning
M03	Clockwise Spin rotation
M04	Anticlockwise Spin rotation
M05	Spindle stop
M02	End of Programme
S ...	Spindle Speed
F ...	Feed Rate

Fig. 2 Some Typical G Code Commands

(i) Describe the key steps of the programme in Fig 1 and suggest additions that might be required to complete the programme [20%]

(ii) Based on the programme in Fig 1, sketch the tool path that the machine tool cutter will follow when the G-Code is executed. Include on your drawing the Z axis depth and direction of the tool path. [20%]

(iii) Currently the loading, unloading and clamping of the valve casting during the machining operation is carried out by hand. However, it is proposed that the machine tool be integrated into an automated production environment. Describe additional requirements for achieving this integration, commenting specifically on additional equipment, control system modifications and new sensor systems that might be needed. Comment on the impact of each addition on manpower requirements for the operation of this machine tool. [30%]

2 A PLC is being used to control a turntable. The turntable must be sent a signal to indicate when to start turning. It will respond positively to this message, and will then perform a 90-degree rotation. To allow this to occur, two connections have been made between the PLC and the turntable. From the PLC these two connections consist of one output O1 to the turntable motor and one input I1 to the PLC indicating task completion. The PLC also has a momentary push button attached to input I2.

The PLC operation is represented by the Petri net in Fig 3 and has been designed to communicate with the turntable, where p_1, p_2, p_3 denote places.

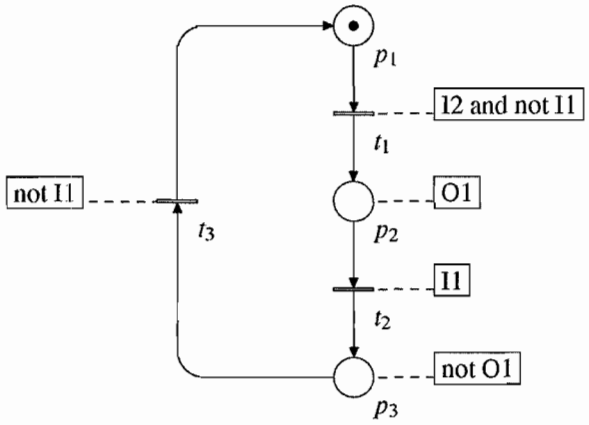

Fig 3 Petri Net Representation of PLC Operation

(a) The input I2 becomes high at time 0 for 200 milliseconds, then goes low, while input I1 goes high 100 milliseconds after O1 becomes high, stays high for 2 seconds, and then goes low. Draw a time-line showing inputs (I1, I2) and output (O1). Assume that the PLC responds instantaneously. [20%]

(b) A tool used to convert the Petri net to ladder logic has produced the following Boolean assignment for the state of p_1:

$$p_1 = p_1.\overline{i_2.\overline{i_1}} + p_3.\overline{i_1}$$

By simplifying this expression or otherwise, convert this Boolean equation to a ladder logic statement. [40%]

(cont.

(c) The place p_1 is intended to contain a token initially. However PLCs generally initialise their internal memory to zero. Assuming the availability of additional logical bits (B1, B2, etc), extend the logic to ensure that p_1 is set to 1 during the first scan only. State your answer as a revised Boolean assignment for p_1 and any other Boolean assignments, clearly indicating in which order you expect them to be executed. [30%]

(d) You have discovered that the PLC being used to implement this system is very old and has an 8 second scan cycle time. Given that a 90-degree turntable rotation takes about 2 seconds, what sort of problems might be expected to occur? [10%]

SECTION B

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

3 An assembly line operation has nine separate operations, and the table below gives the duration of each operation, and the immediate precursors of each operation. The line works 8 hours per day, with two 15 minutes breaks per day.

Operation	**Duration (minutes)**	**Precursors**
A	6	-
B	4	-
C	3	A
D	3	A,B
E	4	C,D
F	9	D
G	3	E,F
H	4	G
I	1	G

(a) You are asked to improve the balance of the assembly line

(i) Draw a suitable diagram for this assembly process.
(ii) Clearly describing and justifying the method you choose, balance this line for a daily demand of 50 units, and show the operations to be completed by each worker.
(iii) Evaluate the performance of the resulting solution, commenting in particular on the minimum number of workers required and the balancing loss for your solution. [50%]

(b) The operations manager is unsure whether holding additional raw material stock would be beneficial, despite the volume discounts to be gained. You have been asked to advise him as part of a management briefing. Explain the main advantages and disadvantages of holding stock for a manufacturing operation. [30%]

(c) The company wants to increase line capacity to 100 units per day, which would enable it to buy raw materials in larger quantities at a bulk discount. What is required for the assembly line to be able to accommodate this increase? [20%]

4 A small restaurant, open 365 days per year, offers fast meals including a range of noodle dishes. All noodles are produced in-house in sequential batches on a single kneading machine by a single cook. The kneading machine operates at a speed of 100 portions per 14 hour working day.

(a) A new noodle dish, *Noodles A*, is being introduced, and the projected annual demand for this dish is 3,000 portions per annum. The setup cost is £20 per noodle batch, and the value of each portion is £1. The company uses an annual interest rate of 6% to account for the opportunity cost of capital.

(i) State the basic assumptions underpinning the Economic Production Quantity (EPQ) model, and derive a mathematical formula for EPQ based on these assumptions. Calculate the EPQ for the case of *Noodles A*.

(ii) An additional new product, *Noodles B,* is proposed. How will the introduction of this product influence the EPQ for *Noodles A?* [50%]

(b) Explain the differences between the Economic Production Quantity (EPQ) and the Economic Batch Quantity (EBQ) models, and identify the key differences in the assumptions of the formulae for each. How do these differences impact on the outcomes of the models? Justify your answer. [30%]

(c) After an operational audit, the owner wants to reduce inventory in order to reduce cost. The total processing time for the three main production steps of kneading, cutting and cooking is 22 minutes, and the restaurant serves – on average – a total of 85 portions of noodles per 14 hour working day. Two cooks each work a shift of 7 hours per day producing 40 and 45 dishes respectively per shift on average. Current work-in-progress (WIP) levels are at 10 portions of noodles. Calculate how many percent the inventory level can be lowered? Justify your answer, identifying any assumptions made. [20%]

SECTION C

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

5 (a) In the present era of rapid change and short product lifetimes it is common for process technology to be used to produce several generations of one or more products. How does this influence decisions related to a) capacity planning and b) the design of factories? [40%]

(b) A factory produces 50 customised products per day and maintains an average of 10 days worth of WIP in the system. The factory currently has orders for 1000 products, including the 500 that have been released to the factory floor. A customer inquires about a new order of 50 products.

(i) What possible delivery dates could you offer the customer? State any assumptions made in each case.

(ii) What factors would you consider in deciding the appropriate delivery date to offer the customer, stating any additional information you might require? [30%]

(c) Contrast the implementation of demand management in MRP and JIT systems. [30%]

6 (a) The manager of a factory is considering increasing its capacity. Under what conditions should the manager:

(i) add capacity before demand has increased?

(ii) add capacity only after demand has increased?

[30%]

(b) The manager is also considering the competitive position of the factory.

(i) Why is the unit cost of a product usually less in a large factory than in a small one?

(ii) When might the unit cost of a product be lower in a small factory than in a large one?

[30%]

(c) The manager is also considering whether to change from the current MRP based planning system to a JIT system modelled on the Toyota Production System. Describe and contrast the consequences of an unexpected machine breakdown within each of these systems?

[40%]

SECTION D

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

7 (a) The selection of a distribution strategy can be critical for a manufacturing company.

(i) Describe and contrast four different distribution strategies that might be adopted by a manufacturing company. [30%]

(ii) Discuss the types of industry setting for which each might be suitable. [15%]

(b) A company operates two regional warehouses (A and B) that receive products from the main distribution centre of the factory. The lead time for shipping products from the main distribution centre to Warehouse A is one week, the standard shipping quantity is 100 units and the safety stock (on-hand at the start of the time period) is 10 units. The lead time for shipping products from the main distribution centre to Warehouse B is two weeks, the standard shipping quantity is 120 units and the safety stock (on-hand at the start of the time period) is 20 units.

(i) Given the demand and scheduled receipt data for the two warehouses in Table 1, calculate the gross requirements for the factory master production schedule, clearly showing the method you use. [40%]

WAREHOUSE A						
Week	0	1	2	3	4	5
Demand	-	-	80	120	70	130
Scheduled receipts	-	100				
WAREHOUSE B						
Week	0	1	2	3	4	5
Demand	-	-	60	140	40	100
Scheduled receipts	-	120				

Table 1 Warehouse Inventory Data

(ii) How might the factory manage the variability in demand indicated in Table 1? [15%]

8 (a) Understanding supply chain performance and factors that influence it is critical for the survival of today's manufacturing companies.

(i) Describe the "Bullwhip Effect" and explain its impact on supply chain performance. [20%]

(ii) What metrics might a manufacturing company use to assess the performance of its supply chain? [10%]

(iii) Discuss the tradeoffs that might exist between different aspects of supply chain performance. [20%]

(b) A company with £1,800,000 in annual sales, operating 50 weeks per year, holds the average levels of raw materials, work in progress and finished goods given in Table 2.

		Inventory level	Unit Price (£)
Raw materials	R1	2000	0.2
	R2	1400	3
	R3	800	5
	R4	700	25
	R5	200	80
Work in Progress	W1	200	250
	W2	120	400
Finished Goods	F1	80	1000
	F2	20	2400

Table 2 Average Inventory Level and Unit Prices

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

(ii) Are these measures sufficient for assessing the company's supply chain performance? Justify your answer. [20%]

END OF PAPER