Version WON/5

MET2
MANUFACTURING ENGINEERING TRIPOS PART IIA

Friday 27 April 2018 9.00 to 10.40

Paper 2

Module 3P2

OPERATION AND CONTROL OF PRODUCTION MACHINES AND SYSTEMS

*Answer **two** questions, one from each of sections **A** and **B**.*

*Answers to sections **A** and **B** must appear in two 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.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS
8 page answer booklet x 2
Rough work pad
Graph Paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper at the start of the exam.

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

SECTION A

Answer **one** question from this section.

1 (a) Discuss the purpose and basic principles of Statistical Process Control (SPC). Your answer should include a discussion of the types of charts that are employed, giving details on how each is constructed. [25%]

(b) A job-shop manufacturing environment is characterised by short production runs. This situation can make the routine use of SPC techniques challenging, as not enough units are produced in any one batch to establish control limits. One particular job shop provides drilling operations across a wide range of diameters and for a wide range of parts. Describe how you would extend SPC techniques to this environment. [15%]

(c) A company machines the internal bore in cast-iron cylinder liners and wishes to understand the levels of process control and process capability for the operation. The specification for bore diameter is 33.0mm ± 0.80mm. In order to perform a statistical analysis of the operation, 20 subgroups of parts had their diameters measured. Each subgroup consisted of 5 consecutively produced parts. Table 1 shows the average and range values for each subgroup.

Table.1 Bore diameter measurements (mm)

Subgroup	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Average	33.2	32.5	33.8	33.8	33.1	32.8	33.3	34.0	34.7	33.4
Range	1.6	1.3	1.2	1.3	1.5	1.1	1.4	1.5	1.2	1.2
Subgroup	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Average	33.2	33.7	33.0	34.1	33.2	32.9	33.2	33.5	33.0	32.8
Range	1.3	1.1	1.7	1.2	1.3	1.8	1.4	1.5	1.0	1.3

(i) Sketch and annotate an appropriate pair of control charts for the data. Control chart coefficients are shown in Fig. 1. [20%]

(ii) What conclusions can you draw from the chart characteristics? [15%]

(iii) Suggest possible causes of the variations observed in this machining operation and comment on the level of process capability. [15%]

(iv) How would you improve it in this case? [10%]

Sample Size = n	**X-bar Charts**			**R Charts**	
	A_2	A_3	d_2	D_3	D_4
2	1.880	2.659	1.128	0	3.267
3	1.023	1.954	1.693	0	2.574
4	0.729	1.628	2.059	0	2.282
5	0.577	1.427	2.326	0	2.114
6	0.483	1.287	2.534	0	2.004
7	0.419	1.182	2.704	0.076	1.924
8	0.373	1.099	2.847	0.136	1.864
9	0.337	1.032	2.970	0.184	1.816
10	0.308	0.975	3.078	0.223	1.777

X-bar chart

$$UCL = \bar{\bar{x}} + A_2\bar{r}$$
$$CL = \bar{\bar{x}}$$
$$LCL = \bar{\bar{x}} - A_2\bar{r}$$

R chart

$$UCL = D_4\bar{r}$$
$$CL = \bar{r}$$
$$LCL = D_3\bar{r}$$

Fig. 1

2 (a) Discuss why the economics of metal cutting are of vital interest to manufacturing engineers. [15%]

(b) Develop a basic equation that can be used to calculate the average cost per item of a machined part as a function of cutting speed. [25%]

(c) It can be shown that the optimum cutting speed, V_c, to minimise cost is given as

$$V_c = C\left(\frac{n}{1-n}\cdot\frac{M}{Mt_c + C_t}\right)^n$$

The cutting speed for maximum production rate, V_p, is given as

$$V_p = \frac{C}{\left[\left(\frac{1}{n}-1\right)t_c\right]^n}$$

where t_c is the tool changing time, n and C are Taylor's tool life constants for the particular operating conditions, C_t is the tool cost, and M is the cost per unit time for machine and operator.

A single pass turning operation is performed with a high speed steel tool on mild steel. Taylor's tool life constants are n = 0.13 and C = 80 m/min. Workpiece length = 500 mm and diameter = 100 mm. Feed rate = 0.25 mm/rev. Handling time per piece = 5.0 min, and tool change time = 2.0 min. Cost of machine and operator = £33/hr, and tool cost = £3.

(i) Determine the hourly production rate and cost per item for the conditions of maximum production rate. Find the equivalent values for the case of minimum cost. [50%]

(ii) What practical observations can you make about the choice of tool material in this operation? [10%]

SECTION B

Answer **one** question from this section.

3

(a) (i) Describe the role a PLC (Programmable Logic Controller) typically plays in factory automation. Your response should include key tasks it performs and interconnections with other devices. [15%]

(ii) Compare the capabilities of a PLC with those of a conventional PC (Personal Computer) in the context of factory automation. [15%]

(b) Compare Ladder Logic with two other approaches for programming PLCs from the IEC 61131-3 PLC programming standard. Why is a standard important for PLC programming? [25%]

(c) A system to spray paint parts moving on a conveyor involves triggering one of three sprays depending on the part height and weight. The conveyor is started by pressing a momentary contact push button. Initially, a height detector measures the height of each part and classifies it as either tall or short and a weighing device classifies each part as light or heavy. Once in the spray zone, the parts are painted a different colour depending on their height [tall/short] and weight [heavy/light] and one of three different spray nozzles is turned on and used to paint a stripe on the part as it passes under the spray stream.

The inputs of the system are:

I1: Spray zone entry limit switch activated
I2: Spray zone exit limit switch activated
I3: Height sensor detects a tall part
I4: Weight sensor detects a heavy part
I5: Momentary contact push button pressed to start conveyor
I6: Momentary contact push button pressed to stop conveyor

The outputs of the system are:

O1: Conveyor motor ON
O2: Red paint spray nozzle activated
O3: Blue paint spray nozzle activated
O4: Yellow paint spray nozzle activated

 (TURN OVER

Part of the ladder logic for the operation of this system is given in Fig. 2.

(i) Explain the function of each rung and in particular the role of variables B1, B2. [15%]

(ii) What additions would need to be made to the ladder logic to ensure the sprays will stop if spray zone exit limit switch (I2) is not activated after a period of 10 seconds following the activation of the spray zone entry limit switch (I1)? [10%]

(iii) Briefly discuss further additions needed for the system to run automatically for a batch of 10 parts. State any assumptions you make. [20%]

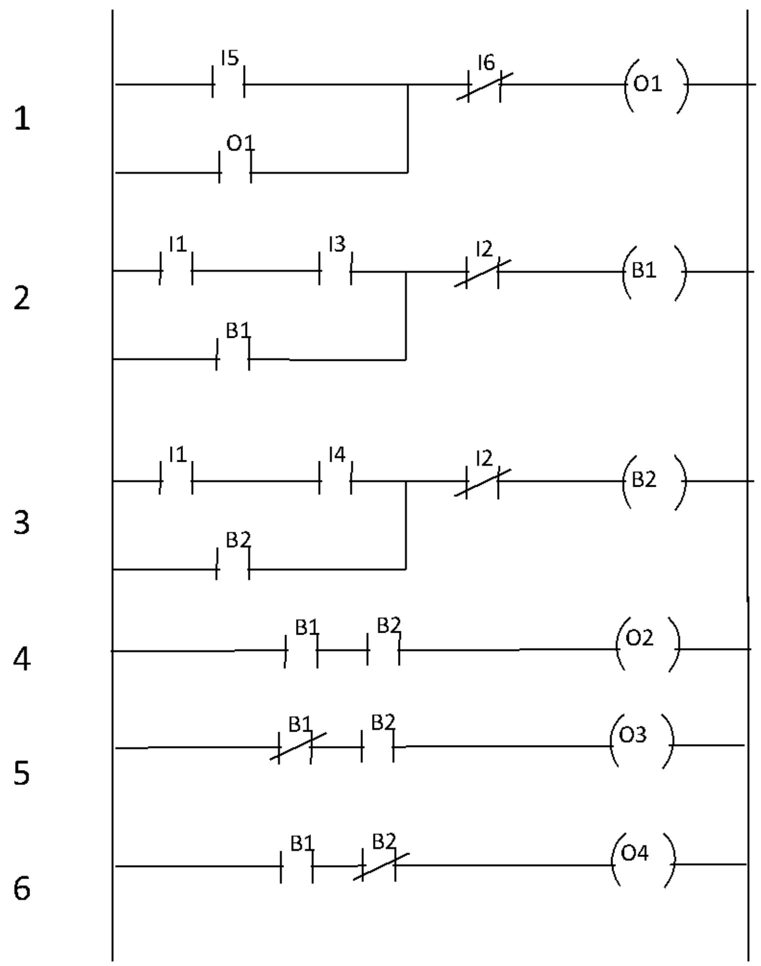

Fig. 2

4

(a) (i) Explain how in a Petri Net diagram an inhibitor arc can be used to manage the prioritisation of a constrained resource.

(ii) Using ordinary places, arcs and transitions, show how this prioritisation can be achieved without an inhibitor arc or external inputs. [30%]

(b) A simplified Petri Net for a critical machining operation is given in Fig 3. The machine can perform customised drilling on parts of types A and B.

(i) The machine is initially used to machine parts of type A arriving in a loading buffer (Buffer A). The parts will be loaded onto the machine by a robot (Robot A). The parts will also be unloaded by Robot A to an output buffer. Redraw and amend the Petri Net to reflect these additional activities, clearly describing the logic behind your amendments. State any assumptions that you make. [25%]

(ii) A second robot (Robot B), and buffer (Buffer B) are now introduced to support the arrival of parts of Type B in addition to the parts of Type A. Redraw your Petri Net to allow for both type A and type B parts being processed by the machine. Further, ensure that parts of type B are always treated as a priority over parts of type A. Assume that only Robot A performs the unloading of the machine and that there is a single output buffer for all parts. State any assumptions that you make, and make sure the logic you have used is clearly described. [30%]

(iii) Identify any further issues that may need to be considered before this Petri Net model is ready to be used for developing an automation environment. [15%]

(TURN OVER

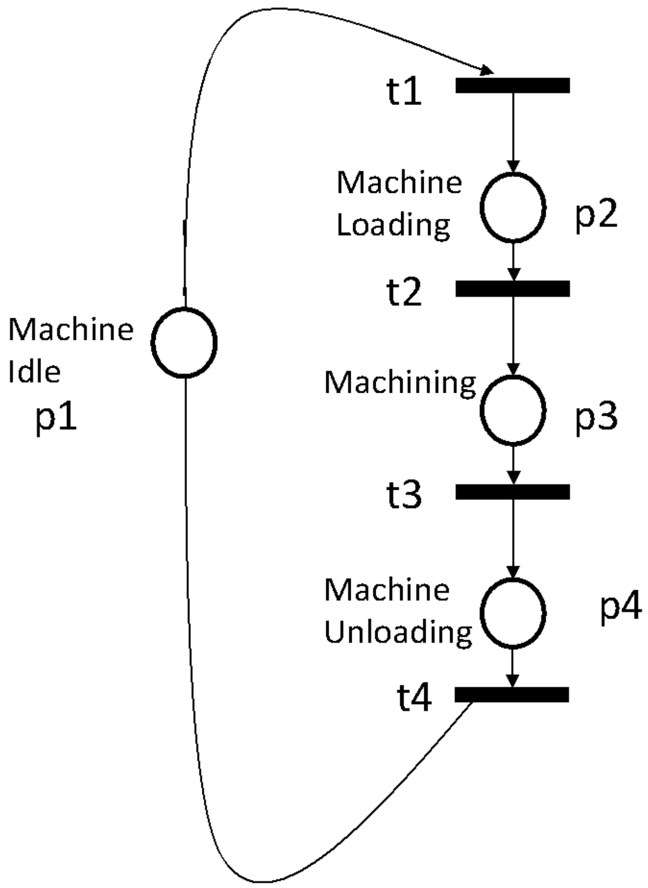

Fig. 3

END OF PAPER