UNIVERSITY OF JOHANNESBURG

PROGRAM	:	NATIONAL DIPLOMA *ENGINEERING: INDUSTRIAL*
SUBJECT	:	**AUTOMATION III**
CODE	:	**BAU 3111**
DATE	:	SUMMER EXAMINATION 2015 10 NOVEMBER 2015
DURATION	:	(SESSION 1) 08:30 - 11:30
WEIGHT	:	40: 60
TOTAL MARKS	:	100

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NUMBER OF PAGES	:	5 PAGES	

INSTRUCTIONS : ONLY ONE POCKET CALCULATOR PER CANDIDATE MAY BE USED.

INSTRUCTIONS TO STUDENTS

PLEASE ANSWER ALL QUESTIONS.
UNDERLINE EACH AND EVERY CALCULATION ANSWER

QUESTION 1

A rail engineering company has a machine shop that manufactures spares for its operations. The company has eight machines in its automatic lathe section. The setup time on an automatic lathe averages 7 hours. The average batch size for parts processed through the section is 90. The average operation time = 10.0 minutes. Under shop rules, an operator can be assigned to run up to two machines. Accordingly, there are four operators in the section for the eight lathes. In addition to the lathe operators, there are two setup workers who perform machine setups exclusively. These setup workers are kept busy the full shift. The section runs one 8-hour shift per day, 5 days per week. However, an average of 20 % of the production time is lost due to machine breakdowns and maintenance. Scrap losses are negligible.

The production control manager claims that the capacity of the section should be about **1047** pieces per week. However, the actual output averages only **1028** units per week. What is the problem? Recommend a solution. **[13 marks]**

QUESTION 2

A dc servomotor drives the x-axis of a NC milling machine table. The motor is coupled directly to the table lead screw, whose pitch = 6.25 mm. An optical encoder is connected to the lead screw. The optical encoder emits 100 pulses per revolution. To execute a certain programmed instruction, the table must move from point (x = 100.0 mm, y = 40.0 mm) to point (x = 25.0 mm, y = 160.0 mm) in a straight-line trajectory at a feed rate = 225 mm/min.

Determine:

(a) the control resolution of the system for the x-axis, (2 marks)
(b) rotational speed of the motor, and (10 marks)
(c) frequency of the pulse train emitted by the optical encoder at the desired feed rate. (3 marks)

[Total marks 15]

QUESTION 3

A DAC uses a reference voltage of 85 V and has 6-bit precision. In four successive sampling periods, each 1 second long, the binary data contained in the output register were 100000, 011110, 011100, and 011000.

Determine the equation for the voltage as a function of time between sampling instants 3 and 4 using:

(a) a zero-order hold, (6 marks)

(b) a first-order hold. (4 marks)

[10 marks]

QUESTION 4

A packaging factory in Wadeville-Germiston produces cardboard boxes. The production sequence consists of three operations: (1) cutting, (2) indenting, and (3) printing. There are three machines in the factory, one for each operation. The machines are 100% reliable and operate as follows when operating at 100% utilization:

(1) In ***cutting***, large rolls of cardboard are fed into the cutting machine and cut into blanks. Each large roll contains enough material for 5000 blanks. Production cycle time = 0.05 minute/blank during a production run, but it takes 40 minutes to change rolls between runs.

(2) In ***indenting***, indentation lines are pressed into the blanks to allow the blanks to later be bent into boxes. The blanks from the previous cutting operation are divided and consolidated into batches whose starting quantity = 2500 blanks. Indenting is performed at 5.5 minutes per 100 blanks. Time to change dies on the indentation machine = 35 minutes.

(3) In ***printing***, the indented blanks are printed with labels for a particular customer. The blanks from the previous indenting operation are divided and consolidated into batches whose starting quantity = 1250 blanks. Printing cycle rate = 25 blanks/minutes. Between batches, changeover of the printing plates is required, which takes 25 minutes.

In-process inventory is allowed to build up between machines 1 and 2, and between machines 2 and 3, so that the machines can operate independently as much as possible.

Based on this data and information, determine the maximum possible output of this factory during a 40-hour week, in completed blanks/week (completed blanks have been cut, indented, and printed)? Assume steady state operation, not startup.

[20 marks]

QUESTION 5

A Small to Medium Enterprise (SME) company based in Gauteng-Isando has just won a tender to manufacture motor vehicle number plates. An Industrial Engineer has recommended that the company uses a stamping press, with two button safety interlock system to prevent the operator from inadvertently actuating the press while his hand is in the die. Both buttons must be depressed to actuate the stamping cycle. In this system, one press button is located on one side of the press while the other button is located on the opposite side. During the work cycle the operator inserts the part into the die and depresses both push buttons, using both hands.

Specify the input/output variables for this system operation and define symbols for them (e.g. X1, X2, C1, Y1, etc)

a) Write the Boolean logic expression for the system, (3 marks)
b) Write the truth table for this interlock system, (3 marks)
c) Construct the logic network diagram for the system, (3 marks)
d) Construct the ladder logic diagram for the system, (3 marks)
e) Write the low level language statements for the system using the standard PLC instructions. (3 marks)

[Total marks 15]

QUESTION 6

The outline of the part in Figure 6, is to be profile milled using a 20 mm diameter end mill with four teeth. The part is 15 mm thick. Spindle speed is 1400 rev/ min and feed is 0.05 mm per tooth. Use the lower left corner (Point A to B), as the origin in the x-y axis system. Milling is to be done from point A in an anti-clockwise direction. The three holes in the part have already been drilled and will be used for clamping the part during milling. Use D04 as your cutter offset register code.
Write the part program in the word address format. Use absolute positioning. **[15 marks]**

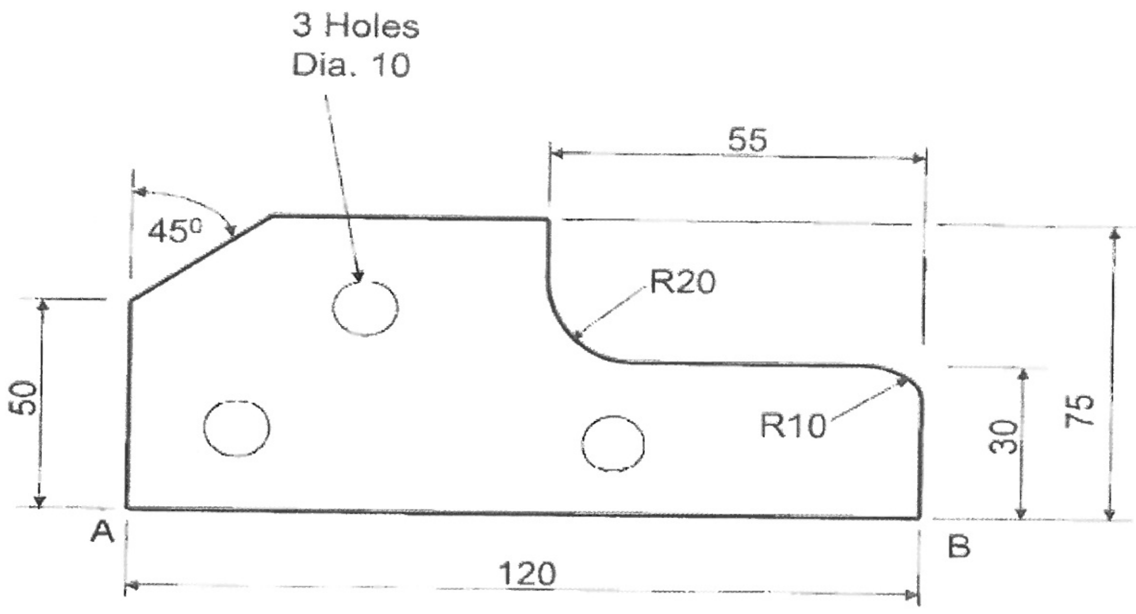

Diagram not to scale

QUESTION 7

7.1 Costs have been compiled for a certain manufacturing company for the most recent year. The summary is shown in the table below. The company operates two different manufacturing plants, plus a corporate headquarters.

Determine:

(a) the factory overhead rate for each plant, and

(b) the corporate overhead rate. The firm will use these rates in the following year.

Expense category	Plant A	Plant B	Corporate headquarters
Direct labor	R1 500 000	R 1 750 000	
Materials	R3 000 000	R 3 500 000	
Factory expense	R1 400 000	R 2 200 000	
Corporate expense			R 6 000 000

(3 marks)

7.2 The hourly rate for a certain work center is to be determined based on the following data: direct labor rate = R 25.00/hr; applicable factory overhead rate on labor = 40%; capital investment in machine = R 250 000-00; service life of the machine = 6 years; rate of return = 14%; salvage value in five years = zero; and applicable factory overhead rate on machine = 35%. The work center will be operated two 8-hour shifts, 250 days per year. Determine the appropriate hourly rate for the work center. (9 marks)

[Total Marks 12]

TOTAL = 100

BAU 3111 AUTOMATION

FORMULAE SHEET

$$Q_f = \sum_{j=1}^{p} Q_j \; ; \; n_{pf} = \sum_{j=1}^{p} Q_j n_{pj} \; ; \; n_{of} = \sum_{j=1}^{p} Q_j n_{pj} \sum_{k=1}^{npj} n_{ojk} \; ; \; Q_f = PQ \; ; \; n_{pf} = PQn_p \; ;$$

$$n_{of} = PQn_p n_o \; ; \; T_c = T_o + T_h + T_{th} \; ; \; T_b = T_{su} + QT_c \; ; \; T_p = \frac{T_b}{Q} \; ; \; R_p = \frac{60}{T_p} \; ; \; T_b = T_{su} + QT_c$$

$$PC = \frac{n S_w H_{sh} R_p}{n_o} \; ; \qquad U = \frac{Q}{PC} \; ; \qquad A = \frac{MTBF - MTTR}{MTBF}$$

$$MLT = n_o \left(T_{su} + QT_c + T_{no} \right) \; ; \; MLT = n \left(T_r + Max\, T_o \right) = nT_c$$

$$WIP = \frac{AU(PC)(MLT)}{S_w H_{sh}} \; ; \; FOHR = \frac{FOHC}{DLC} \; ; \; COHR = \frac{COHC}{DLC} \; ; \; UAC = IC\,(A/P,\, i,\, n)$$

$$(A/P, i, n) = \frac{i(1+i)^n}{(1+i)^n - 1} \; ; \qquad C_o = C_L\,(1 + FOHR_L) + C_m\,(1 + FOHR_m)$$

$$S = C + ms \; ; \; T = K_t I_a \; ; \; E_b = K_v \omega \; ; \; N = \frac{60\omega}{2\pi} \; ; \; I_a = \frac{V_{in}}{R_a} \; ; \; I_a = \frac{V_{in} - E_b}{R_a} = \frac{V_{in} - K_{v\omega}}{R_a}$$

$$T = K_t \left(\frac{V_{in} - K_{v\omega}}{R_a} \right) \; ; \quad P = T\omega \; ; \quad HP = \frac{T\omega}{745.7} \; ; \quad 745.7\ \text{W} = 1\ \text{hp}$$

$$\alpha = \frac{360}{n_s} \; ; \; A_m = n_p \alpha \; ; \; \omega = \frac{2\pi f p}{n_s} \; ; \; N = \frac{60 fp}{n_s} \; ; \; v = \frac{Q}{A} \; ; \; F = pA \; ;$$

$$\omega = KQ \; ; \; N_q = 2^n \; ; \; R_{ADC} = \frac{L}{N_q - 1} = \frac{L}{2^n - 1} \; ;$$

$$E_o = E_{ref} \{ 0.5B_1 + 0.25B_2 + 0.125B_3 + \ldots + (2^n)^{-1} B_n \}$$

$$E(t) = E_o \; ; \qquad E(t) = E_o + \alpha t \; ; \qquad \alpha = \frac{E_o - E(-\tau)}{\tau}$$

$N = \frac{v}{\pi D}$, $f_r = Nn_t f$, $\alpha = \frac{360}{n_s}$, $A_m = n_p \alpha$, $A = \frac{n_p \alpha}{r_g}$, $A = \frac{A_m}{A} = \frac{N_m}{N}$

$x = \frac{pA}{360}$, $n_p = \frac{360xr_g}{p\alpha} = \frac{n_s x r_g}{p}$, $N = \frac{60 f_p}{n_s r_g}$, $v_t = f_r = N_p$,

$f = \frac{v_t n_s r_g}{60p}$ or $\frac{f_r n_s r_g}{60p}$, $n_p = \frac{A}{\alpha}$, $x = \frac{pn_p}{n_s}$, $v = f_r = \frac{60pf_p}{n_s}$, $CR_1 = \frac{p}{n_s r_g}$

$CR_2 = \frac{L}{2^B - 1}$, $CR = Max(CR_1, CR_2)$, $Accuracy = \frac{CR}{2} + 3\sigma$, $Repeatability = \pm 3\sigma$

Common G-words (Preparatory Word)

G-word	*Function*
G00	Point-to-point movement (rapid traverse) between previous point and endpoint defined in current block. Block must include *x-y-z* coordinates of end position.
G01	Linear interpolation movement. Block must include *x-y-z* coordinates of end position. Feed rate must also be specified.
G02	Circular interpolation, clockwise. Block must include either arc radius or arc center; coordinates of end position must also be specified.
G03	Circular interpolation, counterclockwise. Block must include either arc radius or arc center; coordinates of end position must also be specified.
G04	Dwell for a specified time.
G10	Input of cutter offset data, followed by a P-code and an R-code.
G17	Selection of *x-y* plane in milling.
G18	Selection of *x-z* plane in milling.
G19	Selection of *y-z* plane in milling.
G20	Input values specified in inches.
G21	Input values specified in millimeters.
G28	Return to reference point.
G32	Thread cutting in turning.
G40	Cancel offset compensation for cutter radius (nose radius in turning).
G41	Cutter offset compensation, left of part surface. Cutter radius (nose radius in turning) must be specified in block.
G42	Cutter offset compensation, right of part surface. Cutter radius (nose radius in turning) must be specified in block.
G50	Specify location of coordinate axis system origin relative to starting location of cutting tool. Used in some lathes. Milling and drilling machines use G92.
G90	Programming in absolute coordinates.
G91	Programming in incremental coordinates.
G92	Specify location of coordinate axis system origin relative to starting location of cutting tool. Used in milling and drilling machines and some lathes. Other lathes use G50.
G94	Specify feed per minute in milling and drilling.
G95	Specify feed per revolution in milling and drilling.
G98	Specify feed per minute in turning.
G99	Specify feed per revolution in turning.

Note: Some G-words apply to milling and/or drilling only, whereas others apply to turning only.

Common M-words Used in Word Address Format

M-Word	Function
M00	Program stop; used in middle of program. Operator must restart machine.
M01	Optional program stop; active only when optional stop button on control panel has been depressed.
M02	End of program. Machine stop.
M03	Start spindle in clockwise direction for milling machine (forward for turning machine).
M04	Start spindle in counterclockwise direction for milling machine (reverse for turning machine).
M05	Spindle stop.
M06	Execute tool change, either manually or automatically. If manually, operator must restart machine. Does not include selection of tool, which is done by T-word if automatic, by operator if manual.
M07	Turn cutting fluid on flood.
M08	Turn cutting fluid on mist.
M09	Turn cutting fluid off.
M10	Automatic clamping of fixture, machine slides, etc.
M11	Automatic unclamping.
M13	Start spindle in clockwise direction for milling machine (forward for turning machine) and turn on cutting fluid.
M14	Start spindle in counterclockwise direction for milling machine (reverse for turning machine) and turn on cutting fluid.
M17	Spindle and cutting fluid off.
M19	Turn spindle off at oriented position.
M30	End of program. Machine stop. Rewind tape (on tape-controlled machines).

Common Word Prefixes Used in Word Address Format

Word Prefix	Example	Function
N	N01	Sequence number; identifies block of instruction. One to four digits can be used.
G	G21	Preparatory word; prepares controller for instructions given in the block. See Table A7.2. There may be more than one G-word in a block. (Example specifies that numerical values are in millimeters.)
X, Y, Z	X75.0	Coordinate data for three linear axes. Can be specified in either inches or millimeters. (Example defines *x*-axis value as 75 mm.)
U, W	U25.0	Coordinate data for incremental moves in turning in the *x*- and *z*-directions, respectively. (Example specifies an incremental move of 25 mm in the *x*-direction.)
A, B, C	A90.0	Coordinate data for three rotational axes. A is the rotational axis about *x*-axis; B rotates about *y*-axis; and C rotates about *z*-axis. Specified in degrees of rotation. (Example defines 90° of rotation about *x*-axis.)
R	R100.0	Radius of arc; used in circular interpolation. (Example defines radius = 100 mm for circular interpolation.) The R-code can also be used to enter cutter radius data for defining the tool path offset distance from the part edge.
I, J, K	I32 J67	Coordinate values of arc center, corresponding to *x*-, *y*-, and *z*-axes, respectively; used in circular interpolation. (Example defines center of arc for circular interpolation to be at x = 32 mm and y = 67 mm.)
F	G94 F40	Feed rate per minute or per revolution in either inches or millimeters, as specified by G-words in Table A7.2. (Example specifies feed rate = 40 mm/min in milling or drilling operation.)
S	S0800	Spindle rotation speed in revolutions per minute, expressed in four digits. For some machines, spindle rotation speed is expressed as a percentage of maximum speed available on machine, expressed in two digits.
T	T14	Tool selection, used for machine tools with automatic tool changers or tool turrets. (Example specifies that the cutting tool to be used in the present instruction block is in position 14 in the tool drum.)
D	D05	Tool diameter word used in contouring moves for offsetting the tool from the workpart by a distance stored in the indicated register; usually the distance is the cutter radius. (Example indicates that the radius offset distance is stored in offset register number 05 in the controller.)
P	P05 R15.0	Used to store cutter radius data in offset register number 05. (Example indicates that a cutter radius value of 15.0 mm is to be stored in offset register 05.)
M	M03	Miscellaneous command. See Table A7.3. (Example commands the machine to start spindle rotation in clockwise direction.)