UNIVERSITY OF JOHANNESBURG

PROGRAM : NATIONAL DIPLOMA
ENGINEERING: INDUSTRIAL

SUBJECT : **AUTOMATION III**

CODE : **BAU 3111**

DATE : NOVEMBER EXAMINATION 2017
11 NOVEMBER 2017

DURATION : SESSION 1: (8:30-11:30)

WEIGHT : 40: 60

TOTAL MARKS : 100

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MODERATOR : Ms. D.I. MATIDZA 2320

NUMBER OF PAGES : 5 PAGES

INSTRUCTIONS:: ONLY ONE POCKET CALCULATOR PER CANDIDATE MAY BE USED.
UNDERLINE EACH AND EVERY CALCULATION ANSWER
PLEASE ANSWER ALL QUESTIONS.

QUESTION 1

a) A Junior Industrial Engineer, working for Smart Engineering Company, has been tasked to calculate manufacturing lead time and hourly production rate for operation 3 from the given data indicated in Table Q1. The batch size is 120 and the average nonoperation time per machine is 15 hours. (12 marks)

Table Q1

Machine	1	2	3	4	5	6	7	8
Setup times (hours)	5	3	10	4	6	5	3	2
Operation time (minutes)	4.0	3.5	7.5	6.1	4.4	3.0	5.6	3.9

b) Suppose the part in the previous problem is made in very large quantities on a production line in which an automated work handling system is used to transfer parts between machines. Transfer time between stations is 30 seconds. Total time required to set up the entire line is 175 hours. Assume that the operation times at the individual machines remain the same as in the previous problem.
Determine:
- i) manufacturing lead time for a part coming off the line, (2 marks)
- ii) production rate for operation 3, (2 marks)
- iii) theoretical production rate for the entire production line, (2 marks)
- iv) how long would it take to produce 12 000 parts after the setup has been completed? (2 marks)

[Total Marks 20]

QUESTION 2

Puleng Mabasa is working as an Industrial Engineer in an automotive company that has a product line with two models: A and B. Model A consists of 5 components: a, b, c, d and e. The number of processing operations required to produce these five components are 3, 4, 2, 5 and 6 respectively. Model B consists of 4 components: f, g, h and i. The number of processing operations required to produce these four components are, 5, 6, 7 and 6 respectively. The annual quantity of Model A is 1000 units and Model B is 1500 units.
Determine:

a) the total number of components and (5 marks)

b) the total number of processing operations associated with these two models. (5 marks)

[Total Marks 10]

QUESTION 3

FGMC is a local company that has been contracted to produce spare parts for Transnet. The company would like to have an understanding and appreciation of their manufacturing costs. In the operation of one of their production machine, one worker is required at a direct labour rate = R75.00 per hour. Applicable labour factory overhead rate = 50%. Capital investment in machine = R250 000.00, expected service life of the machine = 10 years, rate of return = 20%, salvage value in 10 years = 0, and applicable factory overhead rate on machine = 45%. The work cell will operate 2000 hours per year.

Determine:

a) the appropriate hourly rate for this machine, (5 marks)

b) suppose that the machine was operated three shifts, or 6000 hours per year, instead of 2000 hours per year. What would be the effect of increased machine utilization on the hourly rate compared to the rate determined in (a)? (5 marks)

[Total Marks 10]

QUESTION 4

Pump Masters is a Johannesburg based company that specialises in the manufacturing of pump parts. This company produces pump parts in batches and it uses semi-automated production machines as shown in figure Q4 below. A recently recruited Industrial Engineer graduate wants to introduce Adaptive Control in their manufacturing control system. The Industrial Engineer has argued that Adaptive control can be used to compensate for disturbances, and it can make the machining process self-correcting since it operates in a time-varying environment. Discuss with the aid of well labelled diagram the three functions found in Adaptive Control systems. State at least three sensors associated with this setup.

[15 marks]

QUESTION 5

A consortium of young entrepreneurs who studied Industrial Engineering at the University of Johannesburg, Doornfontein Campus, are in the process of designing a new product line. They are planning to build the new manufacturing plant for this product line in Midrand and they have secured adequate financial help from a local financial institution. The new line will consist of 80 different product types, and for each product type their company wants to produce 12 000 units annually. The products average 1000 components each, and the average number of processing steps required for each component is 12. All parts will be made in their Midrand factory. Each processing step will take an average of 1.5 minutes.

Determine:

a) how many products will be made in this factory? (2 marks)
b) how many parts will be made in this factory? (2 marks)
c) how many production operations will be required each year? and (2 marks)
d) how many workers will be needed in the plant, if each worker works 8 hours per shift for 250 days per year (2000 hr/yr) (4 marks)

[Total Marks 10]

QUESTION 6

A graduate Industrial Engineer working at an automotive company in Rosslyn, Pretoria is planning to automate the opening and closing of electric windows using a DC servomotor that has a torque constant of 0.085 N-m/A and a voltage constant of 0.15 V/(rad/sec). The armature resistance is 3.0 Ω. A terminal voltage of 26 V is used to operate the motor.

Determine:

a) the starting torque generated by the motor just as the voltage is applied, (2 marks)
b) the maximum speed at a torque of zero, and (3 marks)
c) the operating point of the motor when it is connected to a load whose torque characteristic is proportional to speed with a constant proportionality = 0.0175 N-m/(rad/sec). (5 marks)

[Total Marks 10]

QUESTION 7

The outline of the part in Figure Q7, is to be profile milled using a 20 mm diameter end mill with two teeth. The part is 10 mm thick. Spindle speed is 1500 rev/ min and feed is 0.50 mm per tooth. Use the lower left corner, point A, where X-10 Y0, as the origin in the x-y axis system. Milling is to be done from point A in clockwise direction. Use D08 as your cutter offset register code.

Write the part program in the word address format (G-Code programming). Use absolute positioning. **(15 marks)**

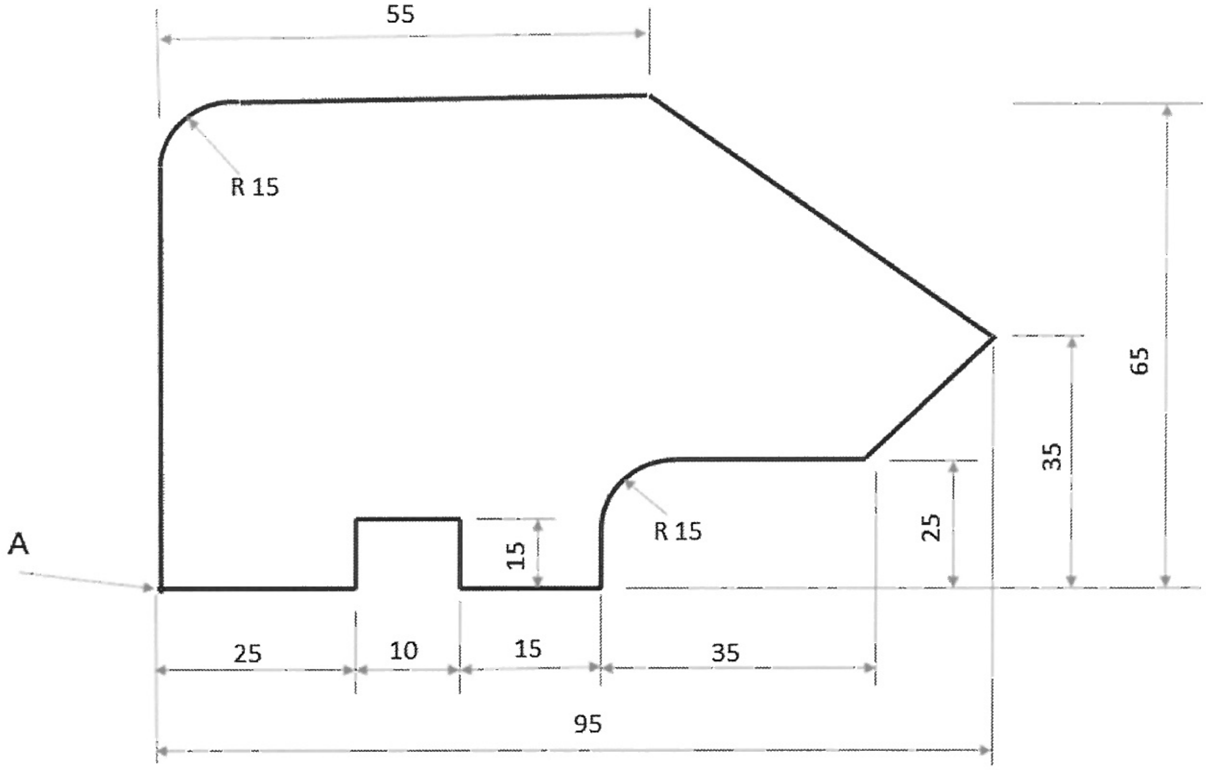

Figure Q7 **Diagram Not To Scale,** **All Dimensions are in mm**

QUESTION 8

DGG Electric is a company that specializes in the design and manufacturing of CNC positioning systems. In one of their designs, one axis of the worktable is driven by a ball screw with a 5.0 mm pitch. The screw is powered by a stepper motor which has 300 step angles using a 5:1 gear reduction (five turns of the motor for each turn of the ball screw). The worktable is programmed to move a distance of 600 mm from its present position at a travel speed of 1000 mm/min.

Determine:

a) how many pulses are required to move the table the specified distance? (4 marks)
b) what is the required motor rotational speed? and (3 marks)
c) what is the pulse rate required to achieve the desired table speed? (3 marks)

[Total marks 10]

TOTAL = 100

FORMULAE SHEET

Production Relationship

$Q_f = \sum_{j=1}^{P} Q_j$ $\quad Q_f = PQ$

$P = \sum_{j=1}^{P_1} P_{2j}$

$n_{pf} = \sum_{j=1}^{P} Q_j n_{pj}$ $\quad n_{pf} = PQn_p$

$n_{of} = \sum_{j=1}^{P} Q_j n_{pj} \sum_{j=1}^{n_{Pj}} Q_j n_{ojk}$

$n_{of} = PQn_pn_o$

$S = C + ms \quad T = K_tI_a \quad E_b = K_v + \omega$

Automation and Process Control

$N = \frac{60\omega}{2\pi}$ $\quad I_a = \frac{Vin}{R_a} = \frac{V_{in}-Eb}{R_a}$ $\quad T = I_a K_t$

$T = K_t(\frac{V_{in}-Kv\omega}{R_a})$ $\quad T_L = K_L\omega$

$HP = \frac{T\omega}{745{,}7}$ $\quad P = T\omega$

$745{,}7 = 1hp$ $\quad \alpha = \frac{360}{n_s}$

$A_m = n_p\alpha$ $\quad \omega = \frac{2\pi fp}{n_s}$

$N = \frac{60fp}{n_s}$ $\quad v = \frac{Q}{A}$

$F = pA \quad \omega = KQ \quad N_q = 2^n$

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

$\text{Quantization error} = \pm\frac{1}{2}R_{ADC}$

$E_o = E_{ref}\{0{,}5B_1+0{,}25B_2+0{,}125B_3+....+(2^n)^{-1}B_n\}$

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

Production Performance Metrics

$T_c = T_o+T_h+T_t$ $\quad T_c = \text{Max } T_o + T_r$

$T_b = T_{su}+QT_C$ $\quad A = \frac{MTBF - MTTR}{MTBF}$

$T_p = \frac{T_b}{Q}$ $\quad PC = \frac{nHpwRp}{n_o}$

$R_p = \frac{60}{T_p} = \frac{1}{T_p}$ $\quad PC = Hpc\sum_{i=1}^{n} R_{pi}$

$R_c = \frac{60}{Tc} = \frac{1}{Tc}$ $\quad R_{pph} = \frac{\sum_{j=1}^{n}\sum_j f_{ij}R_{pij}}{n_{oj}}$

$R_{ppw} = H_{pw}R_{pph}$ $\quad U_i = \sum_j f_{ij}$ $\quad U = \frac{\sum_j Ui}{n}$

$WL = \sum_i\sum_j Q_{ij}T_{pij}$ $\quad MLT = n_o(T_{su}+Q_{Tc}+T_{no})$

$MLT = n_o(\max T_o + T_r) + T_{no}$ $\quad TC = C_f + C_vQ$

$WIP = R_{pph}(MLT)$ $\quad UAC = IC(A/P,i,N))$

$FOHR = \frac{FOHC}{DLC}$ $\quad COHR = \frac{COHC}{DLC}$

$C_o = C_L(1+FOHR_L) + C_m(1+FOHR_m)$

$C_{pc} = C_m + \sum_{j=1}^{P}(CoiTpi + Cti)$

$(A/,P,i,N) = \frac{i(1+i)^n}{(1+i)^n-1}$

Open Loop System

$N = \frac{v}{\pi D}$ $f_r = N n_t f$ $\alpha = \frac{360}{n_s}$ $A_m = n_p \alpha$ $A_s = \frac{n_p \alpha}{r_g} = \frac{A_m}{r_g}$ $r_g = \frac{A_m}{A_s} = \frac{N_m}{N_s}$

$x = \frac{pA_s}{360}$ $n_p = \frac{360 x r g}{p\alpha} = \frac{n_s x r_a}{p}$ $N_s = \frac{60fp}{n_s r_g}$ $v_t = fr = N_s p$

$f_p = \frac{vt n_s r_a}{60p} = \frac{fr n_s r_a}{60p} = \frac{N_m n_s}{60} = \frac{N_s n_s r_a}{60}$

Closed Loop System $\alpha = \frac{360}{n_s}$ $n_p = \frac{A_s}{\alpha} = \frac{A_s n_s}{360}$ $\Delta X = \frac{pnp}{n_s} = \frac{pAs}{n_s \alpha} = \frac{pAs}{360}$

$v_t = fr = N_s p = \frac{N_m p}{r_g}$ $f_p = \frac{vtn_s}{60p} = \frac{fr n_s}{60p}$ $CR_1 = \frac{p}{n_s r_g}$ $CR_2 = \frac{L}{2^B - 1}$

$CR = Max(CR_1, CR_2)$ $Accuracy = \frac{CR}{2} + 3\alpha$ $Repeatability = \pm 3\alpha$

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 the 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 cutters radius (nose radius in turning).
G41	Cutter offset compensation, left of part surface. Cutter radius (nose radius in turning) must be pecified in block
G42	Cutter offset compensation, right of part surface. Cutter radius (nose radius in turning) must be pecified 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 rate per minute in milling and drilling.
G95	Specify feed rate per revolution in milling and drilling.
G98	Specify feed rate per minute in turning.
G99	Specify feed rate per revolution in turning.

Common M-words Used in Word Address Format	
M-word	Function
M00	Program stop; used in the middle of program. Operator must restart machine.
M01	Optional program stop; active only when optional stop button on control panel has been
M02	End of program. Machine stop.
M03	Start spindle in clockwise direction for milling machine (reverse 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 the 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 (reverse 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 degits 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
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 efines 90^0 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 tox-,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 the table A7.2. (Example specifies feed rate = 40mm/min in milling or drilling operation).