The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	:	Bachelor of Technology Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title	**:**	**MEX6273 Advanced Control Engineering**
Academic Year	:	2015/2016
Date	:	05th of December 2016
Time	:	9.30am – 12.30 pm
Duration	:	3 hours

General instructions

Read all instructions carefully before answering the questions.

1. This question paper consists of **Eight** questions and answer to **Five** questions as described below.
2. Section A is a compulsory question.
3. Section B has three questions. Answer any two questions from section B.
4. Section C has four questions. Answer any two questions from section C.
5. Each question carry 20 marks

Section A

Q1

Consider the fuzzy controller design of an automated floor cleaner to automate the ***Speed of the vacuum motor.*** The fuzzy logic system need to process the two inputs for the system that are ***Dirt(D)*** and ***Grease(M)*** of the floor. A fuzzy logic control system will process these, giving a single output, ***Speed of the vacuum motor(P).***

The following fuzzy quantities are defined, with the corresponding states:

D: ***Dirt*** (**SD**: Small Dirt, **MD**: Medium Dirt, **LD**: Large Dirt)

G : ***Grease*** (**NG**: No Grease, **MG**: Medium Grease, **LG**: Large Grease)

P: ***Speed of the vacuum motor*** (**VS**: Very Small, **S**: Small, **M**: Medium, **L**: Large, **VL**: Very Large)

The membership functions of ***Dirt***, ***Grease, Speed of the vacuum motor*** are given in Figure Q1.a, Figure Q1.b and Figure Q1.c respectively.

The rule base for the above case is given in Table Q1.

	Grease	*NG*	*MG*	*LG*
	SD	**VS**	**M**	**L**
Dirt	*MD*	**S**	**M**	**L**
	LD	**M**	**L**	**VL**

Table Q1

At a given instant, the following set of sensor data is available:

- **Dirt – 70**
- **Grease – 75**

a) Determine the corresponding inference membership function for the ***Speed of the vacuum motor*** (10 marks)
b) Determine the crisp value for the control action(7 marks)
c) Clearly label the ***Aggregation*** of this inference process(3 marks)

Use following techniques as applicable

- Min – Max inference method
- Centroid method

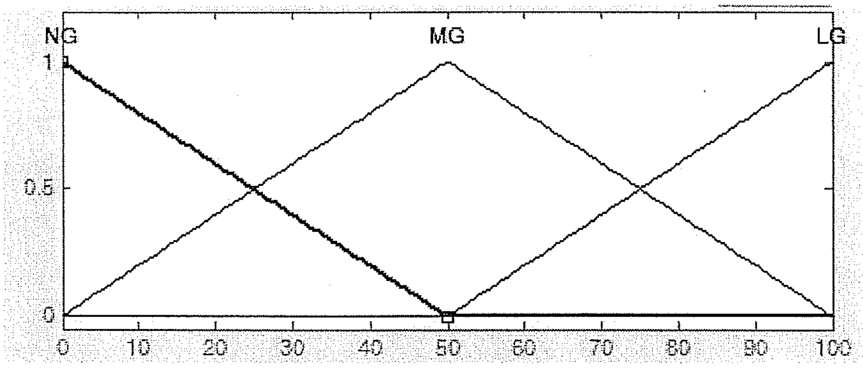

Figure Q1a

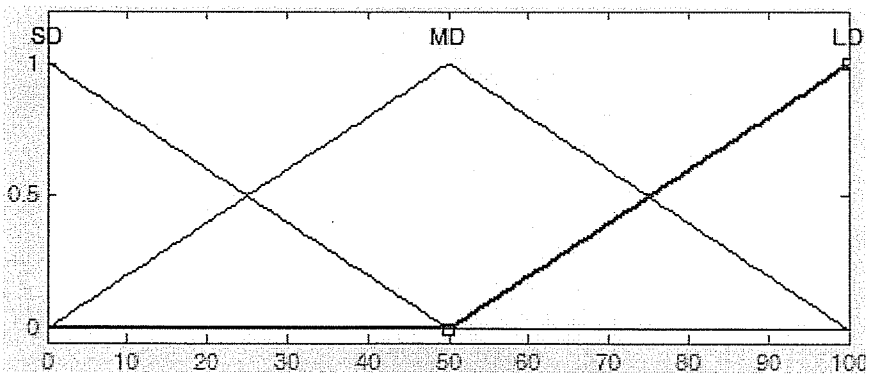

Figure Q1b

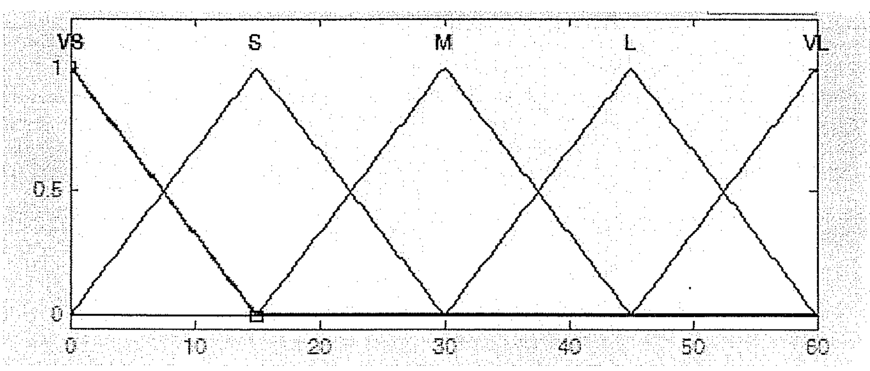

Figure Q1c

Section B

Q2.

a) Let U = {a , b , c , d , e} be the domain and X and Y be fuzzy sets on U as given below. (9 marks)

	a	b	c	d	e
X	0.5	0.0	0.7	0.7	0.2
Y	0.5	0.3	0.9	0.2	0.9

Table Q2

Find the following clearly mentioning all required steps

i. $X \cap Y$
ii. $X \cup Y$
iii. X^1

b) Name two compositions available on any two fuzzy relations. Relate them with fuzzy rules (4 marks)

c) Consider the Ternary Fuzzy Relation T on $U \times V \times W$ which is given by

$$T = \frac{0.2}{(a,x,\&)} + \frac{0.8}{(b,x,\&)} + \frac{1}{(a,y,\&)} + \frac{0.1}{(a,y,*)} + \frac{0.2}{(b,y,*)}$$

Where U= {a,b}, V={x,y} and W={&,*}. (7 marks)

i. Find T_{12} and T_3 clearly mentioning all steps
ii. How many *1- dimensional projections* of T are available, generally on any Ternary Fuzzy Relation?

Q3.

Consider the simple Artificial Neural Network(ANN) given below.

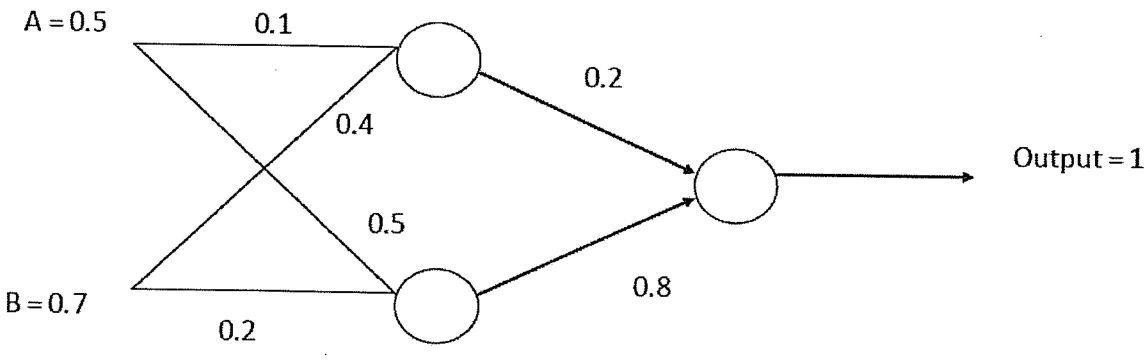

Figure Q3

Assume that the neurons have a Unipolar Continuous Activation function and that λ= 1 and η =1. Use Backpropagation method to find the old and new errors of the trained network. You may use the standard error finding method to find the error. A and B are the two inputs for this ANN. [Error = Output(1-Output)(Target-Output)]
(20 marks)

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Q4.

a) Draw the complete architecture of a Fuzzy logic controller. Name all parts of it and using suitable examples, explain their functionalities. (10 marks)

b) What are the capabilities of Artificial Neural Networks (ANN) ? Briefly discuss them(5 marks)

c) Figure Q4 shows a confusion matrix plot that is plotted after training of an ANN (Artificial Neural Network) using MATLAB software. Answer the following questions considering Figure Q4.
   i. How many samples are considered for the training of the ANN and how many samples for the testing of the ANN?(2 marks)
   ii. How many target classes are available in this ANN?(1 mark)
   iii. What is the overall accuracy percentage of the trained ANN?(2 marks)

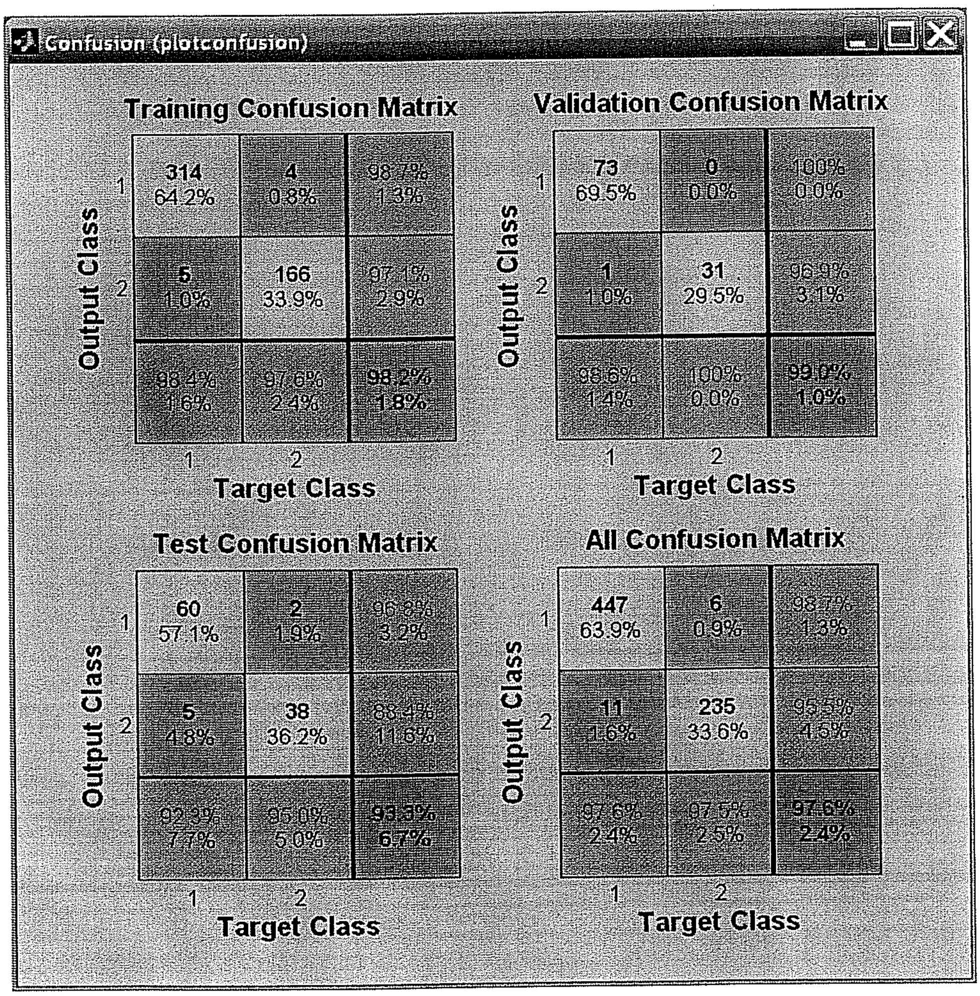

Figure Q4

Section C

Q5

a) Find the state space representation in phase-variable form for the following transfer function

$$\frac{C(s)}{R(s)} = \frac{5(s+1)}{s^2+5s+6}$$ (8 marks)

b) Predict the controllability and observability for the system

$$\dot{x}(t) = Ax(t) + Bu(t)$$
$$y(t) = Cx(t)$$

Where $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & 6 \end{bmatrix}$ $B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$ and $C = \begin{bmatrix} 4 & 5 & 1 \end{bmatrix}$ (12 marks)

Q6.

a) Describe *minimum order state observer*. (4 marks)
b) Consider the system

$$\dot{x}(t) = Ax(t) + Bu(t)$$
$$y(t) = Cx(t)$$

$$A = \begin{bmatrix} 0 & 1 \\ -11 & -6 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \text{ and } C = \begin{bmatrix} 1 & 0 \end{bmatrix}$$

Design a full order state observer

i. Using Ackermann's formula(8 marks)

ii. Using direct substitution approach or any other method(8 marks)

Consider the desired eigen-values for the full order observer as $\mu_1 = -2 + j2\sqrt{3}$ and $\mu_2 = -2 - j2\sqrt{3}$.

Q7

a) Discuss the stability of a digital control system by relating to the pole locations on z plane. Use figures to explain your answer.(6 marks)
b) State one advantage and one disadvantage of state-space modeling. (2 marks)
c) Discuss the necessary and sufficient condition for arbitrary pole placement.(2 marks)
d) Obtain the state-transition matrix $\Phi(t)$ of the system described below.(10 marks)

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

Q8

a) What do you understand by a Digital Control System?(4 marks)

b) The characteristic equation of a closed loop discrete time system is given by $z^2 + (0.158K-1.368)z + 0.368 = 0$. Find the value of K, for the system to be stable. (6 marks)

c) Obtain the pulse transfer function of the system shown in Figure Q8 where $G_p(s) = \frac{1}{s^2(s+1)}$.(10 marks)

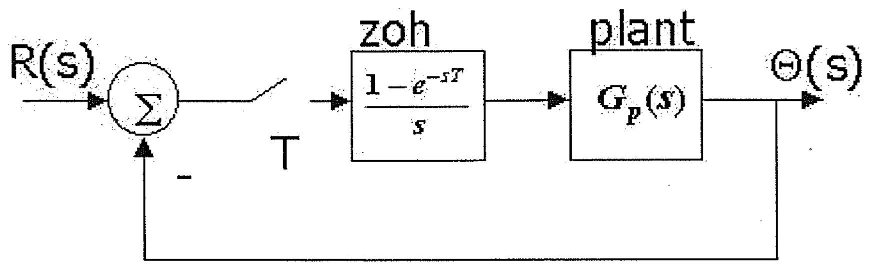

Figure Q8

NOTE:-

Laplace transform	Corresponding z-transform
$\frac{1}{s}$	$\frac{z}{z-1}$
$\frac{1}{s^2}$	$\frac{Tz}{(z-1)^2}$
$\frac{1}{s^3}$	$\frac{T^2 z(z+1)}{2(z-1)^3}$
$\frac{1}{s+a}$	$\frac{z}{z-e^{-aT}}$
$\frac{1}{(s+a)^2}$	$\frac{Tze^{-aT}}{(z-e^{-aT})^2}$
$\frac{a}{s(s+a)}$	$\frac{z(1-e^{-aT})}{(z-1)(z-e^{-aT})}$
$\frac{b-a}{(s+a)(s+b)}$	$\frac{z(e^{-aT}-e^{-bT})}{(z-e^{-aT})(z-e^{-bT})}$
$\frac{(b-a)s}{(s+a)(s+b)}$	$\frac{(b-a)z^2-(be^{-aT}-ae^{-bT})z}{(z-e^{-aT})(z-e^{-bT})}$
$\frac{a}{s^2+a^2}$	$\frac{z \sin aT}{z^2-2z\cos aT+1}$
$\frac{s}{s^2+a^2}$	$\frac{z^2-z\cos aT}{z^2-2z\cos aT+1}$
$\frac{s}{(s+a)^2}$	$\frac{z[z-e^{-aT}(1+aT)]}{(z-e^{-aT})^2}$

Laplace transforms:

TIME FUNCTION $f(t)$	LAPLACE TRANSFORM $F(s)$
Unit Impulse $\delta(t)$	1
Unit step	$\frac{1}{s}$
t	$\frac{1}{s^2}$
t^n	$\frac{n!}{s^{n+1}}$
$\frac{df(t)}{dt}$	$sF(s)-f(0)$
$\frac{d^n f(t)}{dt^n}$	$s^n F(s) - s^{n-1} f(0) - s^{n-2}\frac{df(0)}{dt} \ldots - \frac{d^{n-1} f(0)}{dt^{n-1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at} \cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$

END