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	:	2014/2015
Date	:	06th of September 2015
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.

Section A

Q1 (20 marks)

Consider the following Room Comfort system controlled by a Fuzzy controller.The following fuzzy quantities and corresponding states were considered while designing the controller.

Temp: Temperature (Cold, Cool, Normal, Warm, Hot)

RH: Relative Humidity (Low, Medium, High)

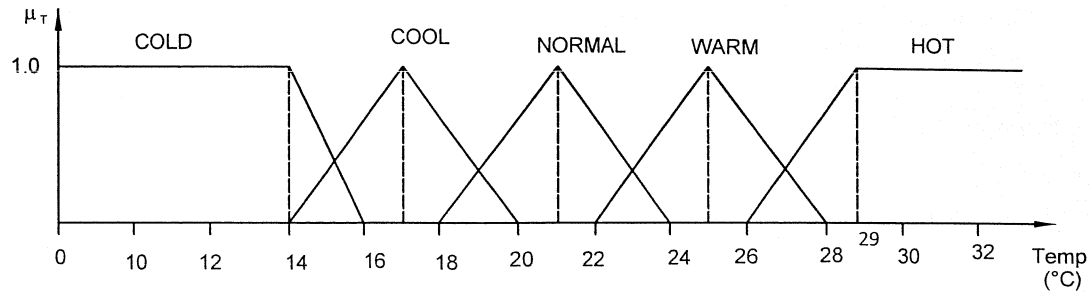
FS: Fan Speed (Low, Medium, High)

The relationship between two inputs Temperature and Relative Humidity, and output Fan Speed is as follows.

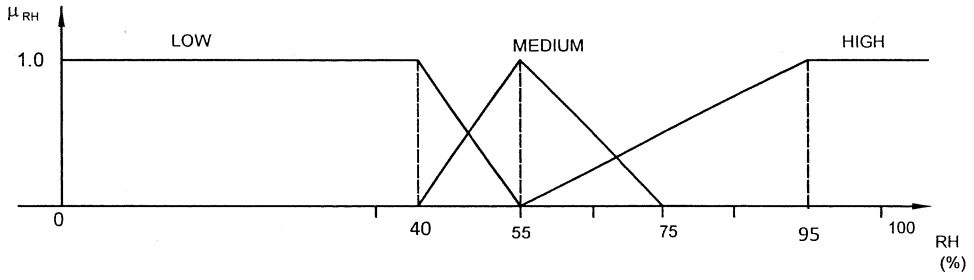
Relative Humidity	**Temperature**				
	COLD	**COOL**	**NORMAL**	**WARM**	**HOT**
LOW	LOW	LOW	LOW	LOW	LOW
MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH
HIGH	HIGH	HIGH	HIGH	HIGH	HIGH

Temperature, **Relative Humidity** and **Fan Speed** have the following membership functions.

Temperature (^{0}C)



Relative Humidity (%)



Fan Speed (rpm)

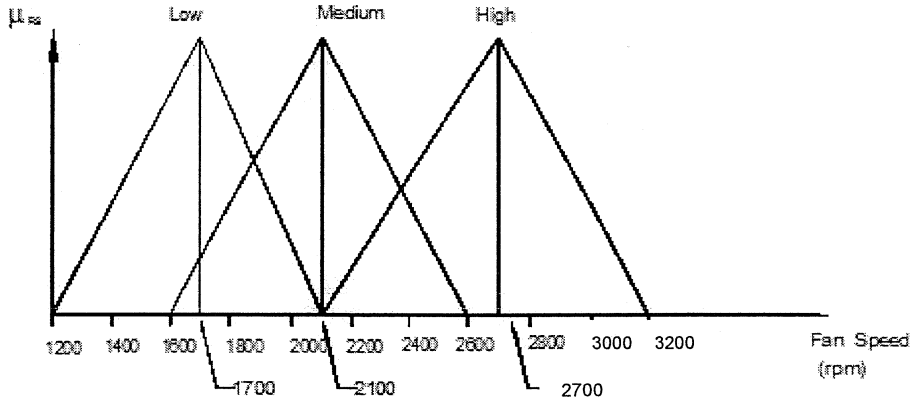


Figure Q1

The crisp measurements of the process at a given instance are

Temperature – 27^0 C

Relative Humidity – 65%

a) Determine the corresponding inference membership function for the **Fan speed.**
NOTE :- Use Graph sheets to prepare your answer

b) Determine the crisp value for the control action.

Use the following techniques as applicable.

- Min – Max inference method
- Centroid method

Section B

Q2. (20 marks)

a) Two fuzzy sets A and B are represented by their membership functions, as shown in Figure Q2.a. Sketch the membership functions of the following fuzzy sets considering fuzzy sets A and B

i. A∪B
ii. A∩B
iii. NOT A

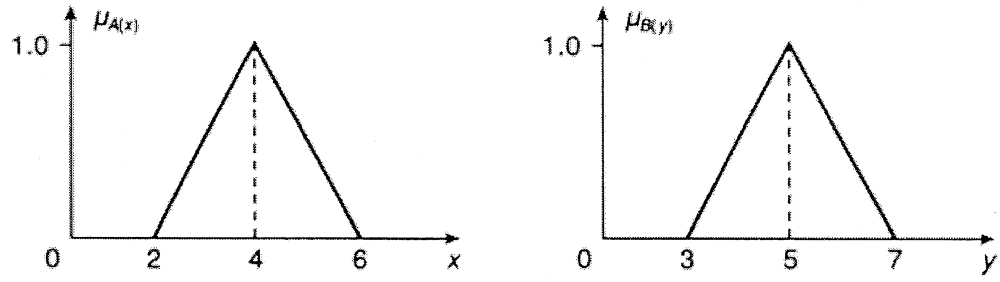


Figure Q2.a

b) Consider two fuzzy subsets of the set U, U = {a , b , c , d , e} referred to as A and B where

$A = \left\{\frac{1}{a}, \frac{0.3}{b}, \frac{0.2}{c}, \frac{0.8}{d}, \frac{0}{e}\right\}$ and $B = \left\{\frac{0.6}{a}, \frac{0.9}{b}, \frac{0.1}{c}, \frac{0.3}{d}, \frac{0.2}{e}\right\}$

Find

i. Support of A and Support of B
ii. Core of A and Core of B
iii. Cardinality of A
iv. If $a = 0.4$ then aA

c) What is the support and 0.5-cut for the fuzzy set shown in Figure Q2.c? Is this a normal fuzzy set? Give reasons to your answers.

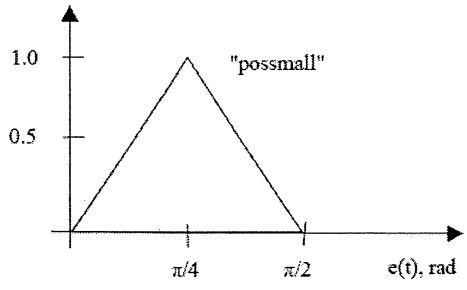


Figure Q2.c

d) Draw the block diagram of a classical PID controller and derive an equation for the incremental control output Δu(k) . Is Δu(k) a fuzzy set , if FLC (fuzzy logic controllers) used ?

Q3. (20 marks)

a) Determine the fuzzy relation between the following two fuzzy sets A1 and A2.

$$A1 = \frac{0.2}{x_1} + \frac{0.7}{x_2} \; ; \quad A2 = \frac{0.1}{y_1} + \frac{0.4}{y_2} + \frac{1}{y_3}$$

b) Let R be a BFR (Binary Fuzzy Relation) on $U \times V$ and S be a BFR on $V \times W$, where U= {a,b}, V={x,y} and W={&,*}.

$$R = \begin{bmatrix} 0.6 & 0.4 \\ 1.0 & 0.9 \end{bmatrix} \qquad S = \begin{bmatrix} 0.7 & 0.9 \\ 0.5 & 0.4 \end{bmatrix}$$

i. Write the formula to find the max-min composition of two fuzzy relations.
ii. Find the max-min composition of the given two fuzzy relations.
iii. Is SoR equal to RoS? Prove your answer.

c) Consider the ternary fuzzy relation T on $U \times V \times W$ is given by

$$T = \frac{0.6}{(a,x,\&)} + \frac{0.2}{(b,x,\&)} + \frac{1}{(a,y,\&)} + \frac{0.9}{(a,y,*)} + \frac{0.2}{(b,y,*)}$$

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

i. Find T_1 , T_2 and T_3
ii. Find T_{12},T_{23}

Q4. (20 marks)

a) State three characteristics of Intelligence. Briefly discuss whether these characteristics are exhibited in 'Artificial Neural Networks' and 'Fuzzy' systems

b) Using suitable examples describe Fuzzification and Defuzzification

c) Construct an architectural graph for the following artificial neural network (ANN)
Fully connected feed forward (acyclic) network has 4 source nodes, 2 hidden layers, one with 5 neurons and the other with 2 neurons and a single output neuron.

d) List two applications each of the following Artificial Intelligence tools
i. Expert systems
ii. Genetic Algorithms

e) Write down the major steps in Back Propagation Algorithm to train a multilayer ANN in supervised manner.

f) The "glass data set" is a famous dataset that has been used in pattern recognition. A neural network can be built to predict the type of the glass (window glass or non-window glass) based on the measurements of the chemical content.

The data set consists of 214 samples.

Attribute information:

Refractive index
Sodium
Magnesium
Aluminum
Silicon
Potassium
Calcium
Barium
Iron

State the following with **reasons** for the neural network that you propose for the glass classification.

i. Number of input nodes
ii. Number of hidden layers
iii. Number of output nodes

Section C

Q5 (20 marks)

a) Describe controllability and observability.

b) Consider the system represented by the equation

$$\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ -10 & -7 \end{bmatrix} x(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t)$$

$$y(t) = [1 \quad 0]x(t)$$

Find the transfer function of the system.

c) Check for the controllability of the system.

Q6. (20 marks)

a) Outline the Laplace transform method of determining the state transition matrix that is required in the solution of the state equation.

b) Develop the state equation and the output equation of the circuit shown in following Figure Q6.

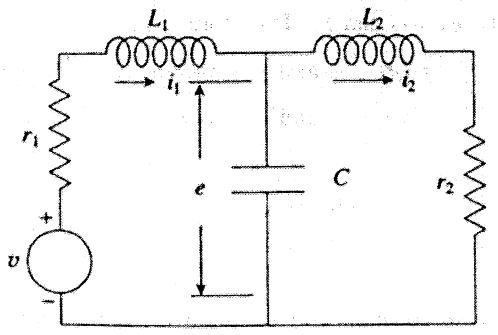


Figure Q6

Q7 (20 marks)

a) Briefly describe Lyapunov's method for the determination of the stability of non-linear systems.

b) If $\frac{dx_1}{dt} = ax_1 + bx_2$ and $\frac{dx_2}{dt} = cx_1 + dx_2$, Determine the sufficient conditions on a, b, c and d so that the asymptotically stable condition can be achieved. Choose $W = x_1^2 + x_2^2$ to apply the Lyapunov's theory.

Q8 (20 marks)

a) Define the stability of discrete control systems and explain the Jury's test of stability.

b) Find the output voltage in discrete form of the RC circuit in the following Figure Q8 when the input voltage is applied as follows.

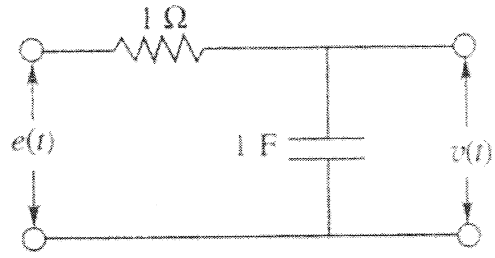


Figure Q8

$e(t) = e(nT)$ where $nT \leq t \leq (n+1)T$ and $T = 1\ s$

END