The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	:	Bachelor of Science Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title	:	**DMX7306 Intelligent Control Systems**
Academic Year	:	2024/2025
Date	:	7th March 2026
Time	:	13.30-16.30
Duration	:	**3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Five (5)** questions in **Four (4)** pages.
3. Answer for each question should commence from a new page.
4. This is a Closed Book Test (CBT).
5. Answers should be in clear handwriting.
6. Answer to all questions.

Question 01

a) Compare the three-level intelligent control architecture with a single-layer traditional feedback control system. [5]

b) For a highly nonlinear system with uncertain parameters, which hybrid approach would you recommend? Justify your answer. [5]

c) Briefly explain the difference between Model Predictive Control (MPC) and Model Reference Control (MRC). [5]

d) What are the challenges involved in designing and implementing intelligent control systems in complex environments? [5]

Question 02

a) Why is the **Black Box** method often associated with data-driven modeling, while the **White Box** method is linked with physics-based modeling? Explain with an example. [4]

b) A model is given as: $Y_i = ae^{bx_i}$

1. Transform the model into a linear form
2. Derive the **normal equations** to estimate the unknown parameters

[6]

c) State the components of the typical cost function used in Model Predictive Control (MPC). [4]

d) A system is described by the discrete-time state-space model:

$$x(k+1) = 0.8x(k) + u(k), \qquad y(k) = x(k)$$

If the current state is $x(0) = 1$, predict the outputs for the next 3 steps, assuming $u(k) = 0$ for all k. [6]

Question 03

a) Explain the architecture of PD-Like Fuzzy logic controller. [4]

b) Two rules fire simultaneously:

- IF Pressure is High THEN Valve = Close (Output = 10) with firing strength 0.7
- IF Pressure is Medium THEN Valve = Open (Output = 70) with firing strength 0.5

1. Compute the final crisp output using the weighted average method.
2. Explain how fuzzy logic handles this apparent conflict.

[6]

c) At a certain operating condition, the error is Positive with full membership:

$$\mu P(E) = 1$$

The controller uses the following Sugeno-type rule base:

Rule	Condition	Output
R1	IF (E) is Positive AND (ΔE) is Zero	20
R2	IF (E) is Positive AND (ΔE) is Positive	5

Two different operating cases occur:

Case 1: Small rate of change of error

$$\mu_Z(\Delta E) = 0.8,\ \mu_P(\Delta E) = 0.2$$

Case 2: Large rate of change of error

$$\mu_Z(\Delta E) = 0.1,\ \mu_P(\Delta E) = 0.9$$

Assume **MIN inference** and **weighted average defuzzification**.

1. For each case, compute the **firing strength of each rule**
2. Determine the **crisp control output** for both cases
3. Compare the two outputs and explain how the fuzzy controller modifies its action when the rate of change of error increases
4. Briefly explain why this behavior helps reduce the effect of measurement noise compared to a classical derivative controller

[10]

Question 04

a) What is meant by ANFIS (Adaptive Neuro-Fuzzy Inference System)? Explain how it performs both fuzzy inference and parameter learning.

[4]

b) For a training sample:

- Desired output = 10
- Actual neuro-fuzzy output = 8

Error function:

$$E = \frac{1}{2}(y_d - y)^2$$

1. Compute the error
2. If output depends on a parameter $\boldsymbol{p}$ as $\boldsymbol{y = p \cdot w}$, where $\boldsymbol{w = 0.5}$, find $\frac{\partial E}{\partial p}$
3. If the **learning rate = 0.1**, compute the updated $\boldsymbol{p}$.

[6]

c) A neural network with one hidden layer is used for function approximation. The hidden and output neurons both use sigmoid activation.

Derive the general backpropagation update rule for:

1. Any weight between the hidden and output layers
2. Any weight between the input and hidden layers

Clearly show how the error term propagates backward through the network.

[10]

Question 05

A schematic diagram of a temperature control system for an industrial heating chamber is shown in Figure Q5.

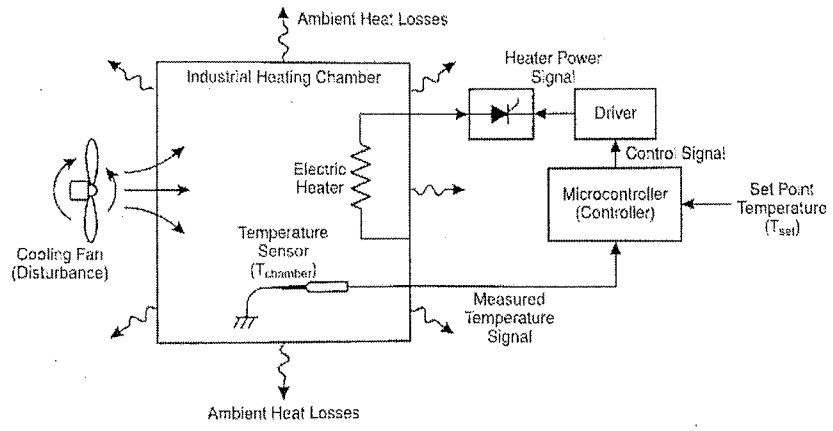

Figure Q5

a) Select a suitable temperature control method and develop a closed-loop control system block diagram for the heating chamber system.

[5]

b) Design a PD-like Fuzzy Logic Controller to regulate the heater power based on the temperature sensor reading. [9]

Note:

- *You can select appropriate ranges for input and output fuzzy sets.*
- *Clearly indicate any assumptions*

c) Develop a Neuro-Fuzzy architecture based on the above PD-Like Fuzzy controller.

[6]

END