PRIFYSGOL ABERYSTWYTH UNIVERSITY

SEMESTER TWO 2026

COMPUTER SCIENCE

CSM6520 : COMPUTATIONAL INTELLIGENCE

Time allowed: **2 HOURS**

Answer **BOTH** questions.

All questions carry equal marks.

YOU MAY BRING THE FOLLOWING INTO THE EXAMINATION:
UP TO 3 SHEETS OF NOTES ON A4 PAPER (WHICH MAY BE DOUBLE-SIDED). THERE ARE NO ADDITIONAL RESTRICTIONS ON CONTENT OR FORMATTING OF THESE NOTES.
NO ELECTRONIC DEVICES.

CALCULATORS ARE NOT PERMITTED.

STUDENTS MAY SUBMIT ANSWERS TO THIS PAPER IN EITHER WELSH OR ENGLISH

Once seated, students may complete the front cover of the answer book(s) and the attendance slip ONLY.

DO NOT TURN THE EXAMINATION QUESTION PAPER OVER UNTIL INSTRUCTED TO DO SO.

1. This question is about FUZZY SYSTEMS.

a) Understanding Fuzzy Systems

(i) Discuss the concept of a *Fuzzy Membership Function* via its three characteristic regions: the *Core*, *Support*, and *Boundary*. Using these regions, explain how fuzzy set modelling is different from that of classical crisp sets. [4 marks]

(ii) Explain the difference between a 'Crisp Set' and a 'Fuzzy Set' in relation to the *Law-of-the-Excluded-Middle*. Describe in a few sentences how violating this law allows Fuzzy Systems to capture detail that crisp modelling cannot. [5 marks]

(iii) Some characteristics of Fuzzy membership functions e.g. relating to the *number of subsets* and the *types of functions* used have direct and far-ranging implications for the performance of any given Fuzzy System. Discuss these two characteristics briefly. [6 marks]

(iv) The following definitions represent Type-2 Fuzzy Sets:

$$\tilde{A} = \{((x,u),1) \mid x \in U,\ u \in J_x,\ J_x \in [0,1]\}$$

$$\tilde{A} = \{((x,u),\mu_{\tilde{A}}(x,u)) \mid x \in U,\ u \in J_x,\ J_x \in [0,1]\}$$

Which particular versions of Type-2 Fuzzy Set do each of these definitions represent and why? Briefly explain <u>one</u> shortcoming of each, making explicit reference to the definitions themselves. [9 marks]

b) Zadeh characterised Fuzzy Systems as 'Computing-with-Words' (CWW). Describe the theoretical foundation of this concept and different stages required to implement a CWW approach (along with a diagram), highlighting the transition from linguistic input to crisp output and identify one unique characteristic that distinguishes Fuzzy Systems from other Computational Intelligence (CI) paradigms. [10 marks]

c) Consider the following data intended for the design of a fuzzy classification system used in automated aircraft maintenance.
The table below (Table 1) summarizes data gathered from a sample of 100 structural engineers regarding the classification of fatigue crack lengths (L)

detected in a titanium aircraft wing spars. The engineers were asked to categorize specific intervals based on risk level, specifically: “If a crack is measured at length L, is it considered ‘Negligible’, ‘Monitor’, ‘Critical’, or ‘Failure Imminent’?” The number of engineers who agreed with each classification for a given interval is recorded in the table.

Crack Int. (mm)	Negligible	Monitor	Critical	Failure Imminent
0-10	95	4	0	0
10-20	5	80	5	0
20-30	0	15	75	4
30-40	0	1	18	12
40-50	0	0	2	84

Table 1: Expert Agreement on Crack Severity Levels

(i) Using the similarity relation shown below, derive an appropriate table-based representation for the concept *critical* and explain its purpose.

$$\mu R_a(x, y) = 1 - \frac{|a(x) - a(y)|}{|a_{max} - a_{min}|} \tag{1}$$

Draw the completed representation as well as the important elements and describe how this can be used to represent that concept. [10 marks]

(ii) Having designed a fuzzy inference system using the approach in i), you discover that the rules in your rule-base are inadequate and do not cover all of the input space - i.e. no rules are fired when performing the inference step. Describe a suitable approach to tackle this problem and thus be able to derive a conclusion. Include a diagram to demonstrate how such an approach might work. [6 marks]

2. This question is about ARTIFICIAL NEURAL NETWORKS.

a) Describe a feasible data processing pipeline for training a Neural Network (NN) for pneumonia classification from chest X-ray images. Discuss the required amount of data and the steps involved in preparing the training and test datasets, including any pre-processing strategies. Specify any assumptions you make. [15 marks]

b) Describe a plausible deep NN architecture that you would implement for this pneumonia classification task, based on the dataset size you proposed in part (a). Discuss the network architecture (input, hidden, and output layers), weight initialisation, activation functions, hyperparameters, and learning strategies. Also, elaborate on how you can evaluate the model's performance, considering the clinical context of the application. [25 marks]

c) Assume that, after the system in part b) is successfully deployed in the hospital, clinicians observe that the model often misclassifies Bacterial Pneumonia as Viral Pneumonia and vice versa, while it continues to identify Normal X-rays with high accuracy. Discuss the possible reasons for this confusion, considering the nature of the data, the network architecture, and the training process. Propose two concrete modifications that could reduce this confusion. [10 marks]

END OF PAPER