CS331 Short-Answer Questions

(Submission Format: A single PDF file via Tabula)

1. a) Consider the following logic function f with three inputs (x_1, x_2, x_3):

$$f(x_1, x_2, x_3) = (x_1 \text{ NIMPLY } x_2) \text{ NIMPLY } x_3$$

where the NIMPLY gate is a binary function with a two-input truth table below:

A	B	A NIMPLY B
0	0	0
0	1	0
1	0	1
1	1	0

Determine the possibility of emulating the function f using a single-layer McCulloch-Pitts neuron. If possible, explain the reasoning and draw the Rojas diagram. If not, provide the mathematical proof for clarification.

(12 marks)

b) Draw a diagram of the structure of a biological neuron and label the four basic parts of the neuron in the diagram (6 marks). Describe the two main factors that influence the speed of signal transmission along the axon and explain your reasons (6 marks).

(Total: 12 marks)

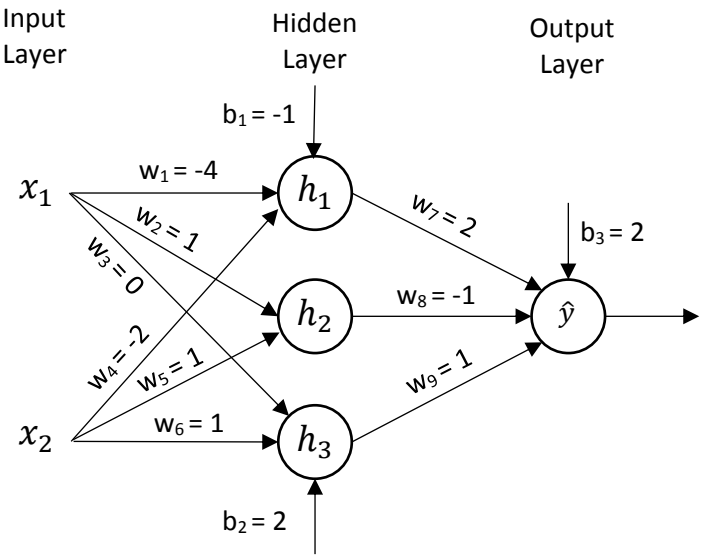
c) Consider the following logic function $f: \{0,1\}^3 \to \{0,1\}$ defined by

$$f(x_1, x_2, x_3) = \begin{cases} 1, & \text{if } (x_1,\ x_2,\ x_3) = (1,\ 1,\ 1) \\ 0, & \text{otherwise} \end{cases}$$

Determine if f can be emulated by a single-layer perceptron. (1 mark). If YES, give your reasons and draw the diagram of this perceptron. If NO, prove your results. (8 marks)

(Total: 9 marks)

2. Consider the following two-layer neural network with two inputs: $x_1 = 1,\ x_2 = -2$. The network is initialised with the following weights and biases:



The activation functions at each layer are as follows:

- Hidden Layer → Tanh function:

$$g^{[1]}(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

- Output Layer → Sigmoid function:

$$g^{[2]}(x) = \frac{1}{1 + e^{-x}}$$

a) Compute the predicted output $\hat{y}$ of the network. (round to 4 decimal places)

(15 marks)

b) Using the predicted output $\hat{y}$ in Question 2(a), we define the loss function *L* between $\hat{y}$ and the target output y as follows:

$$L(y, \hat{y}) = \frac{1}{2}(y - \hat{y})^2$$

Given the target output $y = 0.7$, we backpropagate one pass using the gradient descent method. Compute the derivative $\partial L/\partial w_1$ (Round the final results to 2 decimal places)

(18 marks)

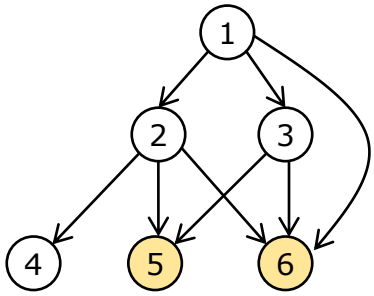
3. a) Provide two limitations of the following Sigmoid function in training artificial neural networks: (4 marks)

$$f(x) = \frac{1}{1 + e^{-x}}$$

Determine whether Sigmoid is a probability density function, and provide the reasons to justify your answer. (9 marks)

(Total: 13 marks)

b) Given the following network *G* and the damping factor *c*=0.6:



Evaluate link-based similarity *s*(5,6) between nodes 5 and 6, using Jaccard and SimRank measures, respectively.

(Round the final results to 2 decimal places)

(10 marks)

c) Given the following network *G* and the damping factor *c*=0.8, compute the PageRank values of all nodes in *G* using a fixed-point iteration method.

(Round the final results to 3 decimal places)

(10 marks)