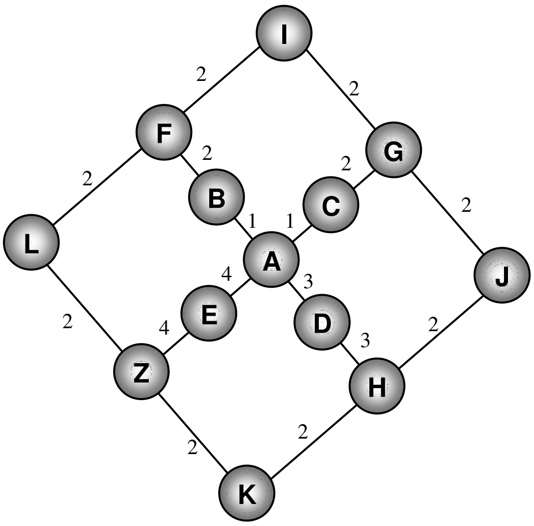
QUESTION 1: STATE SPACE SEARCH [15 marks total]

Consider the graph given below. For the following questions, you are to search from node **A** to node **Z** (start at node **A** and find a path to node **Z**).

Heuristic values:

A=0 H=4
B=4 I=6
C=4 J=6
D=4 K=2
E=4 L=2
F=6 Z=0
G=6



1.1. Search Tree

Draw the search tree for the given graph representation of the search space. Make sure you set node **A** as the root node and **Z** as your goal state.

[5 marks]

1.2. Perform **Breadth-First Search** using the **Visited List**. Search from **A** to **Z**. Show your complete solution using the given table format. Copy your answer (complete table) on the blue answer book.

Step	Dequeued	Enqueued	Visited List
0		(A)	
1			
…and so on			

Sequence of State Expansion: ______________________ Path found: ___________________

[5 marks]

1.3. Perform the **A* Search** algorithm using a **Strict Expanded List**. Search from **A** to **Z**. Show your complete solution using the given table format. Copy your answer (complete table) on the blue answer book.

Step	Dequeued	Enqueued	Expanded List
0		(A)	
1			
…and so on			

Sequence of State Expansion: _____________________ Path found: ____________________

[5 marks]

QUESTION 2: FUNDAMENTALS [8 marks total]

True or False
Write True if the statement is True; False, otherwise.

2.1. A* will generally be more efficient than Uniform Cost search since, in the worst case, an admissible heuristic gives no additional help but it never hurts.

[1 mark]

2.2. It is impossible to over-train a multi-layer feed-forward network using the back-propagation learning algorithm. It is guaranteed that the longer you train your system, the more accurate it will perform.

[1 mark]

2.3. The use of the Visited List improves the performance of Uniform Cost search without affecting its correctness.

[1 mark]

2.4. If constraint propagation leaves some variable with an empty domain, there is no solution.

[1 mark]

2.5. Iterative deepening combined with alpha-beta pruning is suitable for building a computer program that plays chess because the results of previous searches can be used to order the moves. Previous search results can also be used for extracting better initial values for alpha and beta for the next successive iterations of the search. This will help us cut-off irrelevant moves early.

[1 mark]

2.6. A training set is used for estimating how a Neural Network performs in the real-world.

[1 mark]

2.7. Softmax units are used especially for solving regression problems, provided that the sum of the output units is equal to 1.

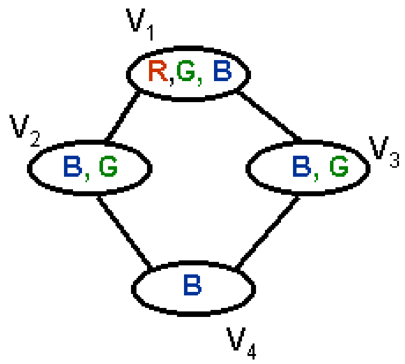
[1 mark]

2.8. The Alpha-beta algorithm will return exactly the same result as the Min-Max algorithm.

[1 mark]

QUESTION 3. CONSTRAINT SATISFACTION PROBLEM [10 marks total]

Refer to the given constraint graph representation of a map colouring problem and apply the different CSP algorithms.



3.1. Backtrack Search with Forward Checking

[5 marks]

3.2. Backtrack Search with Dynamic Variable Ordering

[5 marks]

QUESTION 4. GAMES: Min-Max and Alpha-Beta Pruning [8 marks total]

In the questions below you are given a game tree, which is shown as a table. Each cell in the table corresponds to a node in the tree and the cells right below a cell represent the children of that node. Copy your answer (complete table) on the blue answer book.

4.1. Fill in the interior nodes in this game tree with the value returned by either MAX-VALUE or MIN-VALUE in straight **MIN-MAX without using alpha-beta**, also enter the number of static evaluations in the subtree. Enter two numbers separated by spaces. Copy your answer (complete table) on the blue answer book.

MAX														
MIN														
MAX														
STATIC	4	8	9	3	2	-2	9	-1	8	4	3	6	7	1

[3 MARKS]

4.2. Fill in the interior nodes in this game tree with (a) top box: alpha and beta values, (b) bottom box: returned value and number of static evaluations in the subtree by doing **MiniMax with Alpha-Beta pruning from left to right, with initial values for alpha and beta given as (8, Infinity)**. This means that you always pick the leftmost branch to look at first. Each box requires 2 numbers (or Infinity, - Infinity) separated by spaces; Write None in both boxes if the node is never examined. Copy your answer (complete table) on the blue answer book. Start with **(8, Infinity) as the initial values for alpha and beta at the root node.**

MAX														
MIN														
MAX														
STATIC	4	8	9	3	2	-2	9	-1	8	4	3	6	7	1

[5 MARKS]

QUESTION 5: Fuzzy Logic [7 marks total]

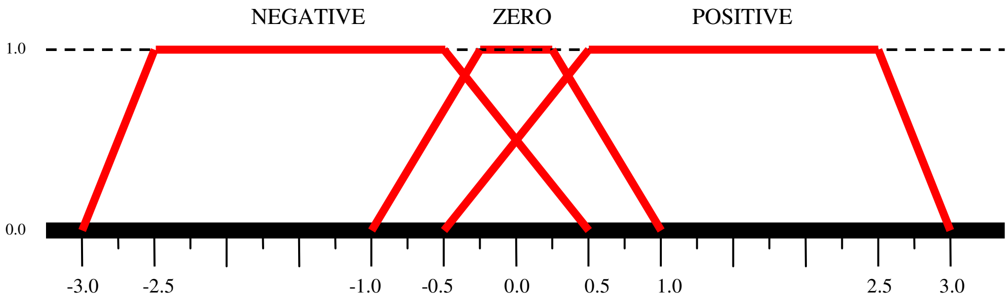
Consider the following **FAMM** with two inputs: **x** and **y**

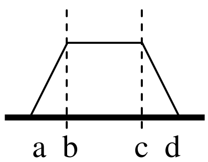
Outputs:
NL= -3
NS= -2.5
ZE= 0
PS= 2.5
PL= 3.0

y \ x	N	ZE	P
N	NL	NS	NS
ZE	NS	ZE	PS
P	PS	PS	PL

Fuzzy Sets = { Negative (N), Zero (ZE), Positive (P) }

Assume that the following Fuzzy Sets (implemented using Trapezoidal membership functions) are applicable to inputs **X** and **Y**.





For all the questions below, refer to the given FAMM above and the corresponding numerical equivalent of the output terms.

5.1.1. Calculate the degree of membership of an input **X= 0.25** to the Fuzzy set **N**.
[1 mark]

5.1.2. Calculate the degree of membership of an input **Y= -0.45** to the Fuzzy set **P**.
[1 mark]

5.2. Calculate the weight for rule #3 (i.e. W3) using Zadeh's fuzzy AND as a logical connective.

y \ x	N	ZE	P
N	W1	W4	W7
ZE	W2	W5	W8
P	**W3**	W6	W9

[2 marks]

5.3. Defuzzification: Write the complete formula for calculating the centre of mass for this particular problem in terms of the weights (e.g. W1, W2, etc.) and the given outputs in linguistic terms (e.g. NL, NS, PS, etc.).

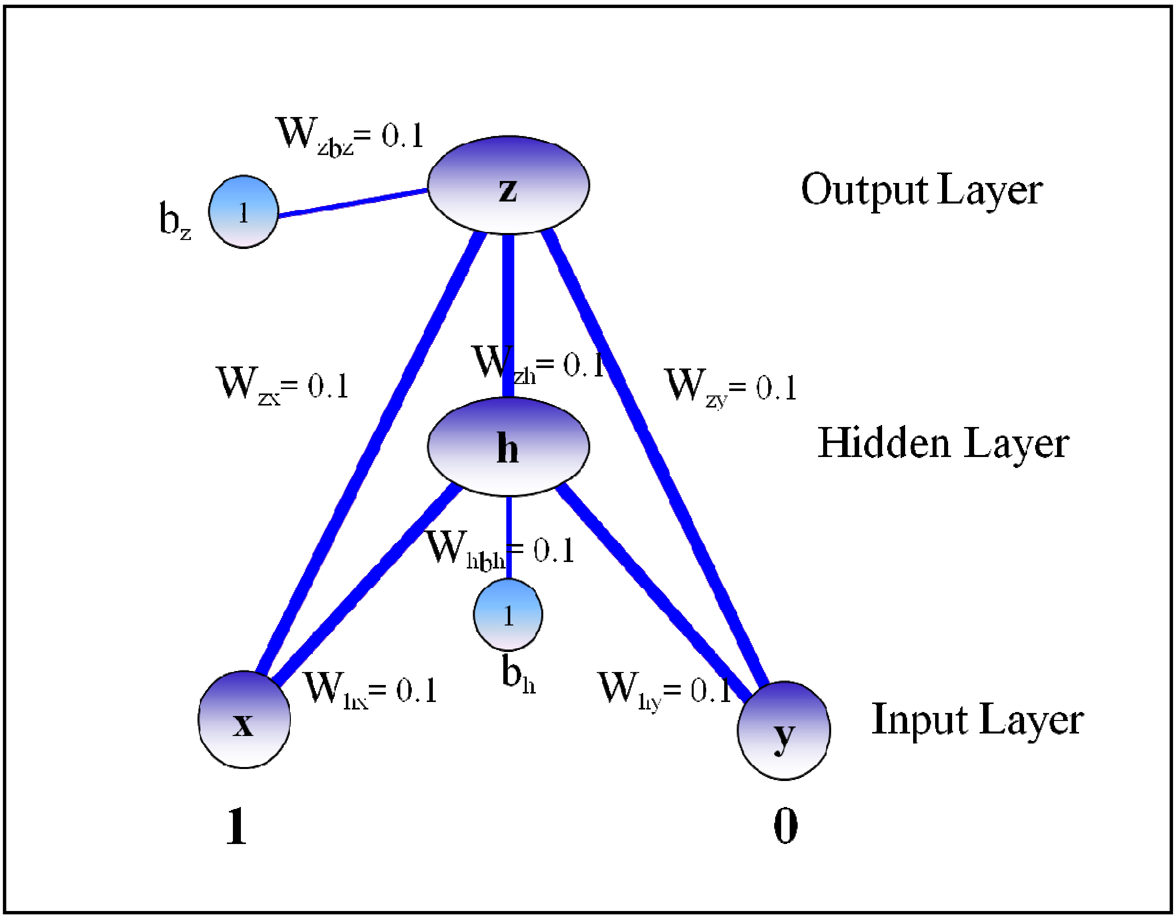
[3 marks]

QUESTION 6. BACKPROPAGATION LEARNING [12 marks total]

Simulate one complete pass of the back-propagation learning algorithm using the following input-output pair and Neural Network configuration given below. Use the sigmoid function as the activation function.

Given:

Input-Output pair: **x=1, y=0, z=0**
Learning rate = **2.5**



Note: All weights have been initialized to **0.1**

For the following weights, give the first "on-line" update.

6.1. W_{hx} [2 marks]
6.2. W_{hy} [2 marks]
6.3. W_{hbh} [2 marks]
6.4. W_{zx} [2 marks]
6.5. W_{zy} [2 marks]
6.6. W_{zh} [2 marks]

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