National University of Computer and Emerging Sciences, Lahore Campus

Course Name:	Artificial Intelligence	Course Code:	CS 461
Program:	BS(CS)	Semester:	Spring 2021
Duration:	180 Minutes	Total Points:	100
Paper Date:	9/7/2021	Weight	60
Section:	ALL	Page(s):	8
Exam Type:	FINAL		

Registration No._____

Instruction/Notes: Solve all questions on the question paper. Rough sheets might not be checked.

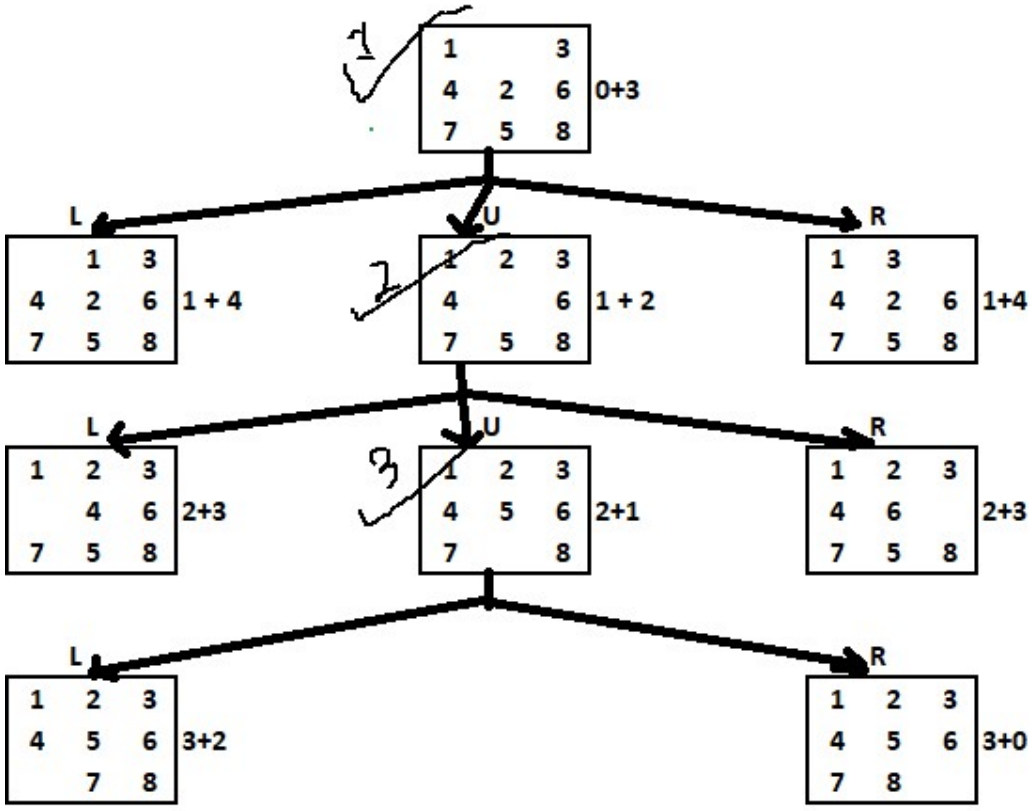
Problem A: **[Search Algorithms]** **[3,3,3,2,2,2 = 15 Points]**

The eight puzzle can be solved by successively moving the empty space Up (U), Down (D), Left (L) or Right (R). Moving the empty space corresponds to moving a corresponding tile. This problem can be posed as a state-space graph search problem with each board position being represented by the state and each move {U, D, L, R} have a unit cost. The *total number of tiles out of place* can be a useful heuristic to guide the graph search function. Assume that the puzzle is to be solved using the following initial and final states and repeated states are to be avoided during the search

Initial State	Final State
1 _ 3 4 2 6 7 5 8	1 2 3 4 5 6 7 8 _

a) Show the working of A* algorithm for solving this eight puzzle in the form of a tree that clearly shows:

- Solution (sequence of moves) found by the algorithm.
- Nodes that are expanded by A*, and their expansion order (by numbering nodes as 1, 2, …)
- Nodes in the open queue when the goal is found

TREE	Description
	1. **Initial Node Expanded** **Three New Nodes Created with Value written to right and move written on top** 2. **Middle Node Expanded and three more nodes go into the QUEUE** 3. **Once again the middle node expanded and two more nodes go into the QUEUS** 4. **GOAL FOUND and the path i.e. sequence of moves is D → D → R**

b) While solving the above puzzle, what is the minimum and maximum number of nodes expanded by each of the following graph search algorithms? Provide a solid justification for your answer

- Breath First Search

  Min: **9** Max: **15**

  Justification:

  Minimum: All nodes on levels 0, 1, and 2 will be processed before goal is found = 1 + 3 + 5 = 9

  Maximum: Goal is found after processing all nodes at level 3 = 1 + 3 + 5 + 7 – 1 = 15

- DFS

  Min: 3 Max: ALL POSSIBLE NODES – 1 = 8! /2 -1

  Justification:
  Minimum: DFS might expand the nodes in the right sequence that leads directly to goal

- Uniform Cost Search

  Min: Max:

  SAME AS BFS as the step cost is constant

  Justification:

  SAME AS BFS as the step cost is constant

Problem B: [GA] **[5, 3, 2, 5 = 15 Points]**

You are given 10 unique numbers. You have to divide these numbers into 2 sets. Set 1 must have numbers such that their product is as close to 240 as possible. Set 2 must contain numbers such that their sum is as close to 40 as possible. You need to solve this problem using genetic algorithms. Specifically,

A. Briefly explain how would you represent the solution as a chromosome. Based on your representation, what is the chromosome for the for the solution in which Set 1 contains **2, 3, 4, 10** and Set 2 has **1, 5, 6, 7, 8, 9.**

B. What should be the fitness function for this problem? Provide mathematical representation only.

C. You have two different chromosomes. The first chromosome represents the solution in which Set 1 contains **2, 3, 4, 10** and Set 2 has **1, 5, 6, 7, 8, 9.** The second chromosome represents the solution in which Set 1 contains **1, 3, 7, 9, 10** and Set 2 has **2, 4, 5, 6, 8.**

i. What is the fitness of the first chromosome?

ii. Apply single point crossover operation and show the resulting chromosomes. Whenever you need a random number, you can select one from the following list starting from index 0, then index 1, and so on.

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0.238	0.096	0.322	0.179	0.967	0.064	0.930	0.014	0.391	0.844

Problem C: **[Local Search/hill climbing]** **[15 Points]**

Now assume that we have 5 unique numbers {0, 2, 10, 22, 40} and want to divide these numbers into two sets A and B such that the product of all numbers in A is as close to 240 and the sum of numbers in B is as close to 40 as possible. We are going to solve this problem using the hill climbing local search strategy.

Assuming that the neighboring solutions of a given solution are computed by changing set of a single number, show the solution found by local search algorithm if A = {0, 2, 22, 40} and B = {10} in the starting solution. Please note that each solution will have 5 neighboring solutions. The sum or product of empty set is 0.

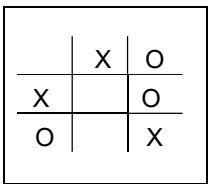
In the space provided below, show all the intermediate solutions along with the cost of each solution during each iteration

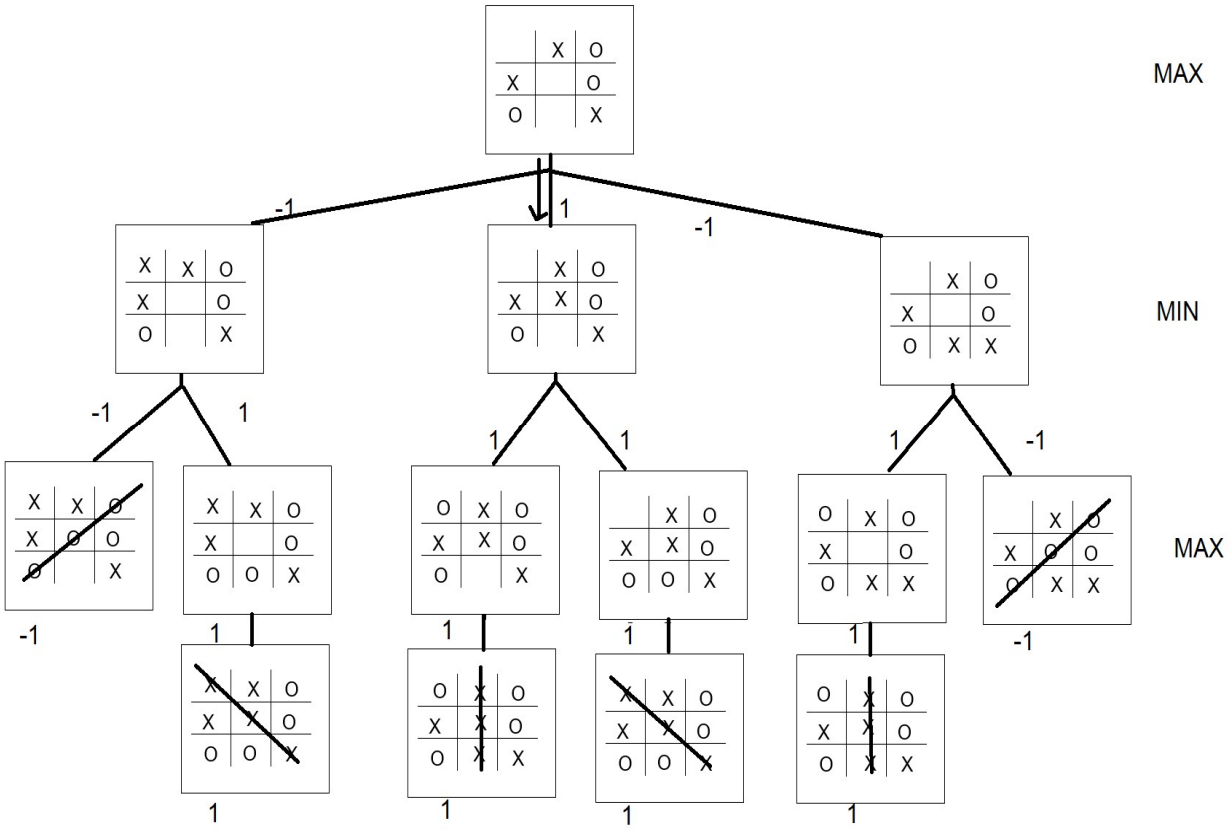
Iteration	**Solution, Cost**

Problem D: **[Game Playing]** **[10,5 = 15 Points]**

The tic-tac-toe game is played on a 3x3 board with players taking turns. Each player marks a single cell during the turn. To win the game a player has to mark three consecutive horizontal, vertical or diagonal cells.

a) Following is the state of the tic-tac-toe game and it is turn of the player marking X. Which move will be selected by the player if he is using **minimax** algorithm for selecting the move. Show the working by making the complete game tree used by minimax for move selection and then use it to select the move.

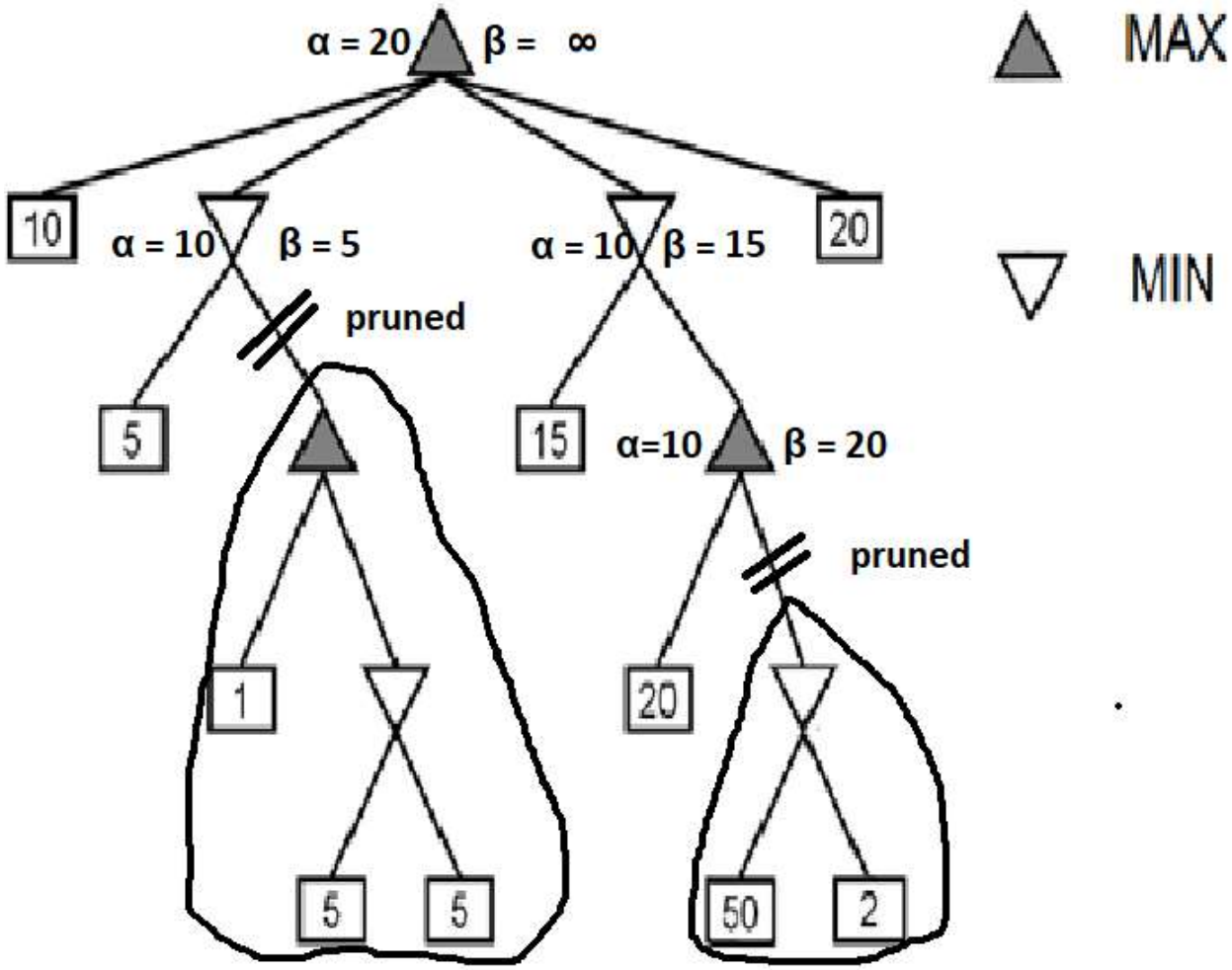




A complete tree with terminal states and values of each node computed min-max

Marking the center cell with a X is the chosen move

b) Assume that the nodes of the following game tree are processed from left to right by minimax implementation. Which nodes will be pruned by the alpha-beta pruning strategy when used for this game tree? Clearly show the values of alpha and beta along each node of the tree and mark the parts of the tree that will be pruned.



Problem E: [ANN] **[6,9 = 15 Points]**

An ANN has 3-2-1 nodes in the input, hidden and output layers respectively. The activation function g(x) is given by:

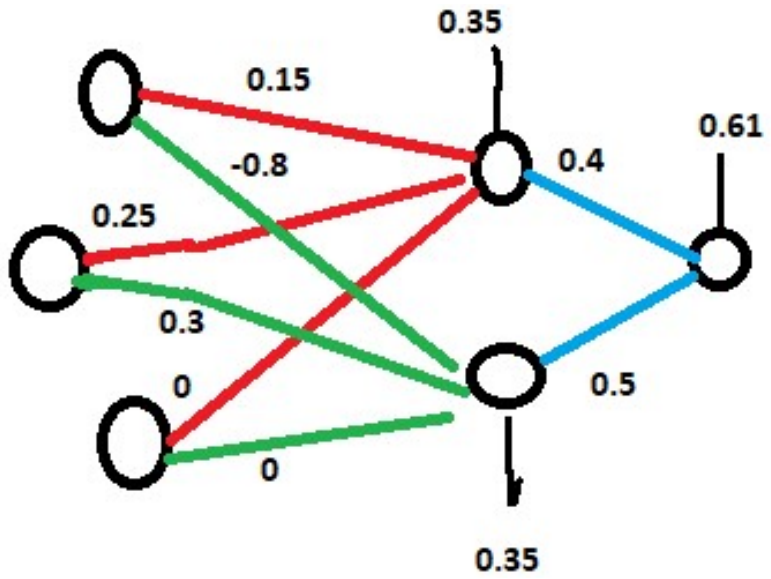
$$g(x) = \begin{cases} 1, & x \geq 0 \\ -1, & x < 0 \end{cases}$$

Consider the initialized weight and bias vectors below:

$$W1 = \begin{bmatrix} 0.15 & -0.80 \\ 0.25 & 0.30 \\ 0 & 0 \end{bmatrix} \qquad W2 = \begin{bmatrix} 0.40 \\ 0.50 \end{bmatrix} \qquad b^1 = \begin{bmatrix} 0.35 \\ 0.35 \end{bmatrix} \qquad b^2 = [0.61]$$

b^1 is the bias or weight of bias term for nodes in the hidden layer and b^2 is the weight of bias term for the node in the output layer.

a. Draw and label the network using the given weight vectors and bias values.



b. What is the output of the nodes in the hidden and output layers for the following single example consisting of three features and one class label? Show all steps.

F1	F2	F3	Class Label
0.50	0.10	1	1

0.5	0.15	-0.8	0.35	0.35	0.075	-0.4
0.1	0.25	0.3			0.025	0.03
1	0	0			0	0
					0.45	**-0.02**
				g(x) =	**1**	**-1**
					H1	**H2**

1	0.4		0.61		0.4	
-1	0.5				-0.5	
					0.51	
				g(x) =	**1**	
					O1	

Problem F: [k-means Clustering] **[8,3,4 = 15 Points]**

For the following points use one iteration of K-means clustering to partition the given points in 3 clusters.

Points: A1 = (2, 10), A2 = (2, 5), A3 = (8, 4), A4 = (5, 8), A5 = (7, 5), A6 = (6, 4), A7 = (1, 2), A8 = (4, 9)

Assume that the following points are the Initial centers: C1= (2, 11), C2= (5, 8), C3= (2, 2)

i) You have to fill the following tables with the correct values.

	Distance From C1	Distance From C2	Distance From C3
A1	**1.00**	**3.61**	**8.00**
A2	**6.00**	**4.24**	**3.00**
A3	**9.22**	**5.00**	**6.32**
A4	**4.24**	**0.00**	**6.71**
A5	**7.81**	**3.61**	**5.83**
A6	**8.06**	**4.12**	**4.47**
A7	**9.06**	**7.21**	**1.00**
A8	**2.83**	**1.41**	**7.28**

ii) Using the table computed in part i, determine the clusters

Points in first Cluster	Points in Second Cluster	Points in Third Cluster
A1	**A3, A4, A5, A6, A8**	**A2, A7**

iii) Calculate the means of the new clusters

2.00	**6.00**	**1.50**
10.00	**6.00**	**3.50**

Problem G: **[Linear Regression]** **[7,3 = 10 Points]**

For the given data set, fit a linear regression model.

X_1	1	1.5	5	3	4	3
X_2	1	1.5	5	4	4	3.5

What will be the value of X_2 at $X_1 = 9$?