Mid IT426

1 Semester 2023/2024

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1) 1445 1sem - Mid1

Question 1: [/ 8]

a) **Please state whether each of the following statements is True or False [2.25 /2.5] [0.25 each]**

1	Progress made in Artificial General Intelligence (AGI) is much greater than progress made in Artificial Narrow Intelligence (ANI).	[T F]
2	An environment is said to be deterministic if there is a finite number of actions and a finite number of percepts. descret	[T F]
3	In depth-first search goal test is applied to each node when it is generated rather than when it is selected for expansion. F	[T F]
4	In model based agent, a model is a map from states to action. T states → action	[T F]
5	In simulated annealing, the worse the solution is, the less chance it will be accepted, even at the same temperature.	[T F]
6	Depth-first search is a special case of uniform-cost search Graph search	[T F]
7	Breadth-first search strategy is implemented using (LIFO) data structure (i.e., the most recently generated node is chosen for expansion). FIFO	[T F]
8	Uniform-cost search finds the optimal solution.	[T F]
9	Greedy Best-first Search expands the node with lowest cost path from start. heuristic	[T F]
10	In hill-climbing the entire solution path is maintained.	[T F]

b) **In each of the following statements, please select the correct choice (only one).** [5.5 /5.5]

1. What is the major component/components for measuring the performance of problem solving?
   a) Completeness
   b) Optimality
   c) Time and Space complexity
   d) All of the mentioned

2. An agent that keeps track of the world state as well as a set of goals it is trying to achieve, and chooses an action that will (eventually) lead to the achievement of its goals is called:
   a) Simple-reflex agent
   b) Model-based agent
   c) Learning agent
   d) Model-based Goal-based agent
   e) Utility-based agent

3. In a Utility-based agent (choose one):
   a) Planning is achieved using search
   b) A set of Rules that maps from states to actions is required.
   c) The performance metric is: does it reach the goal?
   d) A model of percepts is not required.
   e) The performance metric is: acquire maximum rewards (or minimum cost).

4. In a learning agent, which of the following components provides the feedback on how the agent is doing to help the learning element determines how the performance element should be modified to do better in the future. (choose one):
   a) Planner
   b) Critic
   c) Problem generator
   d) Performance Metric
   e) Model

   A^*
   2 → Greedy

5. Best-First search can be implemented using the following data structure.
   a) Queue
   b) Stack
   c) Priority Queue
   d) Circular Queue

6. The A* search algorithm is a combination of which two types of search algorithms?
   a) Breadth-first and depth-first search
   b) Greedy best-first and depth-first search
   c) Greedy best-first and uniform-cost search   Greedy $h(n)$ + uniform cost $g(n)$ = A^*
   d) Breadth-first and uniform-cost search

7. ________ is the set of all states reachable from the initial state by any sequence of actions
   a) Path
   b) Solution Cost
   c) Graph
   d) State space

8. The Set of actions for a problem in a state space is formulated by a __________
   a) Intermediate states
   b) Initial state
   c) Successor function {<state, actions>, ... }
   d) None of the mentioned

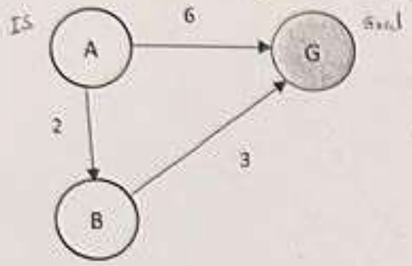
9. The _______ is a touring problem in which each city must be visited exactly once. The aim is to find the shortest tour.
   a) Finding shortest path between a source and a destination
   b) Travelling Salesman problem
   c) Map coloring problem
   d) Depth first search traversal on a given map represented as a graph

10. Consider the taxi driving and the Chess problems. The environment of both problems shares the following property (choose one):
   a) Sequential
   b) Static
   c) Episodic
   d) Deterministic
   e) Single-agent

11. A search algorithm takes _________ as an input and returns ________ as an output.
   a) Input, output
   b) Problem, solution
   c) Solution, problem
   d) Parameters, sequence of actions

Question 2: [2 / 2]

Consider the search problem shown on the left below. It has only three states, and three directed edges. **A** is the start node and **G** is the goal node. To the right, four different heuristic functions are defined.



	A	B	G
H1	4	3	0
H2	5	4	0
H3	4	1	0
H4	5	2	0

For each heuristic function, circle whether it is admissible and whether it is consistent with respect to the search problem given above. $h(n) \leq h^*(n)$ $h(n) \leq c(n,n') + h(n')$

	Admissible?		Consistent?	
H1	Yes	No	Yes	No
H2	Yes	No	Yes	No
H3	Yes	No	Yes	No
H4	Yes	No	Yes	No

H1 A_4, B_3, G_0

$4 \leq 5$ ✓ $4 \leq 2+3$ ✓

$3 \leq 3$ ✓ $3 \leq 3+0$ ✓

adm + con

H2 A_5, B_4, G_0

$5 \leq 5$ ✓ $5 \leq 2+4$ ✓

$4 \leq 3$ × $4 \leq 3+0$ ×

Not admissible Nor consistent

H3 A_4, B_1, G_0

$4 \leq 5$ ✓ $4 \leq 2+1$ ×

$1 \leq 3$ ✓ $1 \leq 3+0$ ✓

admissible, Not C

H4 A_5, B_2, G_0

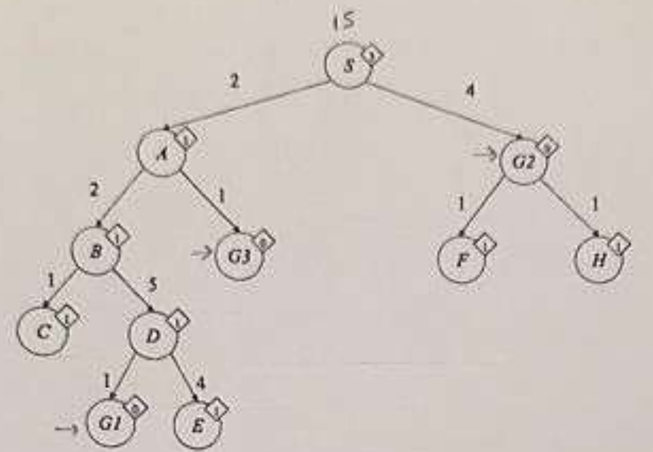
$5 \leq 5$ ✓ $5 \leq 2+2$ ×

$2 \leq 3$ ✓ $2 \leq 3+0$ ✓

ad, Not C

Question 3: [4 5 / 5]

Consider the following graph:



S is the start state and the G1, G2 and G3 are goals. Arrows encode possible state transitions, and numbers by the arrows represent action costs. Note that state transitions are directed; for example, $A \rightarrow B$ is a valid transition, but $B \rightarrow A$ is not. Numbers shown in diamonds are heuristic values that estimate the minimal cost from that node to a goal. Assume that the data structure implementations and successor state orderings are all such that **ties** are broken **alphabetically**. For example, a partial plan $S \rightarrow X \rightarrow A$ would be expanded before $S \rightarrow X \rightarrow B$; similarly, $S \rightarrow A \rightarrow Z$ would be expanded before $S \rightarrow B \rightarrow Z$. Fill in the blanks with the nodes removed from the frontier and the path of the returned solution for each algorithm from the options below.

1. S, G2
2. S, A, B, C, D, G1
3. S, A, G2
4. S,A,B,D,G1
5. S,A,G3
6. S

Search Algorithm	Nodes removed from the frontier explored List	Solution Path
Breadth First Search	3 α	1
Depth First Search	2	4
Uniform Cost Search	5	5
Greedy Search	1	1
A* Search	5	5

2) 1445 1sem - Mid2

Question 1: [4.5 / 4.5]

You are designing a menu for a special event. There are several choices, each represented as a variable: (A)ppetizer, (B)everage, main (C)ourse, and (D)essert. The domains of the variables are as follows:

A: (v)eggies, (e)scargot

→ B: (w)ater, (s)oda, (m)ilk

C: (f)ish, (b)eef, (p)asta

→ D: (a)pple pie, (i)ce cream, (ch)eese

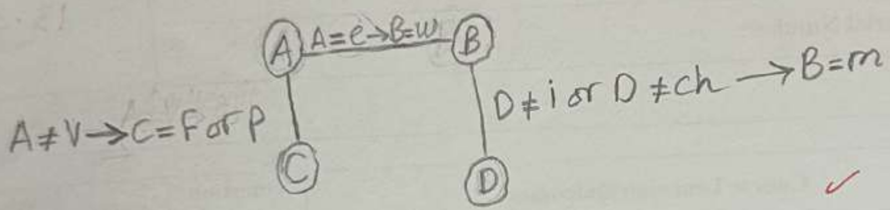
Because all of your guests get the same menu, it must obey the following dietary constraints:

(i) Vegetarian options: The appetizer must be veggies or the main course must be pasta or fish (or both).

(ii) Total budget: If you serve the escargot, you cannot afford any beverage other than water.

(iii) Calcium requirement: You must serve at least one of milk, ice cream, or cheese.

1. Draw the constraint graph over the variables A, B, C, and D. [1.5]



2. Imagine we first assign A=e. Cross out eliminated values to show the domains of the variables after forward checking. [1]

A	{~~v~~,	e}	
B	{w,	~~s~~,	~~m~~}
C	{f,	~~b~~,	p}
D	{a,	i,	ch}

3. **Again imagine we first assign A=e. variables after arc consistency has been enforced. Show the result [1]**

A	{~~b~~,	e}	
B	{w,	~~s~~,	~~m~~}
C	{f,	~~b~~,	p}
D	{~~a~~,	i,	ch}

4. Give a solution for this CSP where A=e or state that none exists. [1]

{A=e, B=W, C=F, D=ch}

Question 2: [3 / 3]

1. **Which of the following propositions are tautologies? Why? [2]**

Number	Proposition	Answer
a	P	not tatologie; It May be T or F
b	$P \Rightarrow P$	Tutologiy; $\neg P \vee P = T$: Valid
c	$(P \Rightarrow P) \Rightarrow P$	Not tatology; $\neg(\neg P \vee P) \vee P = (P \wedge \neg P) \vee P = F \vee P = P$ not ncesseally valid
d	$P \Rightarrow (P \Rightarrow P)$	tutology ; $\neg P \vee (\neg P \vee P) = \neg P \vee T = T$: Valid

2. **Is it possible that (KB |= S) and (¬KB |= S), why? [1]**

2. **Is it possible that (KB |= S) and (¬KB |= S), why? [1]**
Answer: Yes. For example, if S ≡ TRUE, then any interpretation that satisfies KB or ¬KB also satisfies S.

Question 3: [2 / 3]

Apply resolution to each of the following pairs of clauses, then simplify. Write your answer in Conjunctive Normal Form (CNF), or write "None" if no resolution is possible.

Propositional Logic	Result
a $(P \vee Q \vee \neg R \vee S), (P \vee \neg Q \vee W \vee X)$	✓ $(P \vee \neg R \vee S \vee W \vee X)$
b $(P \vee Q \vee \neg R \vee S), (\neg P)$	✓ $(Q \vee \neg R \vee S)$
c $(\neg R), (R)$	✓ ~~none~~ False
d $(P \vee Q \vee \neg R \vee S), (P \vee R \vee \neg S \vee W \vee X)$	✓ $(P \vee Q \vee S \vee W \vee X)$
e $(P \vee \neg Q \vee R \vee \neg S), (P \vee \neg Q \vee R \vee \neg S)$	× none
f $(P \vee \neg Q \vee \neg S \vee W), (P \vee R \vee \neg S \vee X)$	none

T

Question 4: [3.75 / 4.5]

1. For each set of sentences, find the most general unifier, If it exists or explain why the pair is not unifiable. [1,5]

Sentences	Unifier
{p(B, x, f(g(z))) and p(z, f(y), f(y))}	× $\{z/B, x/f(g(z)), y/g(z)\}$
{Q(a, g(x, a), f(y)) and Q(a, g(f(B), a), x)}	$\{x/f(B), y/B\}$ ✓

2. For each of the following FOL sentences, write the letter corresponding to the best English sentence on the right. Use these intended interpretations: (1) "Student(x)" is intended to mean "x is a student." (2) "Quiz(x)" is intended to mean "x is a quiz." (3) "Got100(x, y)" is intended to mean "x got 100 on y." [/3]

A	For every quiz, there is a student who got 100 on it.
B	For every student, there is a quiz on which that student got 100.
C	Every student got 100 on every quiz.
D	Some student got 100 on some quiz.
E	There is a quiz on which every student got 100.
F	There is a student who got 100 on every quiz.

Answer	FOL Sentences
B	$\forall s \exists q\ Student(s) \Rightarrow (\ Quiz(q) \land Got100(s, q)\ )$
E	$\exists q\ \forall s\ Quiz(q) \land (\ Student(s) \Rightarrow Got100(s, q)\ )$
A	$\forall q \exists s\ Quiz(q) \Rightarrow (\ Student(s) \land Got100(s, q)\ )$
F	$\exists s\ \forall q\ Student(s) \land (Quiz(q) \Rightarrow Got100(s, q)\ )$
C	$\forall s \forall q\ (\ Student(s) \land Quiz(q)\ ) \Rightarrow Got100(s, q)$
D	$\exists s \exists q\ Student(s) \land Quiz(q) \land Got100(s, q)$

✓

1) 1444

Question 1: [/ 5.5]

a) **Please state whether each of the following statements is True or False** [2.25 /2.5]

1	Breadth-first strategy is implemented using LIFO queue while Depth-first strategy is implemented using FIFO queue	[T | F]
2	Breadth first search does not always find the optimal solution	[T | F]
3	When graph-search is used, A* is optimal if *h(n)* is a consistent heuristic. The tree-search version is optimal if h(n) is admissible	[T | F]
4	If a heuristic function h(n) is admissible, greedy search is optimal.	[T | F]
5	The problem with the Hill Climbing algorithm is that it can get stuck in a global maximum.	[T | F]
6	The solution in CSP must be complete and consistent assignment.	[T | F]
7	The purpose of the least-constraining value heuristic is to reduce the branching factor of the backtracking search	[T | F] More Flexibility
8	Hill climbing performs a local search and chooses the first state that is better than the current state	[T | F]
9	The least-constrained variable heuristic provides a way to select the next variable to assign in a backtracking search for solving a CSP.	[T | F] MRV
10	A* search minimize the total expected solution cost by avoiding expanding paths that are already expensive.	[T | F]

b) In each of the following statements, please select the correct choice (only one). [2.5/3]

1. Problem-solving agents use ________ representations

   A) state
   B) factored
   C) structured
   D) atomic

2. DFS algorithm is an instance of the

   A) Graph-search algorithm
   B) Tree-search algorithm
   C) Backtracking algorithm
   D) None of the above

3. The Local search in CSP uses the *Min-Conflicts* heuristic to assign a value to each variable with:

   A) Zero conflicts with other variables
   B) Minimum conflicts with other variables.
   C) Maximum conflicts with other values
   D) None of the above

4. In CSP, ________________ tells what the most constraint variable to select first.

   A) Minimum remaining-value (MRV)
   B) Agree heuristic.
   C) Least constraining value (LCV)
   D) Backtracking

5. Which of the Following problems can be modeled as CSP?

   A) Puzzle problem
   B) 8-Queen problem
   C) Schedule for a class of student.
   D) All of the mentioned

6. The term ___________ is used for a depth-first search that chooses values for one variable at a time and returns when a variable has no legal values left to assign.

   A) Forward search
   B) Backtrack search
   C) Hill climbing algorithm
   D) Least constraining value (LCV)

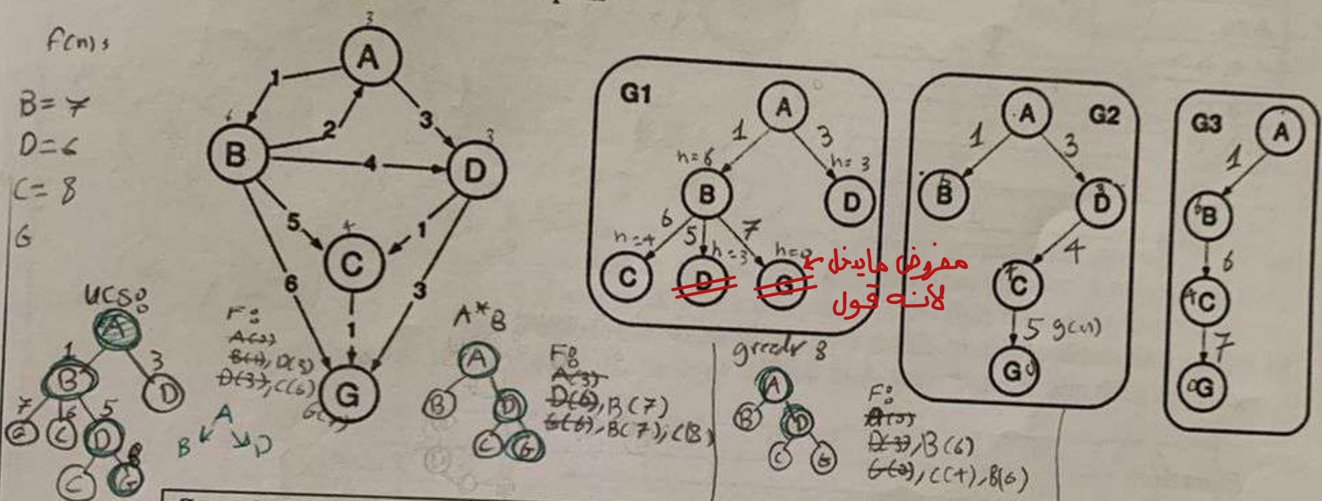
Question 2: [3.25 / 3.25]

Each of the trees (G1 through G3) was generated by searching the graph below with a graph search algorithm. Assume children of a node are visited in alphabetical order. Each tree shows only the nodes that have been expanded. Numbers next to nodes indicate the relevant "cost" used by the algorithm's priority queue. The start state is A, and the goal state is G. Assume the heuristic function H1 = {h(A) = 3, h(B) = 6, h(C) = 4, h(D) = 3}

1. For each tree, indicate:

a) Whether it was generated with depth first search, breadth first search, uniform cost search, A* or greedy search.

b) The cost of solution path



Search Tree	G1	G2	G3
a. Algorithm	Breadth-first	UCS	depth-First
b. Solution Cost	7	5	7

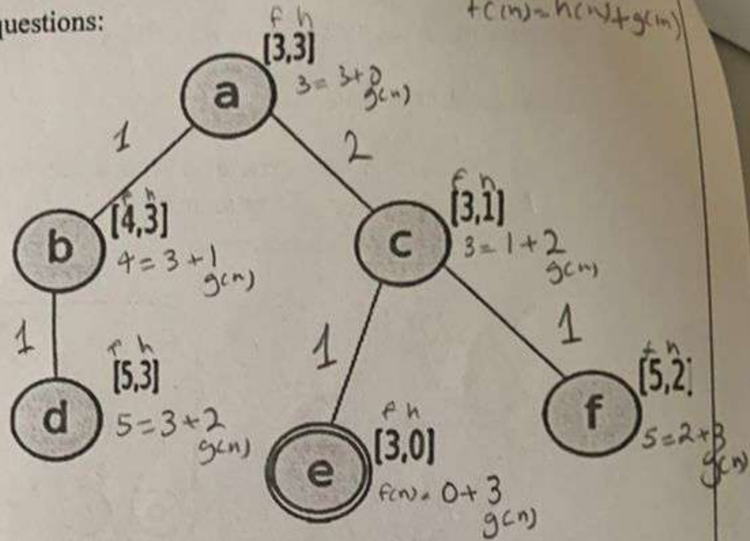
2. The optimal solution can be reached using search tree G# 2 .

UCS 8

Question 3: [4 / 4]

Consider the search problem represented in the following figure, where *a* is the start node and *e* is the goal node. The pair [*f*, *h*] at each node indicates the value of the *f* and *h* functions for the path ending at that node.
[Reminder: *f(n)* is the evaluation function, *h(n)* is heuristic function and *g(n)* is the past cost so far to reach n].
Given this information, answer the following questions:

$f(n) = h(n) + g(n)$



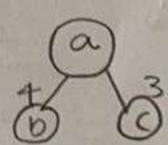
a) What is the cost of each arc? [hint: you might need to calculate g(n) first] [1.25 / 1.25]

Arc	Cost
< a, b >	1
< a, c >	2
< b, d >	1
< c, e >	1
< c, f >	1

b) Trace A* on this problem. Show what paths are in the frontier at each step, explored list, solution path and solution cost [2.25 / 2.25]

Frontier:

~~a(3)~~
~~c(3)~~, B(4)
~~e(3)~~, B(4), f(5)
B(4), f(5)



Explored List: a, c

Solution Path, if any: a-c-e

Solution Cost, if any: 3

c) Is the heuristic function *h* admissible? Explain why or why not [.5 / 0.5]

admissible → $h(n) \leq h^*(n)$
Then for a-c-e:
$3 \leq 3$ ✓

yes it is admissible since heuristic is less then or equal actual cost

$h^*(n) = 3$ actual shortest path to goal
$h(n) = 3$ heuristic

Question 4: [4/5]

You are invited to an event but not sure wha... You stared at your wardrobe for a while... store and found the stock in the ... your satisfaction. Since you ... and which you should ...

Your shoppin... the bag ... tabl...

for

Question 4: [4/ 5]

You are invited to an event but not sure what to wear, which happens 99% of the times ☺ You stared at your wardrobe for a while, then decided to go shopping! You went to your favorite store and found the stock in the table below. Your goal is to optimize your look and increase your satisfaction. Since you have a limited budget, you are not sure which piece you should buy and which you should get from your own wardrobe.

Your shopping bag can hold a maximum **"Price" (P) of 600 SAR**. You can put different stock in the bag, each having its own **"Satisfaction point" (SP)** (which are given for each stock in the table). So, your objective is maximizing the satisfaction points.

Number	Stock	Price (P)	Satisfaction Points (SP)
1	Dress	250	15
2	Belt	120	7
3	Shoos	200	10
4	Bag	130	10
5	Accessory	100	8
6	Make-up	170	12

Giving the following initial population, complete the GA steps to generate off-springs. Note that each individual is represented in 0s and 1s ordered based on the item number. 1 means that the item is in the bag, otherwise, 0 is assigned. **For example,** 1 in the first bit means that a dress in the bag. **Support the Fitness Function of each individual is the sum of satisfaction points (SP). Any individual that exceeds the budget should be rejected.**

Individual 1	1	1	0	1	1	0	600
Individual 2	0	1	1	0	0	1	490
Individual 3	1	0	1	1	0	0	580
Individual 4	1	0	0	1	1	0	480

a) Compute the Fitness Function for each individual [1 /1]

Initial population						Fitness Function $f(x) = \sum_{n=1} SP$
15	7	10	10	8	12	
1	1	0	1	1	0	40 ✓
0	1	1	0	0	1	29 ✓
1	0	1	1	0	0	35 ✓
1	0	0	1	1	0	33 ✓

b) At the Selection step, what are the parents, which are most probably selected? [1 /1]

Parent 1: Individual 1 , **Parent 2: Individual** 3 .

110110
101100

c) At the Crossover step, what are the offspring at crossover point =3 ? [1 /1]

	15	7	10	10	8	12
Offspring 1	1	1	0	1	0	0
Offspring 2	1	0	1	1	1	0

d) What is the fitness function of each offspring generated from pervious question? [1/1]

Offspring 1's fitness function = $15 + 7 + 10 = 32$

Offspring 2's fitness function = $15 + 10 + 10 + 8 = 43$

e) Are offspring1 and offspring2 be accepted as new individuals and added to the population? Circle your answer and explain the reason if not accepted ? [0/ 1]

- Offspring 1: (a) accepted (b) not accepted

  If not accepted, Explain Why? it has lower GP than its parents.

- Offspring 2: (a) accepted (b) not accepted

  If not accepted, Explain Why? Exceed budget

Question 5: [6.25 /7.25]
Consider the following co
and F, the domain fo
1. A

Question 5: [6.25 / 7.25]

Consider the following constraint satisfaction problem: you are given six variables **A, B, C, D, E** and **F**, the domain for each of the variables is **{1,2,3,4,5,6}**, and the constraints are as follows:

1. All the variables should have different values (No two variables can have the same value)
2. **A** > 3
3. **B** is even
4. **D** < **A**
5. **E** ≠1 and **E** ≠ 6
6. **F** is either 5 or 6
7. **|E-C|=1**
8. **A** > **F**
9. **|A-B|**= 2

a) On the table below, write down the updated domains after crossing out the values from each domain that are eliminated by enforcing unary constraints. [1.5 / 1.5]

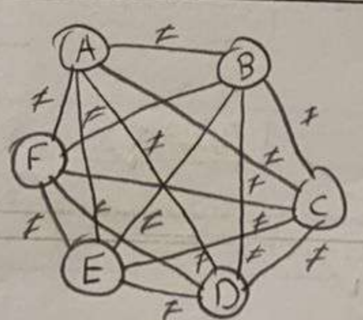
	A	B	C	D	E	F
Initial domains	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}
After enforcing unary constraints	{4,5,6}	{2,4,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{2,3,4,5}	{5,6}

b) According to the Minimum Remaining Value (MRV) heuristic, which variable should be assigned to first (after enforcing unary constraints (**from the previous part a)**)?

[.5 / 0.5]

○ A ○ B ○ C ○ D ○ E ● F

c) Draw a constraint graph where the arcs correspond to the first constraint only. [1 / 1]



d) Based on constraint graph (**from the previous part c**), would applying the degree heuristic have an effect on which variable to assign first? Justify your answer. [1 ~~1~~ 0.75]

No, Because all the six Variables have the same degree. and an assignment of one will affect all the others in the same way.

e) Assume we select to assign **A** first, and assign it the value 6. What are the resulting domains after enforcing unary constraints (from part a) and running forward checking for this assignment (**A=6**)? [1.5 1.5]

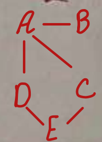
	A	B	C	D	E	F
Initial domains	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}
After enforcing unary constraints (from part a)	{4,5,6}	{2,4,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{2,3,4,5}	{5,6}
After assignment (A=6)	{6} ✓	{4} ✓	{1,2,3,4,5} ✓	{1,2,3,4,5} ✓	{2,3,4,5} ✓	{5} ✓

|A-B|=2 |6-2|=4 × |6-4|=2 ✓ |6-6|=0 ×   A ≠ C   A > D, A ≠ D   A ≠ E   A ≠ F & A > F

f) Complete Consistency (AC3) algorithm on the table below for the specified arcs only and for the following constraints only. [1 /2]

1. **D < A**
2. **E-C=2**
3. **|A-B|=2**
4. **C < A**
5. **E +D = 10**

Queue	A	B	C	D	E	F	Added arcs
Initial domain	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	-
AD	{2,3,4,5,6} ✓						BA-CA-EA-FA
DA				{1,2,3,4,5}			BD-CD-ED-FD
EC E=2+C					{3,4,5,6}		BE-CE-DE-FE-AE
CE C=E-2			{1,2,3,4} ✓				BC-EC-DC-AC-FC



2) 1444

Question 1: [/ 5]

a) **Please state whether each of the following statements is True or False** [2 1/4 /2.5]

1	Graph-search = Tree-search Algorithm + Frontier.	[T | F]
2	In Breadth first search, Goal test is applied to each node when it is generated rather than when it is selected for expansion.	[T | F]
3	Uniform cost search is special case of A* search when h(n)=0.	[T | F]
4	Greedy search can find the optimal solution.	[T | F]
5	A* search minimize the total expected solution cost by avoiding expanding paths that are already expensive.	[T | F]
6	Simulated Annealing accepts a move that is better than the current state depending only on the temperature. ΔE	[T | F]
7	Hill climbing performs a local search and chooses the first state that is better than the current state.	[T | F]
8 مكرر	The solution in CSP must be complete and consistent assignment.	[T | F]
9	In the Minimum Remaining Value (MRV), we choose the variable that is involved in the largest number of constraints on other unassigned variables. -1/4 X	[T | F] Degree heuristic
10	Forward Checking is one of the simplest forms of inference.	[T | F]

b) In each of the following statements, please select the correct choice (only one). [2 /2.5]

1. It expands the deepest node in the current branch of the search tree.
   - A) Breadth first Search (BST)
   - B) Depth First Search (DFS)
   - C) Uniform Cost Search (UCS)
   - D) A*

2. DFS algorithm is an instance of the
   - A) Graph-search algorithm
   - B) Tree-search algorithm
   - C) Backtracking algorithm
   - D) None of the above

مكرر C 3. In CSP, ________________ is the one that rules out the fewest values in the remaining variables.
   - A) Minimum remaining-value (MRV)
   - B) Degree heuristic.
   - C) Least constraining value (LCV)
   - D) Backtracking

$-\frac{1}{2}$

مكرر 4. Which of the Following problems can be modeled as CSP?
   - A) Sudoku problem
   - B) 8-Queen problem
   - C) Schedule for a class of student.
   - D) All of the mentioned

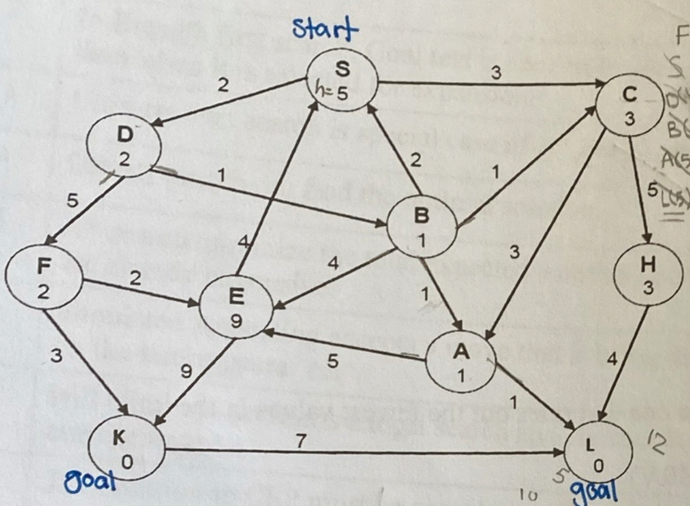
مكرر 5. The term ____________ is used for a depth-first search that chooses values for one variable at a time and returns when a variable has no legal values left to assign.
   - A) Forward search
   - B) Backtrack search
   - C) Hill climbing algorithm
   - D) Least constraining value (LCV)

Question 2: Uninformed and Informed Search [$6\frac{3}{4}$ / 6.75]

Uninformed and Informed Search

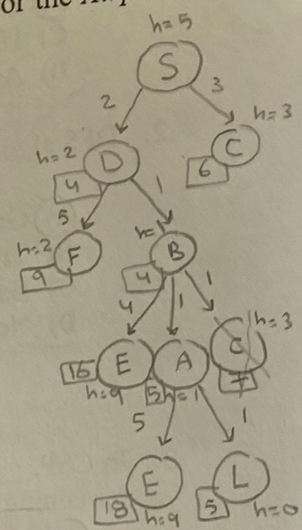
The search graph below represents the bus stations at the Riyadh City, where ***S* (the start node)** is the *KSU station*, and the nodes ***K and L* (the goals)** are the two different gates for the *Airport Station.*

A* = h(n)+g(n)



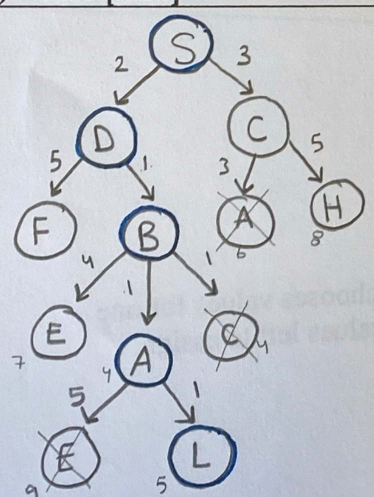
F
S
D(4) C(6)
B(4) C(6) F(9)
A(5) C(6) F(9) E(16)
5 L(5) C(6) F(9) E(6)

E
S
D(4)
B(4)
A



Find the path to the Airport using UCS and A*. Note that numbers on the arcs represent step costs and numbers in the nodes show heuristic cost to the goal of each node. **Expand nodes in alphabetical order when you have more than one candidate for expansion.**

a) UCS [3.25]



Frontier

~~S~~
~~D(2)~~ C(3)
~~B(3)~~ C(3) F(7)
~~C(3)~~ A(4) E(7) F(7)
~~A(4)~~ E(7) F(7) H(8)
goal ~~L(5)~~ E(7) F(7) H(8)

E
S
D
B
C
A

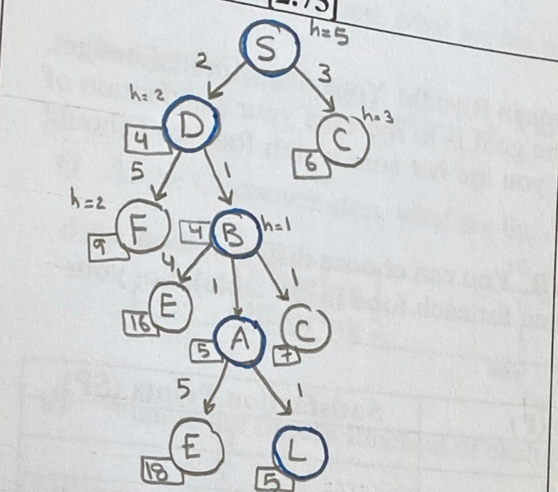
Explored List: S, D, B, C, A

Solution Path, if any: S, D, B, A, L

Solution Cost, if any: 5

Is the solution optimal? yes

b) A* Search [2.75]



Frontier:

~~S~~
~~D~~(4) C(6)
~~B~~(4) C(6)F(9)
~~A~~(5)C(6)F(9) E(16)
~~L~~(5) C(6) F(9)E(6)

Explored List: S, D, B, A

Solution Path, if any: S, D, B, A, L

Solution Cost, if any: 5

Is h(n) admissible? $h(n) \leq h^*(n)$ yes

~~yes, Since 5 ≤ 5 So it is admissible~~

c) Is the heuristic given in the graph admissible? Explain. [/ 0.75]

$h(n) \leq h^*(n)$ yes, Since $5 \leq 5$ So it is admissible.

$5 \leq 5$

S-D-B-A-L

Question 3 [2 / 2]

You decided to join a boot camp class to boost your metabolism and burn body fat. You turned on your Fitbit watch to monitor your heart rate and number of steps. Your goal is to maximize your metabolism rate.

Selected states	Metabolism rate in the current state	Metabolism rate in the next state
1	50	70
2	75	100
3	100	80
4	90	90

You applied a hill climbing (HC) strategy to reach your goal. Based on your understanding of the hill climbing, complete the following table:

Criteria	Hill Climbing (HC)
How does the algorithm choose the next move?	based in our goal we want to maximize the metabolism rate So HC, will take the first better value than the current which is the (maximmim).
Is state 1 accepted?	Yes it will accept the new state, then the current = 70,
Is state 3 accepted?	No, because the Current State is better.
Is state 4 accepted?	No, Since it is equal to the current State not better.

مكرر **Question 4: [4 1/2 /5]**

You want to have a dinner in one of the famous restaurants in Riyadh! You have a limited budget, and you want to try different options from the menu. The goal is to increase your satisfaction of the dinner experience. Since you have a limited budget, you are not sure which food you should choose.

Your dinner can cost a maximum "Price" (P) of $\boxed{600}$ SAR. You can choose different food, each having its own **"Satisfaction point"** (SP) (which are given for each food in the table). So, your objective is maximizing the satisfaction points.

Number	Meal	Price (P)	Satisfaction Points (SP)
1	Steak	250	15
2	Salad	120	7
3	Shrimps	200	10
4	Soup	130	10
5	Fries	100	8
6	Pizza	170	12

Giving the following initial population, complete the GA steps to generate off-springs. Note that each individual is represented in $\boxed{0s}$ and $\boxed{1s}$ ordered based on the food number. 1 means that the meal is chosen, otherwise, 0 is assigned. **For example,** 1 in the first bit means that steak is chosen. **Suppose the Fitness Function of each individual is the sum of satisfaction points (SP). Any individual that exceeds the budget should be rejected.**

	250 15	120 7	200 10	130 10	100 8 SP	170 12	
Individual 1	1	1	0	1	1	0	600
Individual 2	0	1	1	0	0	1	490
Individual 3	1	0	1	1	0	0	580
Individual 4	1	0	0	1	1	0	480

a) Compute the Fitness Function for each individual [/1]

	Initial population						Fitness Function
	15	7	10	10	8	12	
1	1	1	0	1	1	0	40
2	0	1	1	0	0	1	29
3	1	0	1	1	0	0	35
4	1	0	0	1	1	0	33

مكرر **b)** At the Selection step, what are the parents, which are most probably selected? [/1]

Parent 1: Individual __1__ , **Parent 2: Individual** __3__.

$\boxed{110}110$ $\boxed{101}100$

c) At the Crossover step, what are the offspring at crossover point =3 ? [/1]

	15	7	10	10	8	12
Offspring 1	1	1	0	1	0	0
Offspring 2	1	0	1	1	1	0
	250	120	200	130	100	107

d) What is the fitness function of each offspring generated from pervious question? [/1]

Offspring 1's fitness function = 15 + 7 + 10 = 32

Offspring 2's fitness function = 15 + 10 + 10 + 8 = 43

e) Are offspring1 and offspring2 be accepted as new individuals and added to the population? Circle your answer and explain the reason if not accepted ? [/ 1]

- Offspring 1: (a) accepted (b) not accepted $-\frac{1}{2}$

  If not accepted, Explain Why?_ because it has a bad fitness value.

- Offspring 2: (a) accepted (b) not accepted

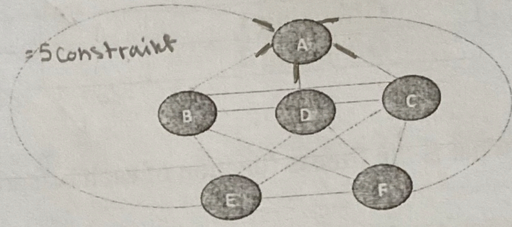
  If not accepted, Explain Why? because it exceed the budget where 250+200+130+100= 680 SR and the budget= 600 SR

مكرر **Question 5:** [6 1/4 / 6.25]

Consider the following constraint satisfaction problem: you are given six variables **A, B, C, D, E** and **F**, the domain for each of the variables is **{1,2,3,4,5,6}**, and the constraints are as follows:

1. All the variables should have different values (No two variables can have the same value)
2. **A** > 3
3. **B** is even
4. **D** < **A**
5. **E** ≠1 and **E** ≠ 6
6. **F** is either 5 or 6
7. |**E-C**|=1
8. **A** > **F**
9. |**A-B**|= 2

A = 1,2,4,8,9 = 5 constraint
B = 1,3,9



a) On the table below, write down the updated domains after crossing out the values from each domain that are eliminated by enforcing unary constraints. [1 1/2 / 1.5]

	A	B	C	D	E	F
Initial domains	{~~1~~,~~2~~,~~3~~,4,5,6}	{~~1~~,2,~~3~~,4,~~5~~,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{~~1~~,2,3,4,5,~~6~~}	{~~1~~,~~2~~,~~3~~,~~4~~,5,6}
After enforcing unary constraints	{4,5,6}	{2,4,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{2,3,4,5}	{5,6}

b) According to the Minimum Remaining Value (MRV) heuristic, which variable should be assigned to first (after enforcing unary constraints (from part a))? [1/2 / 0.5]

○ A ○ B ○ C ○ D ○ E ● F

c) Based on constraint graph, would applying the degree heuristic have an effect on which variable to assign first? Justify your answer. [3/4 / 0.75]

No, because all variabels have the same number of constraint.
and assignment of one will affect the others as the same way.

مكرر **d)** Assume we select to assign **A** first, and assign it the value 6. What are the resulting domains after enforcing unary constraints (from part a) and running forward checking for this assignment (A=6)? [½ **1.5]**

incsestence

	A	B	C	D	E	F
Initial domains	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}
After enforcing unary constraints (from part a)	{4,5,6}	{2,4,~~6~~}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{2,3,4,5}	{5,~~6~~}
After assignment (A=6)	6	4	{1,2,3,4,5}	{1,2,3,4,5}	{2,3,4,5}	5

e) Complete Consistency (AC3) algorithm on the table below for the specified arcs only and for the following constraints only. [2 /2]

1. **D < A**
2. **E-C=2**
3. **|A-B|=2**
4. **C < A**
5. **E +D = 10**

Queue	A	B	C	D	E	F	Added arcs
Initial domain	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	{1,2,3,4,5,6}	-
AD	{2,3,4,5,6}	—	—	—	—	—	CA BA
DA	—	—	—	{1,2,3,4,5}	—	—	ED
EC	—	—	—	—	{3,4,5,6}	—	DE
CE	—	—	{1,2,3,4}	—	—	—	AC

E-C=2

C = E-2

1-
2-
3-1=2
4-2=2
5-3=2
6-4=2

3)

AI Mid 1

My very best wishes to u my friend <3

0.75 **Question 1.** **[1 points] Optimality** For each of the following statements, specify whether it is True or False:

Consider a search problem without repetition where for every action, the cost is *at least* ϵ, with $\epsilon > 0$. Assume the used heuristic is consistent.

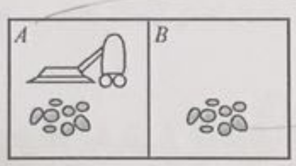
a) Depth-first search is guaranteed to return an optimal solution. [...F..] ✓

b) Breadth-first search is guaranteed to return an optimal solution. [...~~T~~ F..] ✗

c) Uniform-cost search is guaranteed to return an optimal solution. [...T..] ✓

d) A* search is guaranteed to return an optimal solution. [...T..] ✓

2.5/3 **Question 2.** **[3 points] Problem formulation and Search Tree** In a vacuum cleaning problem, you are supposed to design an autonomous agent that makes sure all rooms are clean, you have the following initial state:



Where the state representation is simply the two rooms that mark whether they are currently dirty or not, and the current location of the vacuum cleaning agent.

i) Give the formal problem formulation in terms of:

1/1.25

a) Possible Actions: Righ, Left, Suck

from - to

Right and left → (A→B, B→A). (missing action suck)

b) Goal State: All Rooms Clean

All rooms(A,B) are clean. ✓

c) Path cost: number of Moves ~~Move~~ room to another

agent moved = 1

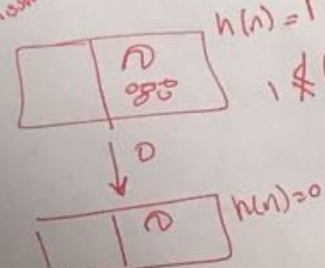
agent didn't move = 0 ✓

ii) Give a non-trivial, admissible heuristic function: number of dirty Squares

The room that the agent is IN:

If it's clean → 0

If it's dirty → 1 ✓ -0.25 not admissible

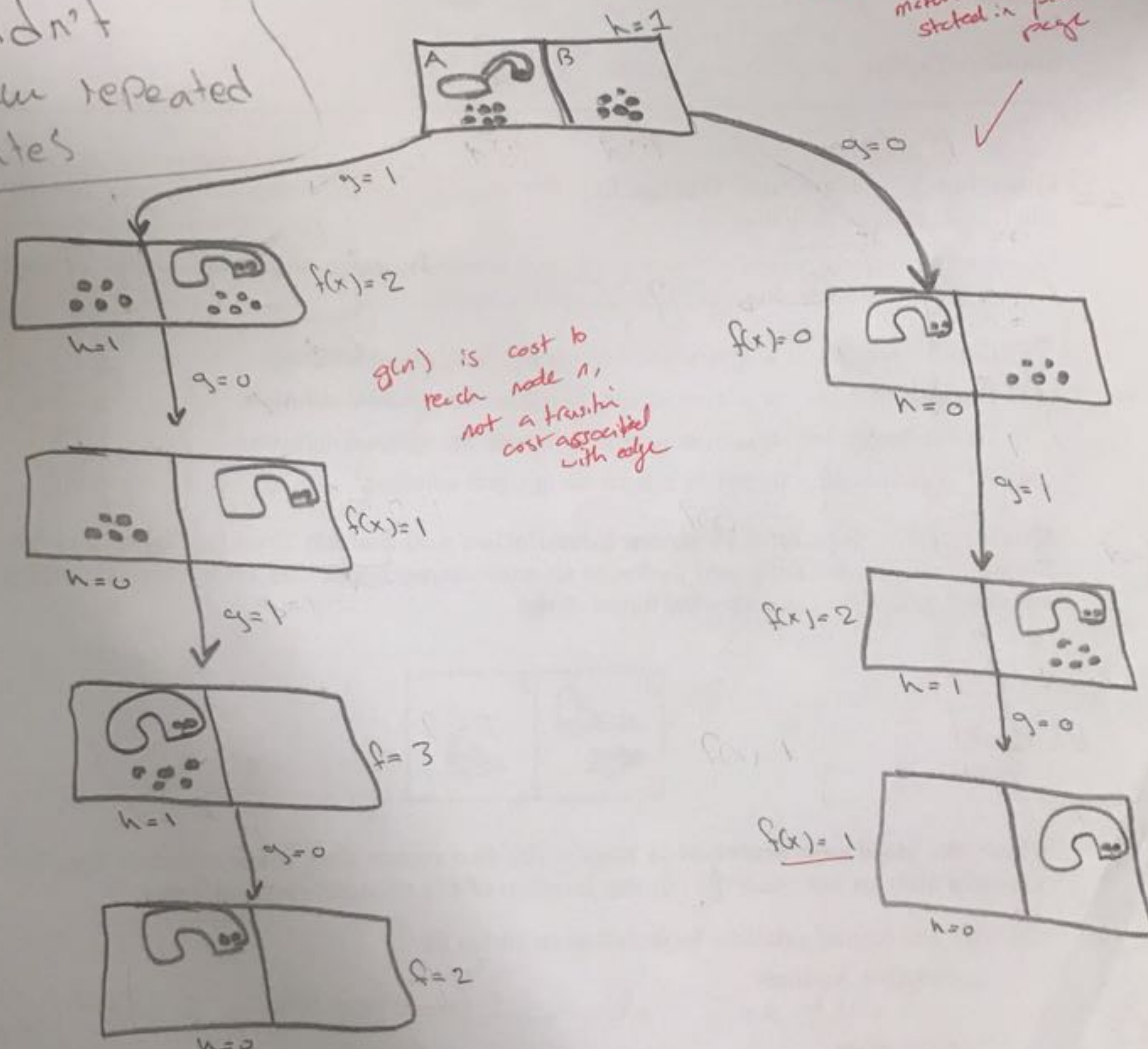


1.5/1.75

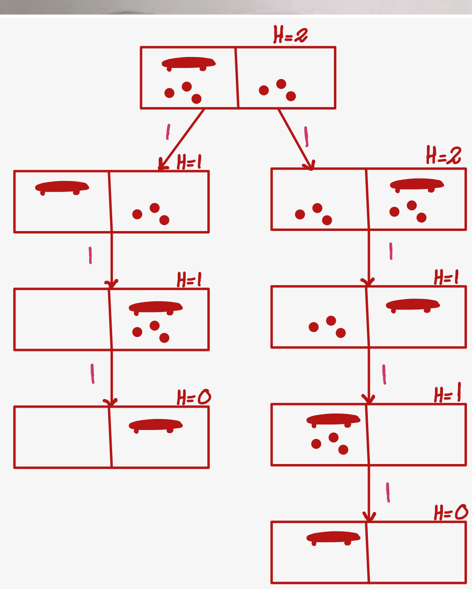
iii) Draw the search tree for solving this problem with A* search, using the heuristic you defined previously. Make sure you specify the f(n), g(n) and h(n) for every node clearly. Ties are broken with first-in first-out order. Do not expand repeated states. Remember, the root for this tree is the initial state.

I didn't draw repeated states

-0.25 doesn't match actions stated in previous page



g(n) is cost to reach node n, not a transition cost associated with edge



Question 3. [7 points]**Search Problems** Consider the following graph:

7

SABCDG1

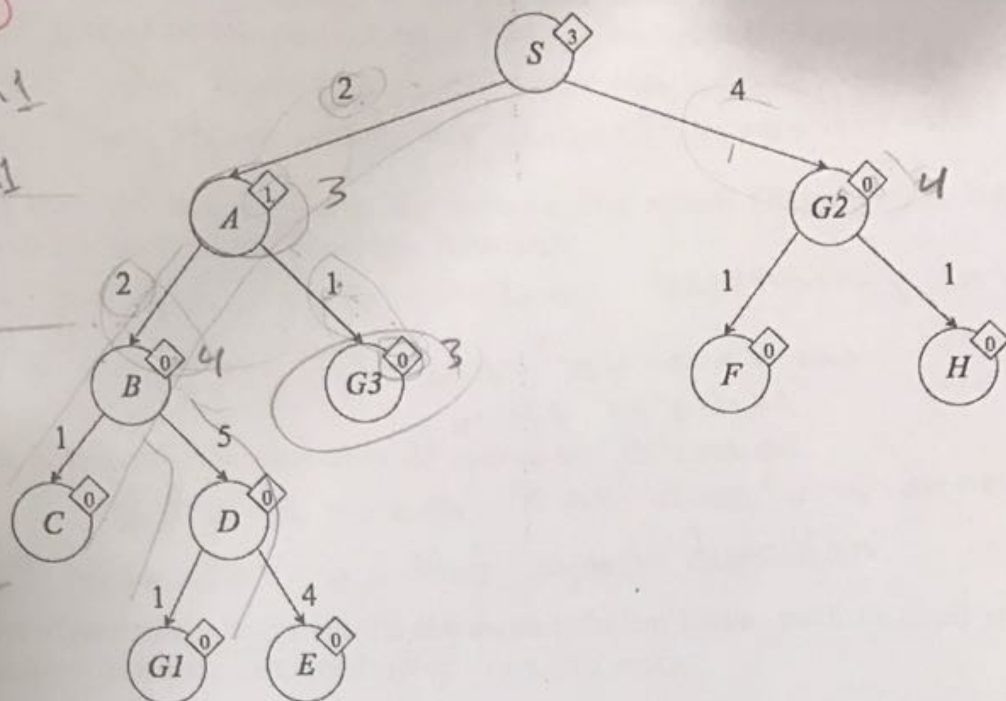
D SABDG1

B SAG2
SAG2

U SAG3
SAG3

G SG2
SG2

SAG3
SAG3



S is the start state and the G1, G2 and G3 are possible goals. Arrows encode possible state transitions, and numbers by the arrows represent action costs. Numbers shown in diamonds are heuristic values that estimate the optimal (minimal) cost from that node to a goal. Note that state transitions are directed. For each of the following search algorithms, write down the nodes that are removed from fringe in the course of the search (expanded nodes), as well as the final path returned. Assume all ties are broken alphabetically.

a) **Depth-First Search**
Nodes removed from fringe: S,A,B,C,D,G1
Path returned: S→A→B→D→G1

b) **Breadth-First Search**
Nodes removed from fringe: SAG2
Path returned: S→G2

c) **Uniform-Cost Search**
Nodes removed from fringe: S A G3
Path returned: SAG3

d) **Greedy Search**
Nodes removed from fringe: S,G2
Path returned: S→G2

e) A^* **Search**
Nodes removed from fringe: S A G3
Path returned: SAG3

Question 4. [2 points] **Short Answer Questions**

a) When is greedy search guaranteed to give you an optimal solution?

when the huersistic is addmisible, and the path to the goal have the lowest hurestic costs. ✓

b) When does A* search behave like breadth first search (Expands the nodes in the same order, and returns the same solution)?

if the f(x) have ordered increasing cost

*level by level and

*left to right ✓

2/2

c) What is the difference between A* search and UCS search?

USC expands nodes in all directions equally, A* expands in the goal direction ✓

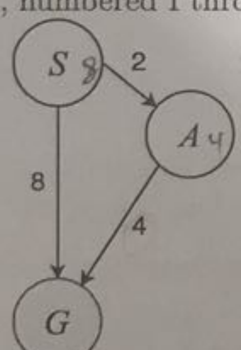
d) What algorithms <u>always</u> return the same solution (same path to goal) -assuming a consistent heuristic function? *Hint: Give two pairs.*

~~* BFS and Iterative deepening~~. ✓

* uniform and A* ✓

Question 5. [2 points] **Heuristic Admissibility and Consistency** Consider the search problem shown on the left. It has only three states, and three directed edges. S is the start node and G is the goal node. To the right, four different heuristic functions are defined, numbered I through IV.

1/2



	h(S)	h(A)	h(G)
I	8	4	0
II	6	3	0
III	6	4	0
IV	6	5	0

h(S)-h(A) ≤ cost to goal & h(A)-h(G) ≤ cost

8-4 ≤ 6 T 4-0 ≤ 4 T
6-3 ≤ 6 T 3-0 ≤ 4 T
6-4 ≤ 6 T & 4-0 ≤ 4 T
6-5 ≤ 6 T 5-0 ≤ 4 F

For each heuristic function in the table above, circle whether it is admissible and whether it is consistent with respect to the search problem given.

$g(x) \geq h(x)$

		Admissible?		Consistent?	
$8 \leq 6,\ 4 \leq 4$	I	Yes	No	Yes	No
$6 \leq 6,\ 3 \leq 4$	II	Yes	No	Yes	No
$6 \leq 6,\ 4 \leq 4$	III	Yes	No	Yes	No
$6 \leq 6,\ 5 \leq 4$	IV	Yes	No	Yes	No

$h(x) \leq g(x)$

If not admisable it will be inconsistent too "Without any calculations"

$6 \leq 5$

$6 \leq 6$

4 ≤ 2 F
3 ≤ 2 F
4 ≤ 2 F
5 ≤ 2 F

2 ≥ 4 X
2 ≥ 3 X
2 ≥ 4 X
2 ≥ 5 X

4) 1439

Q1.1: In each of the following statements, please indicate wither is True or False [7.5 /2.5]

1	Depth first search (DFS) doesn't always find an optimal solution	[T F]
2	Simulated annealing accepts a move that is better than the current state depending only on the temperature	[T F]
3	If a heuristic function h(n) is admissible, greedy search is optimal. A*	[T F]
4	In local search, it is essential to maintain the solution path	[T F]
5	The problem with the Hill Climbing algorithm is that it can get stuck in a global maximum	[T F]
مكرر 6	The solution in CSP is a complete and consistent assignment.	[T F]
7	An admissible heuristic is also a consistent heuristic.	[T F]
8	In local search, successors are generated by combining two states.	[T F]
9	When the heuristic is consistent, f(n) values along any path are nondecreasing. Admissible	[T F]
10	Simulated annealing algorithm combines local beam search and Hill climbing	[T F]
11	Breadth-first strategy is implemented using LIFO queue FIFO	[T F]
12	A* search minimize the total expected solution cost by avoiding expanding paths that are already expensive.	[T F]

Q 1.2 : In each of the following statements, please select the correct choice (only one). [3 / 3]

B 1. DFS algorithm is an instance of the

A) Tree-search algorithm
B) Graph-search algorithm
C) Backtracking algorithm
D) None of the above

2. CSPs are

A) Ways of formulating problems using variables and constraints
B) Problems that come in the way of violating constraints
C) Problems that arise after constraint satisfaction
D) None of the above

3. In the backtracking algorithm which of the following are true?
   A) Backtracking search uses *depth first search to* choose values for one variable at a time and backtracks when a variable has no legal values left to assign.
   B) Backtracking search uses *backward search* by choosing one variable at a time and backtracking from the goal state to the initial state.
   C) Backtracking search is the basic informed algorithm for CSPs.
   D) None of the above

4. In CSP, ______________________ tells what the most constraint variable to select first.
   A) Minimum remaining-value (MRV)
   B) Degree heuristic.
   C) Least constraining value (LCV)
   D) backtracking

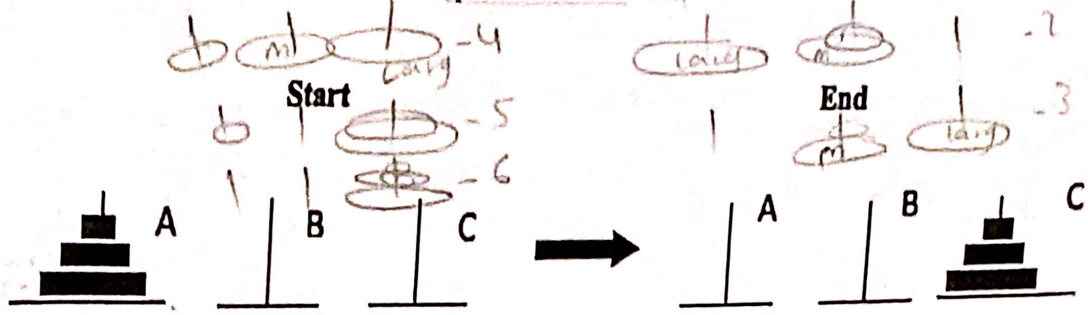
5. The Minimum Remaining Value (MRV) is used to find:
   A) The most constrained variable
   B) The least constrained variable
   C) The most legal values
   D) All of the above

6. The Local search in CSP uses the *Min-Conflicts* heuristic to assign a value to each variable with:
   A) Zero conflicts with other variables
   B) Minimum number of conflicts with other variables
   C) Maximum number of conflicts with other variables
   D) None of the above

Question2 : Problem Formulation [5.5 /6]

We are trying to solve a miniature Tower of Hanoi problem. There are 3 towers (A, B, C), and ~~2~~ 3 disks (one small, one medium and one large). The purpose of this problem is to move both disks from tower A to tower C (as illustrated in the figure below), subject to following two conditions:

- You can move only one disk at a time
- You cannot move a larger disk under a smaller one
- You cannot put the larger disk on top of the smaller disk



a) Propose a simple state representation (mathematical representation): [1 /1]

example

$$\begin{bmatrix} S & 0 & 0 \\ M & 0 & 0 \\ L & 0 & 0 \end{bmatrix}$$

Matrix of 3X3 where the colum indecat the location (Disk): A, B, C and the row indecate the order of the tower ✓

b) What is the initial state: [0.5 /0.5]

$$\begin{bmatrix} S & 0 & 0 \\ M & 0 & 0 \\ L & 0 & 0 \end{bmatrix}$$

✓

c) Give the goal test: [0.5 /0.5]

$$\begin{bmatrix} 0 & 0 & S \\ 0 & 0 & M \\ 0 & 0 & L \end{bmatrix}$$

✓

d) What are the actions: [0.5 /1]

1- Take a tower (move)

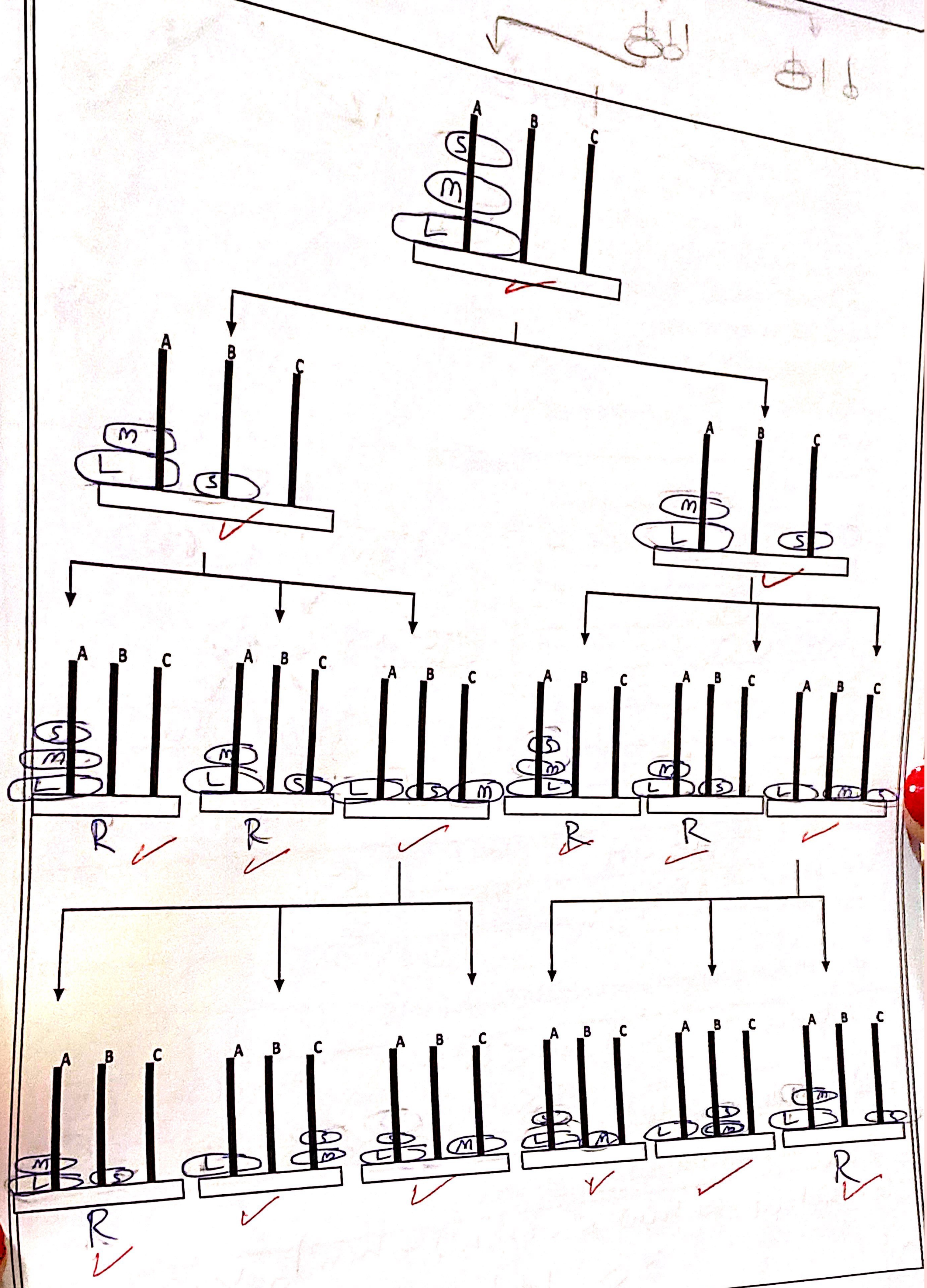
2- Put the tower

X left? right?

Move one of the disks to left or right

e) Draw the state space considering all the possible actions until the 4th level: [3 /3]

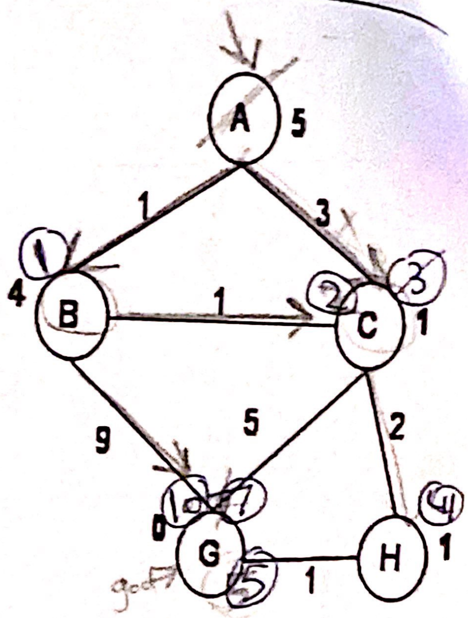
Sketch page



Search [4.5 /7]

Q3.1 UCS search: [4.5 /4.5]

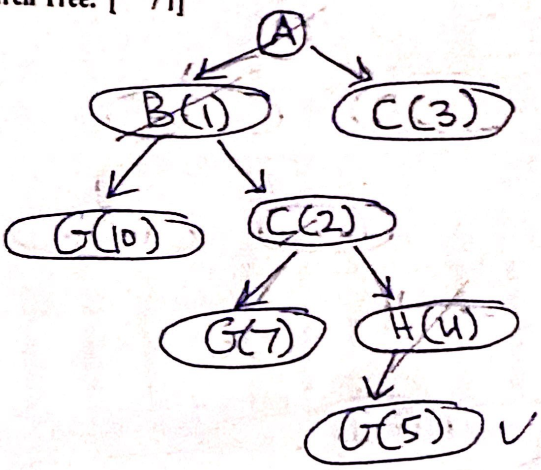
Consider the search graph drawn on the right. Using the uniform cost search algorithm, indicate which goal state is reached (if any) and show the explored list, the frontier, the search tree, the solution path and the solution cost. Expand nodes in alphabetical order when you have more than one candidate for expansion. The numbers on the links are link costs and the numbers next to the states are heuristic estimates. Note that the arcs are undirected. Let A be the start state.



Frontier: [/1]

~~A(0)~~
~~B(1)~~, C(3)
~~C(2)~~, G(10)
~~H(4)~~, G(7)
~~G(5)~~

Search Tree: [/1]



Explored list: [/0.25] ABCH

Goal: [/0.25] G

Solution path: [/0.25] ABCHG

Cost: [/0.25] 5

a) Is the heuristic given in the graph admissible? Explain. [/0.5]

Admissable $\Rightarrow$ $h(n) \leq h^*(n)$ "initial Stat A"

$5 \leq 5$

it's Admissable

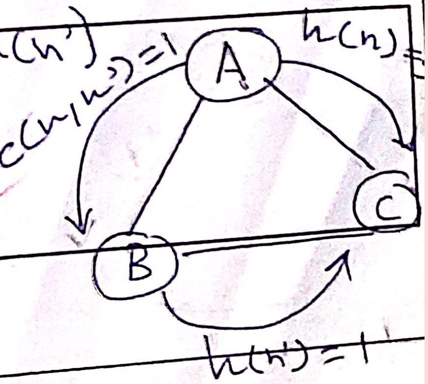
b) Is the heuristic given in the graph consistent? Explain. [/0.5]

Consistent $\Rightarrow$ $h(n) \leq c(n,n') + h(n')$

$3 \leq 1+1$

$3 \leq 2$

$\Rightarrow$ No is not A consistent



c) Did the UCS algorithm find the optimal solution. Explain. [/0.5]

Yess, Beause it's depond on the least cost Path at the selection of the nodes (next node).

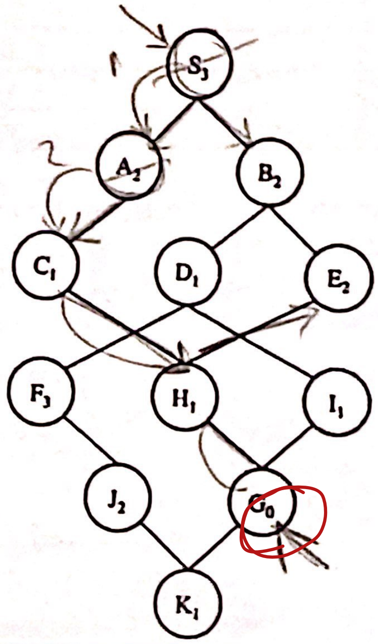
Q3.2 Greedy-best first search: [/2.5]

Consider the problem of moving a knight on a 3x4 board, with start and goal states labeled as S and G in the figure below. The search space can be translated into the following graph. The letter in each node is its name and the subscript digit is the heuristic value. All transitions have cost 1.

Assume that nodes are selected in alphabetical order when the algorithm finds a tie. Write the sequence of nodes in the order visited by the greedy-best first search. Note: You may find it useful to draw the search tree corresponding to the graph above. Trace the Greedy-best first search algorithm on the graph and answer the following:

h(n)

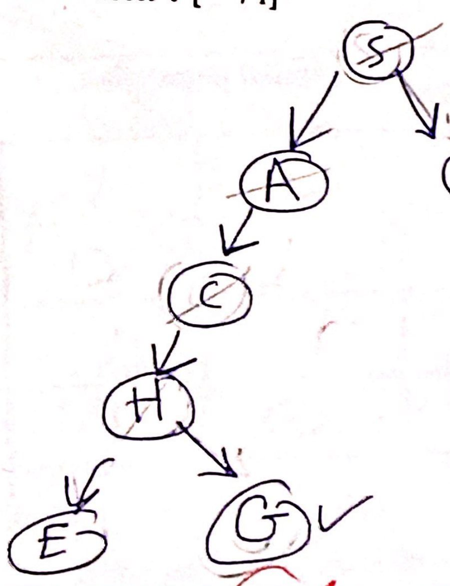
S_3	H_1	D_1	K_1
I_1	J_2	A_2	E_2
C_1	B_2	G_0	F_3



Frontier: [/1]

S(3)
A(2), B(2)
C(1), B(2)
H(1), B(2)
G(0), B(2), E(2)

Search Tree: : [/1]



Solution path: [/0.25] SACHG

Cost: [/0.25] ~~4~~ 4

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Question 4: [5 /6.5]

Q4.1: Local Search Problem [3.5 / 4]

You are invited to an event but not sure what to wear, which happens 99% of the times ☺ You stared at your wardrobe for a while, then decided to go shopping! You went to your favorite store and found the stock in the table below. Your goal is to optimize your look and increase your satisfaction. Since you have a limited budget, you are not sure which piece you should buy and which you should get from your own wardrobe.

P < 600

Your shopping bag can hold a maximum "Price" (P) of 600 SAR. You can put different stock in the bag, each having its own "Satisfaction point" (SP) (which are given for each stock in the table). So, your objective is maximizing the satisfaction points.

Number	Stock	Price (P)	Satisfaction Points (SP)
1	Dress	250	15
2	Belt	120	7
3	Shoos	200	10
4	Bag	130	10
5	Accessory	100	8
6	Make-up	170	12

Giving the following initial population, complete the GA steps to generate off-springs. Note that each individual is represented in 0s and 1s ordered based on the item number. 1 means that the item is in the bag, otherwise, 0 is assigned. For example, 1 in the first bit means that a dress in the bag. **Support the Fitness Function of each individual is the sum of satisfaction points (SP)**

Individual 1	1	1	0	1	1	0
Individual 2	0	1	1	0	0	1
Individual 3	1	0	1	1	0	0
Individual 4	1	0	0	1	1	0

a) Compute the Fitness Function for each individual [1 \1]

Initial population						Fitness Function
15 Dress	7 Belt	10 Shoos	10 Bag	8 Accessory	12 Makeup	
1	1	0	1	1	0	40
0	1	1	0	0	1	29
1	0	1	1	0	0	35
1	0	0	1	1	0	33

Sum → 137

b) At the Selection step, what are the parents, which are most probably selected? [0.5 /0.5]

Parent 1: Individual 1 , **Parent 2: Individual** 3 .

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c) At the Crossover step, what are the offspring at crossover point =3? [1 /1]

	15	7	10	10	8	12
Offspring 1	1	1	0	1	0	0
Offspring 2	1	0	1	1	1	0

d) What is the fitness function of each offspring generated from pervious question? [1 /1]

Offspring 1's fitness function = 32

Offspring 2's fitness function = 43

e) Are offspring1 and offspring2 be accepted as new individuals and added to the population? Circle your answer and explain the reason if not accepted ? [0.5/0.5]

- Offspring 1: (a) accepted (b) not accepted

If not accepted, Explain Why? Worst then the individuals Befor

- Offspring 2: (a) accepted (b) not accepted

If not accepted, Explain Why? Better then the individuels Befor

overbudget

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Q4.2: Constraint Satisfaction Problems [1.5/2.5]:

You are designing a menu for a special event. There are several choices, each represented as a variable: Appetizer (A), Beverage (B), Main Course (C), and Dessert (D).

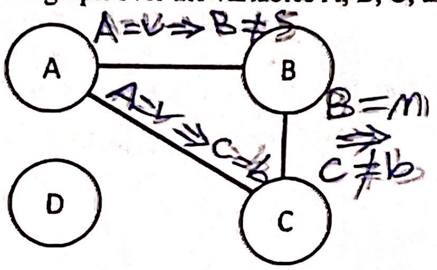
The domains of the variables are as follows:

- A: veggies (v), Garlic prawns (g)
- B: water (w), soda (s), milk (m)
- C: fish (f), beef (b), pasta (p)
- D: apple pie (a), ice cream (i), cheese (c)

Because all of your guests get the same menu, it must obey the following dietary constraints:

(i) Vegetarian options: If the appetizer is veggies, then the main course must be beef. A = V C = b ✓
(ii) Total budget: If you serve veggies, you cannot afford soda.
(iii) Food consistency: you cannot serve beef and milk together.

Considering the following constraint graph over the variables A, B, C, and D, answer the following questions:



or C = b ⇒ B ≠ M

A) if the variable A= v (veggies), show the domain values for each variable after *Forward Checking*. [0.75 /1]

Variable	Domain	
A {v}	{V} ✓	{v}
B {w, ~~s~~, m}	{W, ~~M~~} X	{W}
C {b, p, f}	{b} ✓	{b}
D {a, i, c}	{a, i, c} ✓	{a, i, c}

B) Again if A=v, show the domain values for each variable in the blank cells after *Arc Consistency (AC-3)* has been enforced. [0.75 /0.75]

	A	B	C	D
	{v}	{w, s, m}	{b, p, f}	{a, i, c}
AB	{v}	{w, ~~s~~, m}	{b, p, f}	{a, i, c}
BA	{v}	{w, m} ✓	{b, p, f}	{a, i, c}
AC	{v}	{w, m}	{b, ~~p~~, ~~f~~}	{a, i, c}
CA	{v}	{w, m}	{b} ✓	{a, i, c}
BC	{v}	{w} ✓	{b}	{a, i, c}
CB	{v}	{w}	{b}	{a, i, c}

C) Give one possible solution for this CSP if A=v or state that none exists. [0 /0.75]

there is no othere Possicable solution when A=V X

{A=V, B=W, C=b, D=C}

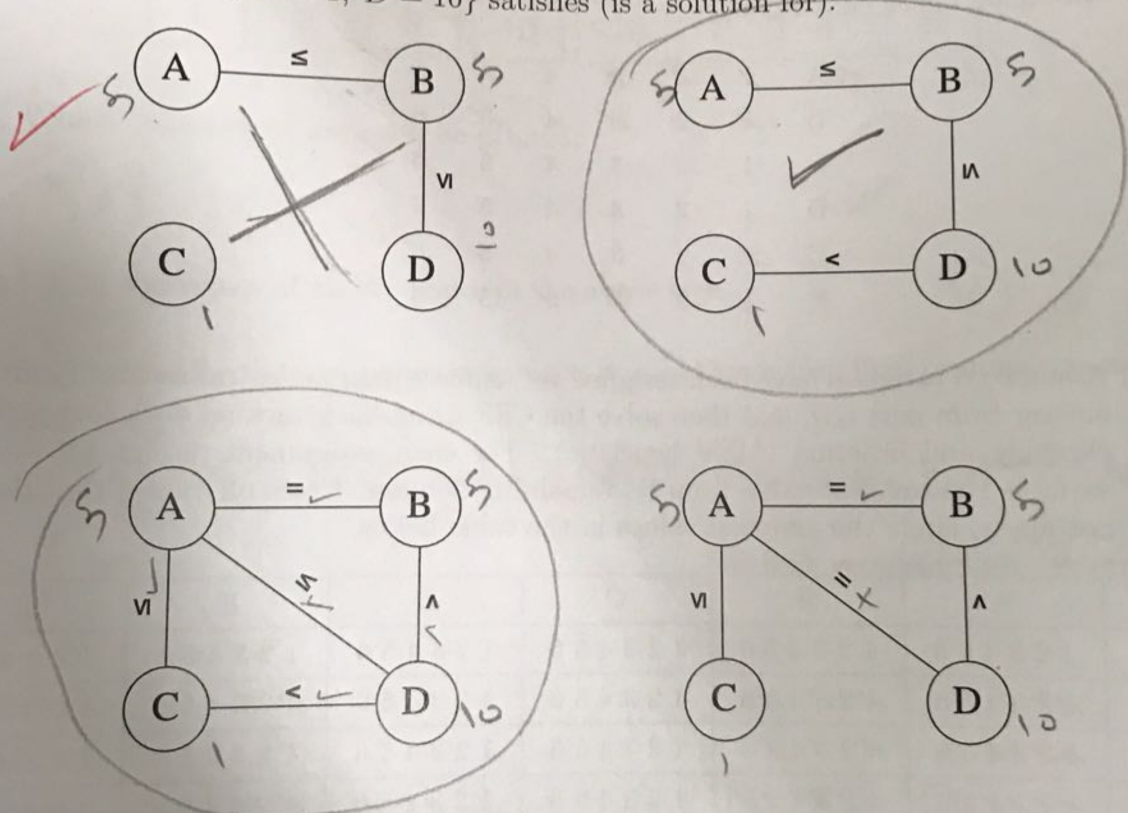
5)

AI mid 2

Question 1. [5 points] CSP

2/2

(a) For each of the following constraint-graphs, circle the graphs that this assignment $\{A = 5,\ B = 5,\ C = 1,\ D = 10\}$ satisfies (is a solution for):



4/5

(b) Assume that you are given a CSP over six variables, A, B, C, D, E and F, each having domains $\{1, 2, 3, 4, 5, 6\}$, with the following constraints:

1) No two variables can have the same values

2) **A** > 3 unary

3) **B** is even unary

B 4) **D** is less than **A** D<A

5) **E** is not 1 or 6 unary

6) **F** is either 5 or 6 unary

B 7) |**E-C**| = 1

B 8) **A** > **F**

B 9) |**A-B**| = 2

مكرر (i) On the grid below cross out the values from each domain that are eliminated by enforcing unary constraints.

(2)

3<A	~~1~~	~~2~~	~~3~~	4	5	6
B	~~1~~	2	~~3~~	4	~~5~~	6
C	1	2	3	4	5	6
4+ A>D	1	2	3	4	5	6
E	~~1~~	2	3	4	5	~~6~~
F	~~1~~	~~2~~	~~3~~	~~4~~	5	6

(6)

(ii) Assume no variables have been assigned yet, enforce unary constraints first (your answer from part (i)), and then solve the CSP using backtracking with forward checking and ordering (MRV heuristic). For each assignment, assign to the variable the smallest value from its remaining domain. Cross off values that do not apply, circle the assigned values in the table below. ???

So I'm doing forward checking and removing invalid domains from neighboring states.

I'm using MRV as follows, I'm chosing the one with minimum number of domain nos, but if 2 of them has the same number, I'm chosing alphabatically.

	A	B	C	D	E	F
Initial	1 2 3 4 5 6	1 2 3 4 5 6	1 2 3 4 5 6	1 2 3 4 5 6	1 2 3 4 5 6	1 2 3 4 5 6
unary	~~1~~ ~~2~~ ~~3~~ 4 5 6	~~1~~ 2 ~~3~~ 4 ~~5~~ 6	1 2 3 4 5 6	1 2 3 4 5 6	~~1~~ 2 3 4 5 ~~6~~	~~1~~ ~~2~~ ~~3~~ ~~4~~ 5 6
F=5	~~1~~ ~~2~~ ~~3~~ ~~4~~ ~~5~~ 6	~~1~~ 2 ~~3~~ 4 ~~5~~ 6	1 2 3 4 5 6	1 2 3 4 5 6	~~1~~ 2 3 4 5 ~~6~~	~~1~~ ~~2~~ ~~3~~ ~~4~~ 5 6
A=6	~~1~~ ~~2~~ ~~3~~ ~~4~~ ~~5~~ 6	~~1~~ ~~2~~ ~~3~~ 4 ~~5~~ ~~6~~	1 2 3 4 5 6	1 2 3 4 5 ~~6~~	~~1~~ 2 3 4 5 ~~6~~	~~1~~ ~~2~~ ~~3~~ ~~4~~ 5 ~~6~~
B=4	~~1~~ ~~2~~ ~~3~~ ~~4~~ ~~5~~ 6	~~1~~ ~~2~~ ~~3~~ 4 ~~5~~ ~~6~~	1 2 3 4 5 6	1 2 3 4 5 ~~6~~	~~1~~ 2 3 4 5 ~~6~~	~~1~~ ~~2~~ ~~3~~ ~~4~~ 5 ~~6~~
E=2	~~1~~ ~~2~~ ~~3~~ ~~4~~ ~~5~~ 6	~~1~~ ~~2~~ ~~3~~ 4 ~~5~~ ~~6~~	1 ~~2~~ 3 ~~4~~ ~~5~~ ~~6~~	1 2 3 4 5 ~~6~~	~~1~~ 2 3 4 5 ~~6~~	~~1~~ ~~2~~ ~~3~~ ~~4~~ 5 ~~6~~
C=1	~~1~~ ~~2~~ ~~3~~ ~~4~~ ~~5~~ 6	~~1~~ ~~2~~ ~~3~~ 4 ~~5~~ ~~6~~	1 2 3 ~~4~~ ~~5~~ ~~6~~	1 2 3 4 5 ~~6~~	~~1~~ 2 ~~3~~ ~~4~~ ~~5~~ ~~6~~	~~1~~ ~~2~~ ~~3~~ ~~4~~ 5 ~~6~~
D=3	~~1~~ ~~2~~ ~~3~~ ~~4~~ ~~5~~ 6	~~1~~ ~~2~~ ~~3~~ 4 ~~5~~ ~~6~~	1 ~~2~~ 3 ~~4~~ ~~5~~ ~~6~~	1 2 3 4 5 ~~6~~	~~1~~ 2 ~~3~~ ~~4~~ ~~5~~ ~~6~~	~~1~~ ~~2~~ ~~3~~ ~~4~~ 5 ~~6~~

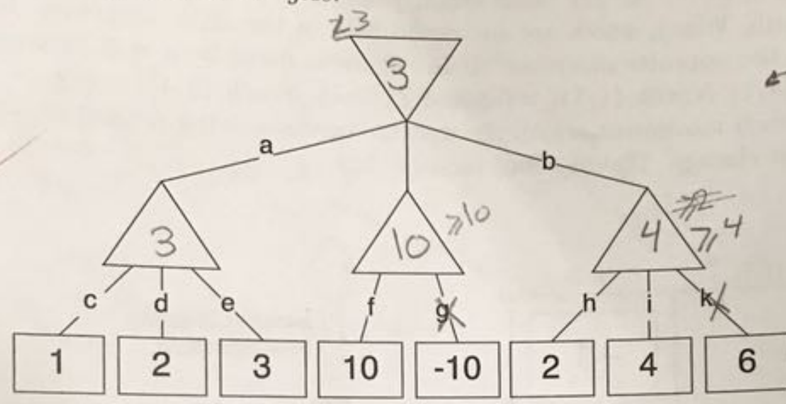
(iii) In the previous solution, how many times (if any) did you have to backtrack?

I didn't backtrack.

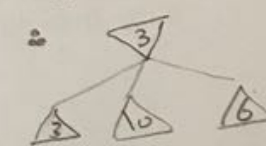
Question 2. [2.5 points] Given the following game tree, apply minimax algorithm with $\alpha - \beta$ pruning: *Remember that max nodes are upward pointing triangles, and min nodes are downward pointing triangles.*

4/4

I'm solving here using pruning



if not pruning



(a) Which branches (if any) will be pruned?

g, k

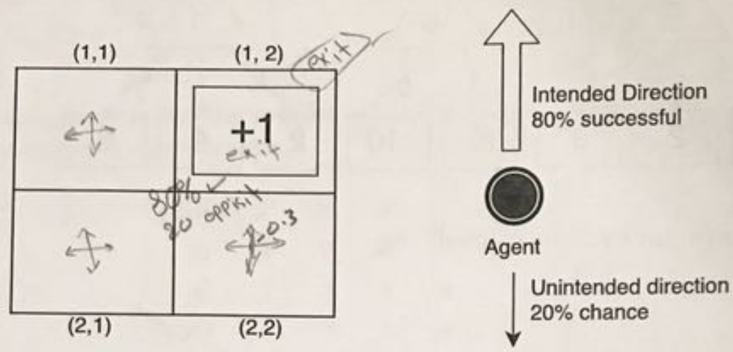
(b) Fill in the values of all the nodes in the above tree.

(c) Is the value for the <u>root node</u> the same as it would have been if no pruning was used?

Yes, the root node never change, but its children might.

Question 3. **[3 points]** Consider the following Grid World problem, where there is one terminal state (1,2). In the terminal state, you only have one action (exit) which will give you a reward of (+1). At any other state, you can go in any of the four directions (North, East, South, West), which are successful 80% of the time, otherwise, the agent ends up going in the opposite direction. If the agent is faced by a wall, it stays in the same cell e.g. $T((1,1), North, (1,1)) = 0.8$ and $T((1,1), North, (2,1)) = 0.2$. Assume that for each movement action the agent receives a living reward of -0.3, even if the state did not change. The discount factor $\gamma = 1$.

2/2



(a) Give the formula of V_{k+1} in value iteration.

$$V^*_{k+1}(s) = \max_a \sum_{s'} T(s,a,s') * [R(s,a,s') + \gamma * V^*_k(s')]$$

$V_2(1,1) \updownarrow = 0.054$

(b) Apply value iteration until k=2:

I'm using the empty last Page

	$V_k((1,1))$	$V_k((1,2))$	$V_k((2,1))$	$V_k((2,2))$
k=0	0	0	0	0
k=1	-0.3	1	-0.3	-0.3
k=2	0.44	2	-0.6	0.44

$V_1(1,1) = \max_a$ $[T((1,1), \uparrow, (1,1)) * [R((1,1), \uparrow, (1,1)) + \gamma^0 V_0(1,1)]] + [T((1,1), \uparrow, (2,1)) * [R((1,1), \uparrow, (2,1)) + \gamma^0 V_0(2,1)]]$

$[0.8 * [-0.3 + 1(0)]] + [0.2 * [-0.3 + 1(0)]] = -0.24 + (-0.06) = -0.3$

$\rightarrow$ $[(0.8) * [-0.3 + 0]] + [(0.2) * [0.3 + 0]] = -0.3$

$\leftarrow$ $= -0.3$

$\downarrow$ $= -0.3$

so all of them are -0.3 bc: K = 0

$V_1(1,2) = T((1,2), exit, \text{Terminal state}) * [R((1,2), exit, \text{Terminal}) + 1(0)] = 1 * [1 + 0] = 1 * 1 = 1$

$V_2(1,2) = T((1,2), exit, \text{Terminal}) * [R((1,2), exit, \text{Terminal}) + 1(1)] = 1 * [1 + 1] = 1 * 2 = 2$

$V^*_1(2,1) = \max_a$ $\uparrow$ $[T((2,1), \uparrow, (1,1)) * (R((2,1), \uparrow, (1,1)) + V_0(1,1))] + [T((2,1), \uparrow, (2,1)) * [R((2,1), \uparrow, (2,1)) + V_0(2,1)]]$

$[0.8 * (-0.3 + 0)] + [0.2 * (-0.3 + 0)] = -0.3$

$V_2^*(1,1) = \max$

$\uparrow \rightarrow T((1,1), \uparrow, (1,1)) * [R((1,1), \uparrow, (1,1)) + -0.3] + T, (2,1)$ ---

$[(0.8) * [-0.3 + -0.3]] + [0.2 * (-0.3 + -0.3)]$

$= -0.48 + -0.12 = -0.6$

$\downarrow \rightarrow [0.2 * (-0.3 - 0.3)] + [0.8 * (-0.3 + -0.3)]$

$= -0.12 - 0.48 = -0.6$

$\therefore \max_a = \rightarrow$

$\therefore T = 0.44$

$\rightarrow\ [0.8 * [-0.3 + 1]] + [0.2 * (-0.3 + -0.3)] = 0.56 + -0.12$

$= 0.44$

$\leftarrow\ [0.8 * [-0.3 + -0.3]] + [0.2 * (-0.3 + 1)] = -0.48 + 0.14$

$= -0.34$

$V_2^*((2,1)) = \max_a$

$\uparrow \rightarrow [0.8 * (-0.3 + -0.3)] + [0.2 * (-0.3 + -0.3)] = -0.48 - 0.12$

$= -0.6$

$\downarrow \rightarrow 0.2 * (-0.3 + 0.3)] + [0.8 * (-0.3 - 0.3)]$

$= -0.12 + -0.48 = -0.6$

$\therefore T = -0.24$

$\rightarrow\ [0.8 * (-0.3 + -0.3)] + [0.2 * (-0.3 + -0.3)] = -0.6$

$\leftarrow\ =$

$V_2^*((2,2)) = \max$

$\uparrow \rightarrow [0.8 * (-0.3 + 1)] + [0.2 * (-0.3 + -0.3)] = 0.56 + -0.12$

$= 0.44$

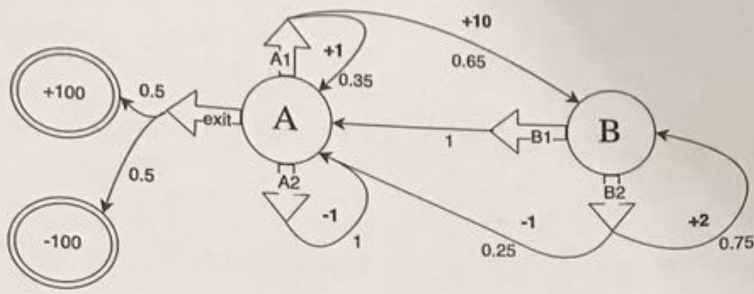
$\downarrow \rightarrow [0.2 * (-0.3 + 1)] + [0.8 * (-0.3 + -0.3)] = 0.14 + -0.48$

$= -0.37$

$\rightarrow$

2.25/3

Question 4. **[2.5 points]** Consider the following MDP with two states (A and B), where immediate rewards are in bold, and terminal rewards in displayed inside the terminal states:



(a) What are the deterministic actions in this problem?

B1, A2 ماعندهم نسب احتمال بالرسمة

(b) Given the following Q*-values, when $\gamma = 0.1$, what is V*(S) for each state?

state-action	Q-value
Q*(A, A1)	7.2
Q*(A, A2)	-0.28
Q*(A, exit)	0
Q*(B, B1)	0.72
Q*(B, B2)	1.54

State	V*
V*(A)	7.2
V*(B)	1.54

$V^*(s) = \max_a Q^*(s)$

(c) From the values above, what is the optimal policy π^* for this problem?

State	Policy
π^*(A)	A1
π^*(B)	B2

(d) What effect would increasing the value of γ (making it closer to 1) have on the optimal value of state B, would the optimal policy change?

Result in higher Values of B, Yes policy Can change.

-0.25

It will change the Value but wont change the policy

the more γ get closer to 1 ⇝ means the more I will have no discount.

I need the discount because:

1) to make the sooner rewards higher than the latter rewards.

2) Helps the algorithm coverage.

6) 2020

جامعة الملك سعود
King Saud University

College of Computer & Information Sciences

Information Technology Department

Course Code: IT 426	**Mid2** Exam
Course Title: Intelligent Systems	Wed 8th April-2020
Semester: Second Semester 2019-2020	**Time: 3:00 pm-9:00 pm (Paper Part)**
Answer Sheet	
Student Name:	
Student ID:	
Section No.	
Student Serial No:	**10**

Course Learning Outcomes	**Question No**	**Points**	**Student's Points**
Provide a suitable formulation for a problem. (2.1 – b)	**Q1**	**1.25**	
Employ the different search techniques: uninformed search, informed search and constrained search when solving a problem (4.1-a)	**Q1.2**	**3**	
	Q2	**1.25**	
Apply machine learning techniques to solve a problem. (2.4 - j)	**Q3**	**4.5**	

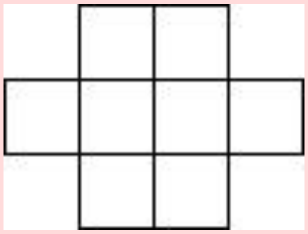
IMPORTANT INSTRUCTOR NOTES:

A. This is an **open book, notes, no mobile phones** exam.
B. This is self-exam, so discussions are **NOT** allowed.
C. Calculators are allowed.
D. Write your answers CLEARLY. The answer is wrong if the instructor cannot read it.
E. This exam has two parts:
   - Paper part: you should solve all questions on this file in details and submit it on LMS. Please note that you can:
     - Type in your answers on this word document, save it, and upload it to LMS.
     - Print out this document, write your answers in pen, scan it, and upload it to LMS.
     - Use a separate paper to write your answers in pen, scan it, and upload it to LMS. However, if you choose this option, please make sure that you answer the questions in order and make it clear each answer belongs to which question.
   - Online part: you should answer all question on the online exam on LMS.
F. If you provide more than one answer, you will get zero for the question.
G. Your answers online must be consistent with your answers on the paper.
H. Please follow the instructions for each online question carefully.

Question 1: Constraint Satisfaction Problem [/ 4.25]

Part One: CSP Problem Formulation

Consider the 8-squares board game below:



The task is to uniquely label the squares above with the numbers in the range [1-8] such that the labels of any pair of adjacent squares horizontally or vertically differ by at least 2 (i.e. 2 or more).

a) What are the variables of this CSP ?

Squares
S1-S8
{(S1,S2,S3,S4,S5,S6,S7,S8)}

b) What is the domain of the variables of this CSP ?

Domain :{1,2,3,4,5,6,7,8}

c) What are the constraints of this CSP ?

that the labels of any pair of adjacent squares horizontally or vertically differ by at least 2.

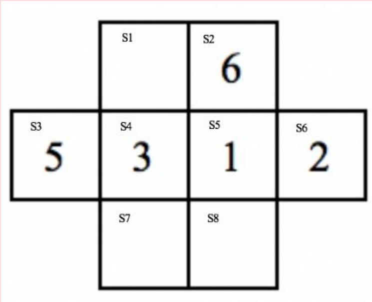
Any two adjacent squares horizontally or vertically x1 and x2, x1- x2>=2 and all value are unique

1) All values are unique

2) The labels of any pair of adjacent squares horizontally or vertically differ by at least 2

Part Two: CSP

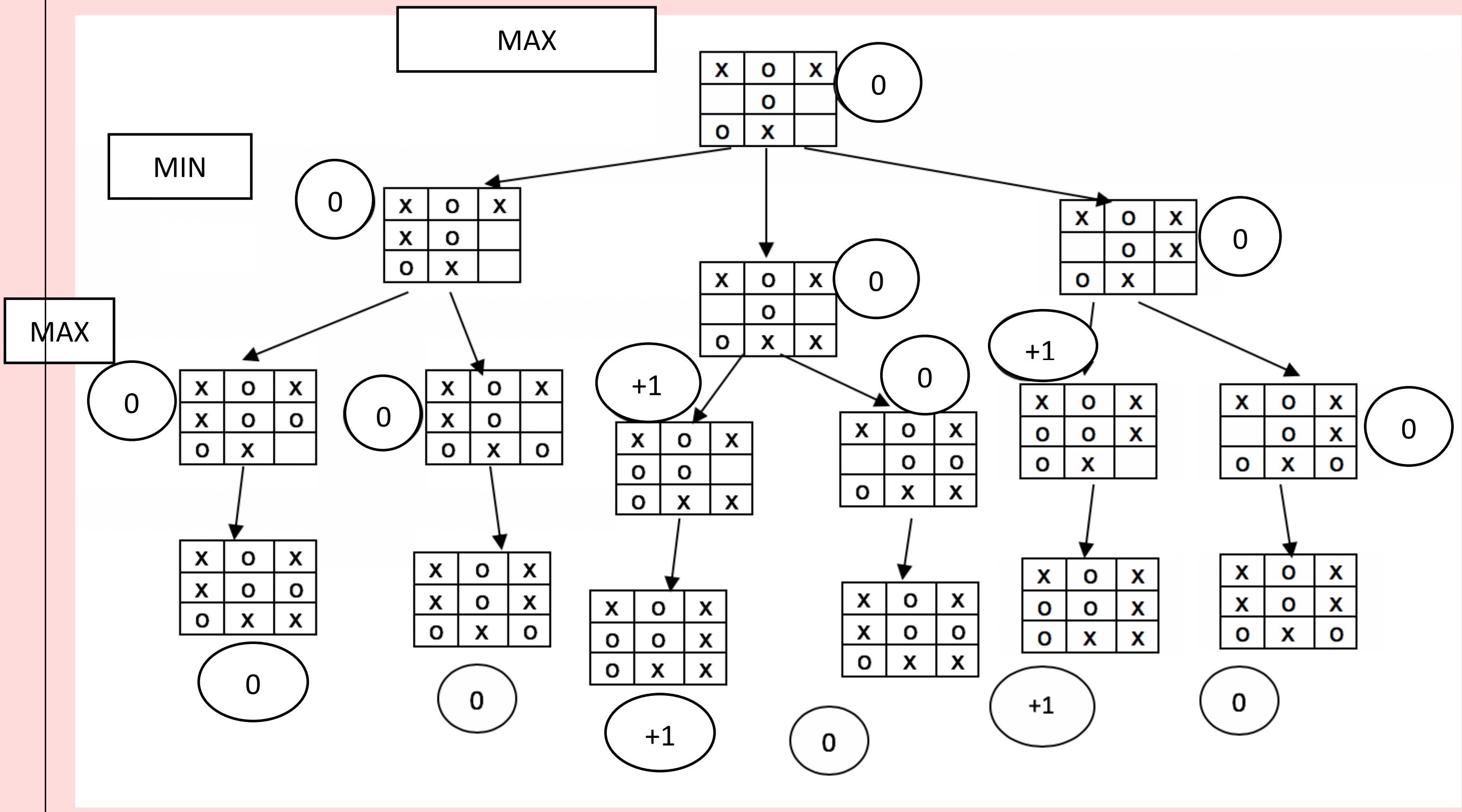
Assuming the graph has the following values, show using arc consistency (AC-3) what would be the value of the empty cells.
Hints:
1) The domain of all empty squares is {4,7,8}.
2) Consider only arcs connected to empty cells.



	S1	S2	S3	S4	S5	S6	S7	S8	Added Arcs
Domain	4,7,8	6	5	3	1	2	4,7,8	4,7,8	
S1S2	4,8	6	5	3	1	2	4,7,8	4,7,8	S4 S1
S2S1	4,8	6	5	3	1	2	4,7,8	4,7,8	
S1S4	8	6	5	3	1	2	4,7,8	4,7,8	S2 S1
S4S1	8	6	5	3	1	2	4,7,8	4,7,8	
S7S4	8	6	5	3	1	2	7,8	4,7,8	S8 S7
S4S7	8	6	5	3	1	2	7,8	4,7,8	
S7S8	8	6	5	3	1	2	7,8	4,7,8	
S8S7	8	6	5	3	1	2	7,8	4	S5 S8
S8S5	8	6	5	3	1	2	7,8	4	
S5S8	8	6	5	3	1	2	7,8	4	
S4 S1	8	6	5	3	1	2	7,8	4	
S2 S1	8	6	5	3	1	2	7,8	4	
S8 S7	8	6	5	3	1	2	7,8	4	
S5 S8	8	6	5	3	1	2	7,8	4	

Question 2: Game Playing [/ 1.25]

Consider the game of 3x3 Tic-Tac-Toe (XO), which ends when Max (or X) wins (+1), Min (or O) wins (-1), or a draw occurs (0). Suppose that your goal is to let the player X win. Suppose that the players have taken a few turns in the game. The current state is as shown below, and it is the player X's turn to play. Perform a MinMax backup and fill in each blank circles with the proper mini-max search value.



Question 3: Machine Learning [/4.5]

Part1 Given the following training data set about the suitable dress for a wedding party. You decided that you want to build a decision tree model.

Instance	Price	Color	Size	Suitable
1	Expensive	Black and White	Small	No
2	Not Expensive	Light Color	Large	No
3	Not Expensive	Light Color	Large	No
4	Not Expensive	Dark Color	Small	Yes
5	Expensive	Dark Color	Small	Yes
6	Expensive	Black and White	Large	No
7	Expensive	Dark Color	Large	Yes
8	Not Expensive	Light Color	Small	Yes
9	Not Expensive	Light Color	Small	Yes
10	Expensive	Black and White	Large	No

a. What is the root of the decision tree?

Is root :COLOR

5 yes , 5 No =10

Color	Yes	No	total
Black and White	0	3	3
Light Color	2	2	4
Dark Color	3	0	3

Info $_{color}$ (D)= 3/10 (-0/3 $\log_2$ 0/3 -3/3 $\log_2$ 3/3)+4/10(-2/4 $\log_2$ 2/4 -2/4 $\log_2$ 2/4) +3/10(-3/3$\log_2$3/3 -0/3 $\log_2$ 0/3) = 0.4

Price	Yes	No	Total
Expensive	2	3	5
Not Expensive	3	2	5

Info $_{Price}$(D)= 5/10 (-2/5 $\log_2$ 2/5 -3/5 $\log_2$ 3/5)+5/10(-3/5 $\log_2$ 3/5 -2/5 $\log_2$ 2/5)=0.97

Size	Yes	No	Total
Small	4	1	5
Large	1	4	5

Info $_{Size}$ (D)= 5/10 (-4/5 $\log_2$ 4/5 -1/5 $\log_2$ 1/5)+5/10(-1/5 $\log_2$ 1/5 -4/5 $\log_2$ 4/5)=0.72

b. What is the information gain associated with choosing the attribute “Color” ?

Color :

Color	Yes	No	total
Black and White	0	3	3
Light Color	2	2	4
Dark Color	3	0	3

Info $_{color}$ (D)= 3/10 (-0/3 $\log_2$ 0/3 -3/3 $\log_2$ 3/3)+4/10(-2/4 $\log_2$ 2/4 -2/4 $\log_2$ 2/4) +3/10(-3/3$\log_2$3/3 -0/3 $\log_2$ 0/3) =0.4

Gain :

Info(D)- Info $_{color}$ (D)=1-0.4= 0.6
Info(D)- Info $_{Price}$ (D)=1-0.97=0.03
Info(D) - Info $_{Size}$ (D)=1- 0.72= 0.28

<u>Part2</u> If you trained and tested your model multiple times using different parameter settings and got the error rates in the table below. How well do the following runs of a classification algorithm **fit** into a model? [/1]

Run no.	**Training Error**	**Testing Error**	**Fitting Type (Under fit – Over fit – Good fit – Unknown fit)**
1	**10%**	**15%**	**Good fit (Low test error, slightly higher than the training error)**
2	**50%**	**80%**	**Under fit(Training and test errors are high)**
3	**10%**	**60%**	**Over fit(Low training error and high test error)**
4	**90%**	**50%**	**Unknown fit(Training error is high)**

<u>Part 3</u> Assume that your dataset consists of **250 example/records** of both suitable and not suitable dresses**.** After training your model, you found out that **25 not suitable** were **predicted to be suitable, and 50 out of 100 suitable were predicted to be not suitable.** Fill the confusion matrix table below to evaluate the performance of your model. [/1]

TOTAL 250	Predicted suitable	Predicted not suitable
Actual suitable	50 (TP)	50 (FN)
Actual not suitable	25 (FP)	125 (TN)

Compute accuracy, precision, and recall of the model. [/1.5]

P= TP+FN

N=FP+TN

Accuracy: TP +TN /P+N = 50+125 /250 =0.7

Precision: TP /TP+FP = 50/50+25 = 0.66

Recall: TP /P = 50/100 = 0.5

7)

Question1: State whether each of the following statements is True or False: [3.5 / 4]

1.	$(R \wedge E) \Leftrightarrow C$ is considered a horn form $(R \wedge E)$	[T | F]	$R \wedge E \to C \wedge C \to R \wedge E$ $\neg R \vee \neg E \vee C$
2.	Existential Instantiation can be applied several times to replace the existential sentence.	[T | F]	once
3.	A predicate is an atomic sentence in Propositional Logic.	[T | F]	
4.	*Mini-Conflicts* is a heuristic for use with local search on constraints satisfaction problems.	[T | F]	
5.	*Minimum-remaining value* is a heuristic for deciding which variable to choose next in a backtracking search. MRV	[T | F]	
6.	The resolution based inference algorithm is sound but not complete.	[T | F]	Sound & Complete
7.	Arc consistency detects failure earlier than Forward chaining in CSPs.	[T | F]	
8.	Forward chaining is basically done by applying resolution rule successively.	[T | F]	Modus Ponens

Question2: (Constraint Satisfaction Problem) [10 /10]

Consider the problem of Sudoku, where a 4x4 board should be filled with values within {1, 2, 3, 4}, such that:

- No value appears twice in the same row.
- No value appears twice in the same column.
- No value appears twice in the same block (2X2 block)

3	V_1	V_2	1
V_3	1	V_4	4
4	V_5	1	V_7
V_6	3	4	2

$B_{1,1}$ $B_{1,2}$

a. **Formulate the problem as a constraint satisfaction problem (CSP) by giving the variables, their domains, and the constraints. [/5.5]**

Variables: (1.75)

$\{V_1, V_2, V_3, V_4, V_5, V_6, V_7\}$

Domains: (1.75)

$D_1 = \{2, 4\}$, $D_2 = \{2\}$, $D_3 = \{2\}$, $D_4 = \{2, 3\}$, $D_5 = \{2\}$

$D_6 = \{1\}$, $D_7 = \{3\}$

Constraints: (2) 2

Row 2x2 Block Col

no values appears twice in the same Row

no values appears twice in the same Column

no values appears twice in the same Block

$B_{1.1} \neq B_{2.1} \neq B_{3.1} \neq B_{4.1}$

$B_{1.2} \neq B_{2.2} \neq B_{3.2} \neq B_{4.2}$

$B_{1.3} \neq B_{2.3} \neq B_{3.3} \neq B_{4.3}$

$B_{1.4} \neq B_{2.4} \neq B_{3.4} \neq B_{4.4}$

$C_3 = B_{3.1} \neq B_{3.2} \neq B_{3.3} \neq B_{3.4}$

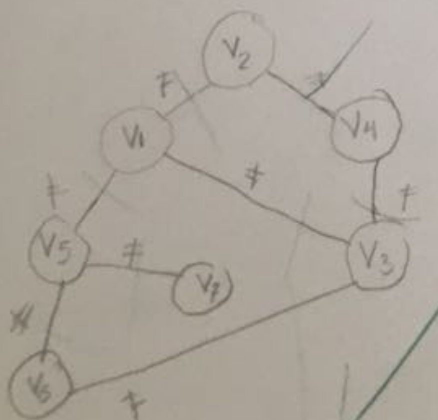
$C_4 = B_{4.1} \neq B_{4.2} \neq B_{4.3} \neq B_{4.4}$

$B_{4.3} \neq B_{4.4} \neq B_{3.4} \neq B_{3.3}$

?

b. **Draw the corresponding constraint graph and compute the degree heuristic for five nodes of the constr graph. [4.5 /4.5]**

its this constraints



Node	Degree heuristic
V_1	3
V_5	3
V_3	3
V_6	2
V_4	2

Question3: (Propositional Logic& First Order Logic) [24 /26]

1. Complete the following table: [8 / 10]

Criteria	Propositional Logic	First Order Logic
Assumption about the real world. The language assumes that real world consists of...... (2 marks) 1	~~Knowledge base~~ facts Fact	~~Variable~~ ~~function~~ ~~object~~ objects, Facts etc...
What is a model? (1 mark) 0.5	~~Truth table~~ Truth Table	~~Set of objects~~ ~~contradiction~~ Set of objects
Expressive power (Limited/Powerful). (1 mark) 1	~~Limited~~ Limited	Powerful
Translate the following sentences using your own vocabulary (prepositional symbols, constants, predicates,..) (4 marks) F: fever H = headache VD = visit Doctor 3.5 O= Open h = hospital Go to = g Nora go to h	**a. Nora had a fever and also she had headache, so she need to visit a specialist doctor.** $= F_N \wedge H_N \wedge VD_N$ $F_N \wedge H_N \to D_N$ 1 **b. If the hospital is open, Nora will go.** $O_h \to g_{Nh}$ $O_H \to G_N$ 0.5	**a. All professors are people.** $\forall x$ professors(x) $\wedge$ people(x) $\forall x$ proffesor(x) $\to$ People(x) 0.75 **b. Some of deans are not professors.** $\exists x$ deans(x) $\wedge \neg$proffesor(x) $\exists x$ Dean(x) $\wedge \neg$Professor(x) 1.25
xpress the following logical tatements in ONE natural nguage sentence. (2 marks) 2	**c. P: Sara left the classroom** **$\neg\neg$P** No, Sara ~~left~~ didn't leave the classroom Sara left the classroom	**c. $\exists$x Student (x) $\wedge$ Takes (x, IT422, Summer2016) $\wedge$ ($\forall$y y$\neq$ x$\Rightarrow$ $\neg$ Takes (y, IT422, Summer2016)** one student took IT422 in Summer 2016 and the rest of the students didn't take IT422 in Summer 2016 Some student takes IT422 in Summer 216 and the other student Does not take IT422 in Summer 2016

2. FOL Backward Chaining [9 /9 marks]

Given the following sentences in First-Order Logic:

KB:

Father(a,b) ∧ Father(c,d) ∧ Brothers(a,c) ⇒ Cousins(b,d)

Father(a,b) ∧ Father(a,c) ⇒ Siblings(b,c)

Mother(a,b) ∧ Mother(a,c) ⇒ Siblings(b,c)

Siblings(a,b) ∧ Male(a) ∧ Male(b) ⇒ Brothers(a,b)

Male(Badr)

Male(Carim)

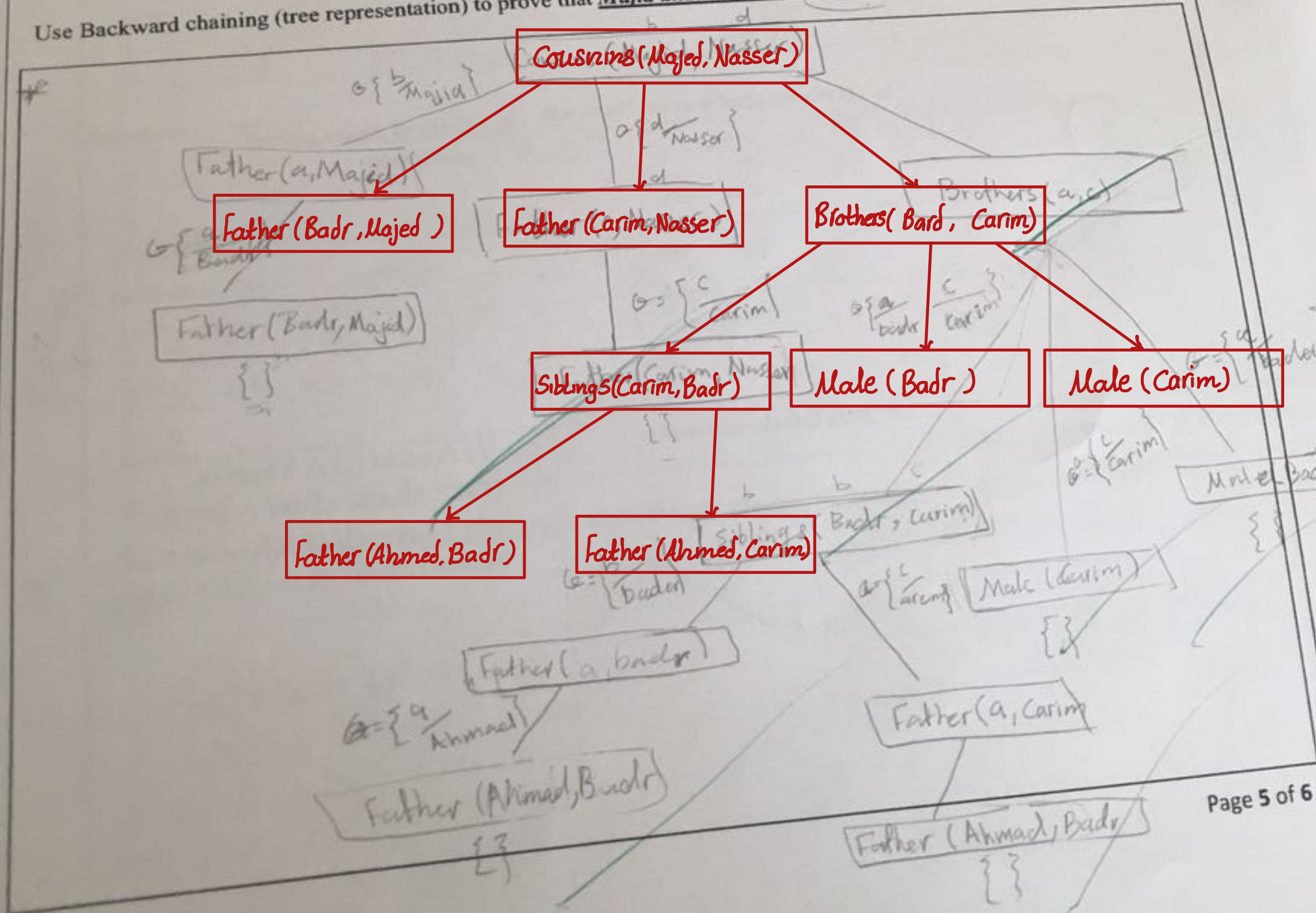
Father(Ahmed,Badr)

Father(Ahmed,Carim)

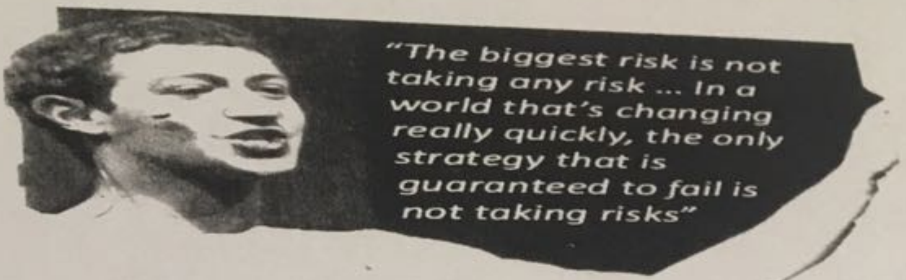
Father(Badr,Majid)

Father(Carim,Nasser)

Use Backward chaining (tree representation) to prove that ***Majid and Nasser are cousins***. Show any unifications required.



3. Model checking and inference rules in PL [7 /7marks]



Mark Zuckerberg states that the strategy that guaranteed to fail is not taking risks:

$$(\neg R \Rightarrow \neg S) \Rightarrow (R \vee \neg S)$$

$\neg(\neg R \Rightarrow \neg S) \wedge (R \vee \neg S)$

$(R \Rightarrow S) \wedge (R \vee \neg S)$

a. Is the Mark Zuckerberg sentence valid, satisfiable, or unsatisfiable? (1 mark)

$(R \vee \neg S) \rightarrow (R \vee \neg S)$

$\neg(R \vee \neg S) \vee (R \vee \neg S)$

T

.........valid.........

b. Prove your statement in part (a) using model checking. (3 marks)

R	S	¬R	¬S	R∨¬S	¬R⇒¬S	(¬R⇒¬S)⇒(R∨¬S)	
T	T	F	F	T	T	T	
T	F	F	T	T	T	T	
F	T	T	F	F	F	T	
F	F	T	T	T	T	T	

c. Convert to Conjunctive Normal Form: $(W \Rightarrow (S \Leftrightarrow R))$. (3 marks)

$W \Rightarrow (S \Leftrightarrow R)$

$= W \Rightarrow (S \rightarrow R \wedge R \rightarrow S)$ "biconditional elimination"

$= \neg W \vee (S \rightarrow R \wedge R \rightarrow S)$ "implication"

$= \neg W \vee ((\neg S \vee R) \wedge (\neg R \vee S))$ "distribution"

$= (\neg W \vee \neg S \vee R) \wedge (\neg W \vee \neg R \vee S)$

$W \rightarrow (S \rightarrow R \wedge R \rightarrow S)$

$W \rightarrow ((\neg S \vee R) \wedge (\neg R \vee S))$

$\neg W \vee ((\neg S \vee R) \wedge (\neg R \vee S))$

$\neg W \vee (\neg S \vee R) \wedge \neg W \vee (\neg R \vee S)$

$(\neg W \vee \neg S \vee R) \wedge (\neg W \vee \neg R \vee S)$

End of Exam

Good Luck ☺

8)

4.5

Question1: Indicate whether each of the following statements is true or false. [5 marks]

1. Semantics define the "meaning" of sentences.	[T | F] T
2. A complete inference algorithm is one that proves some entailed sentences, not all of them.	[T | F] F
3. A sound inference algorithm is the one that derives only entailed sentences.	[T | F] T
4. Existential Instantiation can be applied several times to replace the existential sentence.	[T | F] F
5. Forward chaining consists of applying Modus Ponens rule successively.	[T | F] T
6. The resolution based inference algorithm is sound but not complete.	[T | F] F
7. To show that KB ⊨ α, we show that (KB ⇒ α) is unsatisfiable.	[T | F] F KB⊨¬α
8. A predicate is an atomic sentence in Propositional Logic.	[T | F] T F
9. Substitution in First Order Logic consists of replacing a ground term by a variable.	[T | F] F للعكس
10. Generalized Modus Ponens is an inference rule in First Order Logic.	[T | F] T

Question2: (PL Proof) [6 marks]

For the following sentence: (P ⇒ S) ⇒ (¬P ∨ S)

6

a. Compute the truth value using model checking.

P	S	P⇒S	¬P	¬P∨S	(P⇒S)⇒(¬P∨S)	
T	T	T	F	T	T	
T	F	F	F	F	T	
F	T	T	T	T	T	
F	F	T	T	T	T	

b. Is the sentence valid, satisfiable, or unsatisfiable?

valid (tautology)

Question3: (PL) [4 marks] 3,5

Translate the following sentences in PL using a vocabulary which you must define:

a. **If Mary has a runny nose and she has a fever, then she has a cold.**

~~hasRN_M ∧ hasF_M → hasC_M~~ $R_M \wedge F_M \rightarrow C_M$

M: Mary
RN: runny nose
F: fever
C: cold

b. **Nada likes Muna, and Jana likes Muna, but Lama does not like Muna.**

$LI_{NM} \wedge LI_{JM} \wedge \neg LI_{LM}$

$L_{NM} \wedge L_{JM} \wedge \neg L_{LM}$

N: Nada
M: Muna
J: Jana
L: Lama
LI: Like

c. **All the vegetables in the fridge are ripe.**

$I_{VF} \rightarrow R_V$ R_V

V: vegetables
I: in
F: Fridge
R: Ripe

d. **None of the vegetables taste bad, except those that are red.**

-0.5 $\neg T_{VB} \Leftrightarrow R_V$ $(V \wedge \neg R \rightarrow G) \vee (V \wedge R \rightarrow B)$

OR $V \wedge G \leftrightarrow \neg R$

V: vegetables
B: Bad
T: taste
R: Red

Question4: (FOL) Translation to first order logic [4.25 marks] 4

Suppose we have the following predicates and a universe where all of the objects are people.

Sat(X) --- X is satisfied with his life
Doc(X) --- X is a doctor
Den(X) --- X is a dentist
Child(X,Y) --- X is a child of Y
Ahmad --- an individual person

ess the following statements in FOL using the predicates and objects above.

English	FOL
1. A person is satisfied with his life if all his/her children are doctors.	-0.25 $\exists x\ Sat(x) \wedge (\forall y\ child(y,x) \wedge Doc(y))$ $\forall x\ Sat(x) \rightarrow \forall y\ child(x,y) \wedge Doc(y)$
2. All of Ahmad's children are dentists	$\forall x\ child(x, Ahmad) \rightarrow Den(x)$
3. Dentists are doctors.	$\forall x\ Den(x) \rightarrow Doc(x)$
4. Ahmad is satisfied with his life.	$Sat(Ahmad)$

Question5: (FOL) Translation to first order logic [6 marks]

5

Choose the correct translation for each sentence.

Sentence	**Choose the correct Translation**
1. No two adjacent countries have the same color.	1) $\forall x \exists y (Country(x) \land Country(y) \land Adjacent(x,y) \land \neg (x = y))) \Rightarrow \neg (Color(x) = Color(y))$
	2) $\neg \exists x, \quad \exists y\ Country(x) \land Country(y) \land Adjacent(x,y) \land (Color(x) = Color(y))$
2. Every student takes at least one course.	1) $\forall x (Student(x) \Rightarrow \forall y (Course(y) \land Takes(x,y)))$
	2) $\forall x (Student(x) \Rightarrow \exists y (Course(y) \land Takes(x,y)))$
3. No student likes every lecture.	1) $\neg\exists x [Student(x) \land \forall y[Lecture(y) \rightarrow Likes(x, y)]]$
	2) $\neg\exists x [Student(x) \rightarrow \forall y[Lecture(y) \rightarrow Likes(x, y)]]$
4. All students that had missed a lecture answered at least one question incorrectly.	1) $\forall x\ Student(x) \land \exists y\ Lecture(y) \land Missed(x,y) \Rightarrow \exists z\ Question(z) \land \neg CorrectAnswer(x,z)$
	2) $\forall x\ Student(x) \land \exists y\ Lecture(y) \land Missed(x,y) \Rightarrow \forall z\ Question(z) \rightarrow \neg CorrectAnswer(x,z)$
5. Sara and Nora are taking IT422.	1) $Taking(Sara, IT422) \land Taking(Nora, IT422)$
	2) $Taking(Sara, IT422) \rightarrow Taking(Nora, IT422)$
6. Males and Females are welcome to attend IT422.	1) $\forall x\ (Male(x) \lor Female(x)) \Rightarrow WelcomToattend(x,IT422))$
	2) $\forall x\ (Male(x) \lor Female(x)) \land WelcomToattend(x,IT422))$

Question6: **(FOL) Proof by contradiction [4.75 marks]**

a. **Given the following sentences in First-Order Logic:**

1. $\forall x$ pass(x, IT422) ⇒ satisfy (x)
2. $\forall x$ pass(x, IT422) ∧ grade (x, excellent) ⇒ happy(x)

Put each of the previous sentences into Conjunctive Normal Form showing all the inferences rules used.

( ) ∧ (∨ ∨) ∧ ( )

1) ¬ pass (x, IT422) ∨ satisfy (x) implication elemination

2) ¬(pass (x, IT422) ∧ grade (x, excellent)) ∨ happy(x) implication elemination

¬pass (x, IT422) ∨ ¬grade (x, excellent) ∨ happy (x) DeMorgan

✓

B. Apply **resolution rules in FOL** by using the **principle of proof by contradiction** and prove that **Amal** is designer and not programmer i.e. ***Designer(Amal) ^ ¬Programmer(Amal).*** Show any unifications required.

α = Designer (Amal) ∧ ¬ Programmer (Amal)

$\neg\alpha$ = ¬ Designer (Amal) ∨ Programmer (Amal) ✓

1. Programmer (x) v *Designer* (x)
2. ¬ Programmer (x) ∨ Likes(x, Java)
3. ¬ Likes(Amal, y) ∨ ¬Likes(Rami, y)
4. Likes(Rami, Java)
5. Likes(Rami, Photoshop)

KB ∧ ¬ a

Programmer (x) ∨ Designer (x) , ¬Designer (Amal) ∨ Programmer (Amal)

θ = {x/Amal}

¬Programmer (x) ∨ Likes (x, Java) , Programmer (Amal)

θ = {x/Amal}

¬Likes (Amal, y) ∨ ¬ Likes (Rami, y) , Likes (Amal, Java)

θ = {y/ Java}

Likes (Rami, Java) , ¬ Likes (Rami, Java) ✓

[] Empty clause

KB ∧ ¬ α is unsatisfiable

KB ⊨ α (KB entails α)

8) 1430

King Saud University
College of Computer and Information Sciences
Information Technology Department
CAP492- Artificial Intelligence-
Midterm 2 semester 2 1430-1431

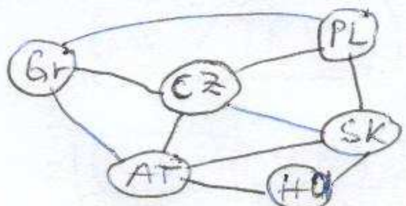
Student Name: Section:
Student ID: Serial #:

10 pts

Question1: Given the map of central Europe, consisting of the following countries : Germany (Gr), Poland (PL), Check republic (CZ), Slovakia (SK), Austria (AT), and Hungary (HU). You are required to color this map with three colors: **Red, Green, Blue** , so that any adjacent countries have different colors.

1. Give a formulation of this problem as a CSP stating: the variables, their domains, the constraints and draw the constraint graph.

Variables: Gr, PL, CZ, SK, AT, HU → 1,5 (0,25 each)
Domains: {Red, Green, Blue} ← 0,5
Constraints: Adjacent Countries have different Colors ; PL ≠ CZ ; PL ≠ SK
AT ≠ CZ ; AT ≠ SK ; AT ≠ HU ; CZ ≠ SK ; SK ≠ HU
2,5 (0,25 each)
Constraint graph:



2. Compute the degree heuristic for each node of the constraint graph.

AT	CZ	Gr	HU	PL	SK
4	4	3	2	3	4

→ 3 (0,5 each)

3. Solve the problem using forward checking starting with the region with the highest degree heuristic then regions are selected using MRV. Order your variables alphabetically.

	4 AT	4 CZ	3 Gr	2 HU	3 PL	4 SK
initial	RGB	RGB	RGB	RGB	RGB	RGB
AT=R	R	GB	GB	GB	RGB	GB
CZ=G	R	G	B	GB	RB	B
Gr=B	R	G	B	GB	R	B
PL=R	R	G	B	GB	R	B
SK=B	R	G	B	G	R	B
HU=G						

3 pts (0,5 each line)

4. Explain why the minimum number of colors required to color this map is 3?

maximum closed graph extracted from constraint graph contains 3 nodes ⇒ 3 colors at least

There is Three adjacent Cities and they Must have different Colors

1

6 pts

Question 2

1. What is the dimension (number of rows and number of columns) of the truth table for a sentence with n variables and m connectives (counting identical connectives multiple times)? Justify your answers.

1 Number of rows…2^n because with n variables we have 2^n possibilities

1 Number of columns…at most $(n+m)$ (n = nbr of variables, m = " " connectives including final expression)

2. Convert the following propositional sentence into CNF form. Simplify when necessary:

$(P \Rightarrow Q) \vee \neg(Q \vee \neg R) = (\neg P \vee Q) \vee (\neg Q \wedge R)$ 1

$= (\neg Q \wedge R) \vee (\neg P \vee Q)$

$= (\underbrace{\neg Q \vee \neg P \vee Q}) \wedge (R \vee \neg P \vee Q)$ distributivity of $\wedge$ over $\vee$

$=$ True $\wedge (R \vee \neg P \vee Q)$

$= \boxed{(R \vee \neg P \vee Q)}$ 1

3. Describe modus Ponens rule. Using a truth table, prove that it is a sound rule.

Modus Ponens Rule : $\dfrac{\alpha \Rightarrow \beta, \alpha}{\beta}$

1

prove Rule is sound means prove that $(\alpha \Rightarrow \beta) \wedge \alpha \models \beta$

by truth table

α	β	$\alpha \Rightarrow \beta$	$(\alpha \Rightarrow \beta) \wedge \alpha$
1	1	1	1
1	0	0	0
0	1	1	0
0	0	1	0

1 proof

14pts **Question 3**

Given the following sentences:

Sentence	FOL translation
1) All cats are mammals	1) $\forall x\ cat(x) \Rightarrow mammal(x)$ (1)
2) All mammals produce milk	2) $\forall x\ mammal(x) \Rightarrow Produce\text{-}milk(x)$ (2)
3) Pussy is a cat	3) $cat(Pussy)$ (1)

a) Translate these sentences into first order logic. It is required to specify any **function** or **predicate** used. Use the table above to give your answers.

3 predicates (no functions)
$cat(x)$: x is a cat
$mammal(x)$: x is a mammal
$Produce\text{-}milk(x)$: x produces milk

1,5 — 0,5 each

b) Suppose that we have a Knowledge Base containing rules 1 and 2, and given that Pussy is a cat, prove that **Pussy is a mammal** using resolution algorithm. For this purpose recall the steps to follow and apply them to this context.

1,5

1 KB = $(cat(x) \Rightarrow mammal(x)) \wedge (mammal(x) \Rightarrow Produce\text{-}milk(x)) \wedge (cat(Pussy))$

0,5 $\alpha = \neg mammal(Pussy)$

Steps of Resolution:
- convert $KB \wedge \neg\alpha$ to CNF
- find unification
- apply resolution (merge clauses in CNF) if empty clause $\Rightarrow$ entailement

(1)

$KB \wedge \neg\alpha \xrightarrow{\text{to CNF}} (\neg cat(x) \vee mammal(x)) \wedge (\neg mammal(x) \vee Produce\text{-}milk(x)) \wedge cat(Pussy) \wedge \neg mammal(Pussy)$ (1)

$\theta = unif(\neg cat(x), \neg cat(Pussy))$

$\theta = \{x/Pussy\}$ (1)

c) ~~Using Forward chaining to prove that~~ **~~Pussy produces milk~~**. → Nex page

after unification

$KB \wedge \neg\alpha = (\neg cat(Pussy) \vee mammal(Pussy)) \wedge (\neg mammal(Pussy) \vee Produce\text{-}milk(Pussy)) \wedge cat(Pussy) \wedge \neg mammal(Pussy)$ (1)

$mammal(Pussy) \wedge (\neg mammal(Pussy) \vee Produce\text{-}milk(Pussy)) \wedge \neg mammal(Pussy)$ → $\square$ empty clause (1)

so Pussy is a mammal

c) Use forward chaining to prove that Pussy Produces milk.

Produce-milk (Pussy) ?

KB : 1) $cat(x) \Rightarrow mammal(x)$

2) $mammal(x) \Rightarrow Produce\text{-}milk(x)$

Fact Cat (Pussy)

using FC :

Produce-milk (Pussy)

x / Pussy

mammal (Pussy)

x / pussy

cat (Pussy)

1

1

اختبارات قديمة

1) ~

-1

1. *Please use* ***reflex agent*** *or* ***planning agent*** *to mark the following robots* **(2pts, 0.5pts/ea)**

Reflex 1.1 Deep Blue which plays chess game with human world champion (Reflex /Planning agent)

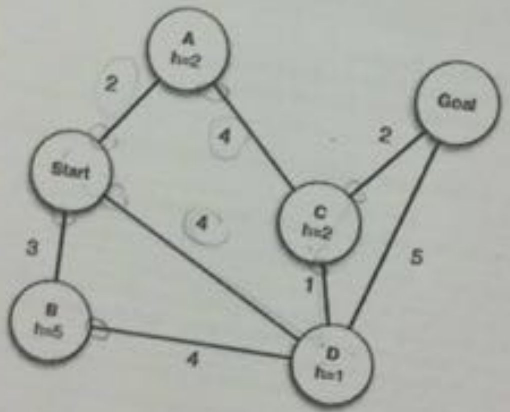
Reflex 1.2 Alarm Robot which makes sound when someone enters room (Reflex /Planning agent)

Planning 1.3 Car Robot which can drive itself on a curving and congested road (Reflex /Planning agent)

Planning 1.4 Water Robot which automatically supplies certain amount of water to the plants in a garden at 10am every day based on whether or not raining has been detected during the past 12 hours. (Reflex /Planning agent)

2. *Consider the following graph* **(5pts, 1pts/ea)**

Assume the ties are broken alphabetically. The sequence is A>B>C>D>G. The search algorithm ***does not expand to the same node*** *which has already been checked.*



-1

2.1 Which solution (not search process) would depth-first search find? ***(1 pts)*** DFS

A. S to A to C to G
B. S to A to C to D to G
C. S to D to G
D. S to A to C to D to B to G

2.2 Which ***solution*** *(not search process) would* ***breadth-first search*** *find?* ***(1 pts)***

A. S to A to C to G
B. S to B to D to G
C. S to D to G
D. S to D to C to G

2.3 Which ***solution*** *(not search process) would* ***uniform cost search*** *find?* ***(1 pts)***

A. S to A to C to G SAB DC

B. S to B to D to G

C. S to D to G

D. S to D to C to G

2.4 Which **solution** (not search process) would **greedy search** find? (*1 pts*)

A. S to A to C to G

B. S to B to D to G

C. S to D to G

D. S to D to C to G

2.5 Which **solution** (not search process) would **A* search** find? And is the **heuristic admissible**? (*1pts*)

-1

A. S to A to C to G, yes

B. S to B to D to G, no

C. S to D to G, no

2 D. S to D to C to G, yes

3. Draw a search tree for the 8-puzzle problem up to depth 4 (start state is depth 0) using the A* algorithm (omit repeated states) with the evaluation function f(n) = p(n) + h(n), where p(n) is the number of steps from the start state (start state is step 0) and h(n) is the number of misplaced tiles. Note that the actions for sliding tiles should be used in this order: right, left, up and down. Write the values of f and of its components p and h under each state. You may use an abbreviated notation indicating only the tiles that change. (6pts)

Start state

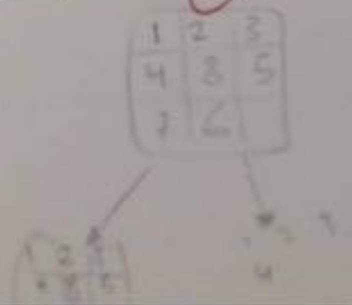
1	2	3
4	8	5
7	6	

→

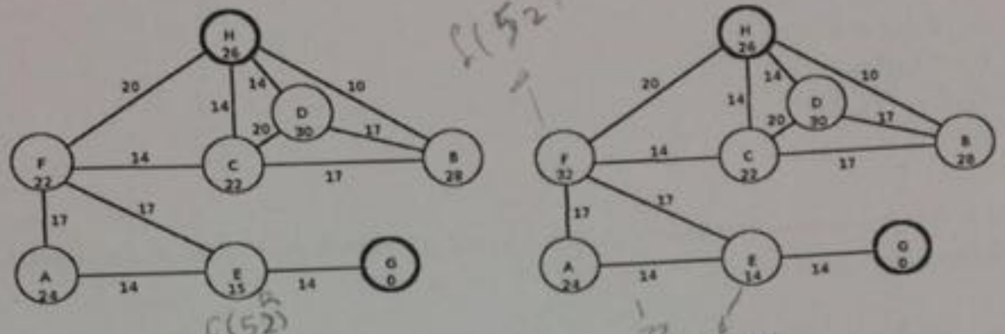
Goal state

1	2	3
4	5	6
7	8	

	No.+Direction (i.e., 5→)	p(n) No.of steps from start state	h(n) No. of misplaced tiles	f(n)=p(n)+h(n) Evaluation function
Depth 0	----------------	0	3	3
Depth 1	6 → R	1	3	4 = (1+3)
Depth 2	8 ↓ D	2	2	4 = (2+2)
Depth 3	5 ← L	3	1	4 = (3+1
Depth 4	6 ↑ U	4		4 = (4+0)



4. *Suppose you are asked to find the shortest path from H to G in the graphs below. For both of the graphs* **explain why** *the heuristic values shown are not valid for A*. Note the differences in the graphs at nodes F and E.*



(a) (b)

Reasons (explain using **one sentence**!):

4.1 (a) not admisable $h(n) \leq g(n)$ $15 \nleq 4$ ✗ **(1pts)** −0.5

how u got this heuristic

4.2 (b) not Consistent ✗ **(1pts)** —1

forgot to check consistency!

$h(n) \leq c(n,n') + h(n')$

$32 \leq 17+14$

$32 \nleq 31$

2) ~

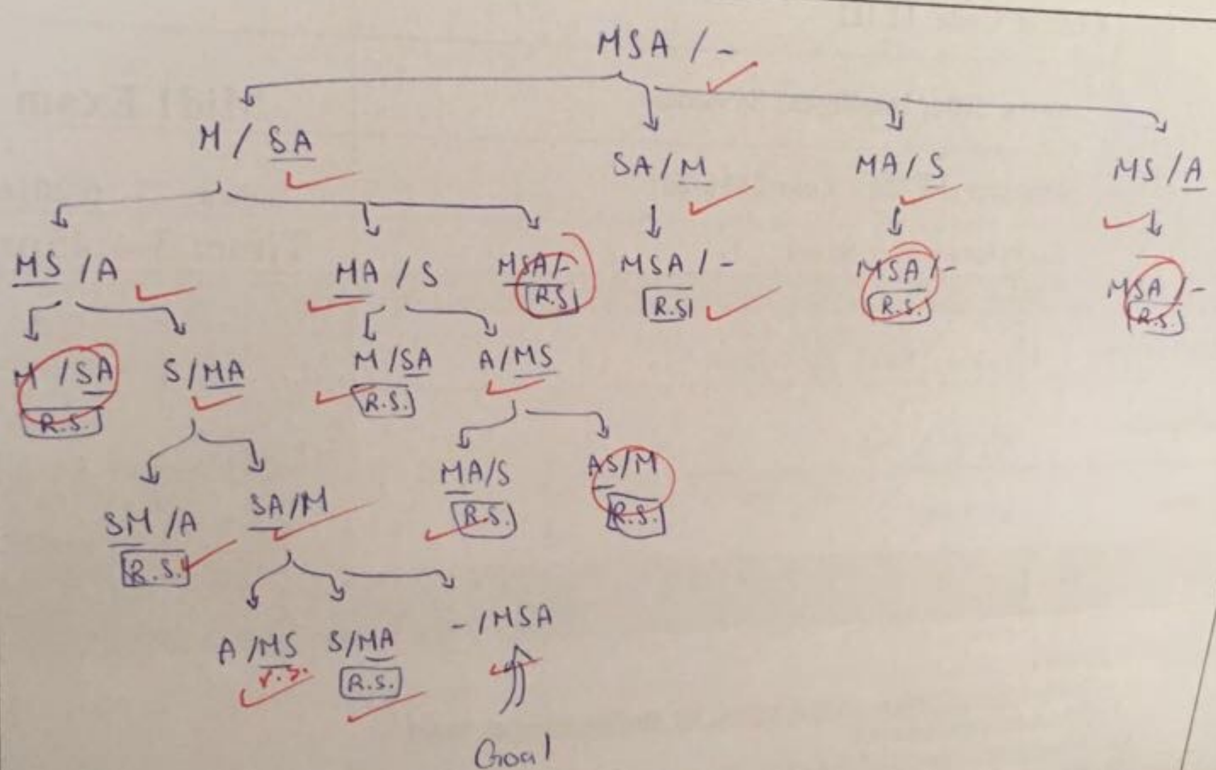
Section A - Problem formulation [8.5/ 8.5 marks]

Excellent !

Question 1:

Three friends want to cross a river. There is a boat that can carry a maximum of 100KG. Majid weighs 80KG, Sami weighs 60KG, and Ahmed weighs 40KG. How can they all cross the river ?

a) Draw the state space considering all the possible available actions.



Section B – Search

A) Question2. Answer the following questions regarding search algorithms.

a) **State whether the following statements are true or false:** [4.5 / 5 marks]

1.	In local search, it is essential to maintain the solution path	[T/F] — F
2.	The problem with the Hill Climbing algorithm is that it can get stuck in a global maximum.	[T/F] — F
3.	Breadth-first search is not optimal when all step costs are equal, because it always expands the shallowest unexpanded node.	[T/F] — F
4.	An admissible heuristic is also a consistent heuristic.	[T/F] — F
5.	In local search, successors are generated by combining two states.	[T/F] — F
6.	When the heuristic is consistent, *f(n)* values along any path are nondecreasing.	[T/F] — T

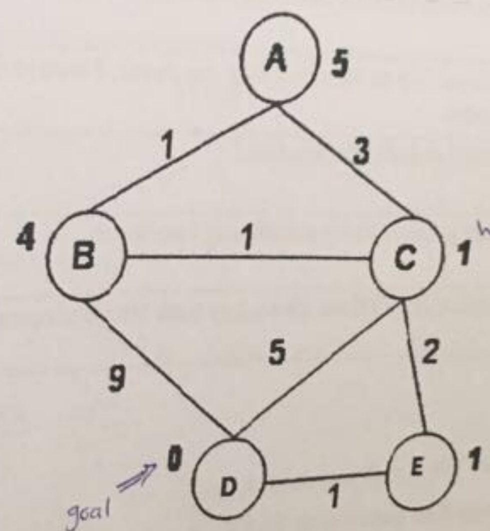
b) **Fill in the blank:**

1. Local beam search with k=1 is hill climbing.
2. Uniform-cost search is best-first search with f(n) = g(n) ~~depth of the node~~ × g(n)
3. In genetic algorithm, new states are generated by crossover and mutation.
4. In Simulated Annealing, at each iteration, the successor of current state is selected randomly
5. The major four criteria for evaluating search methods are: time complexity, space complexity, optimality, and completeness. Using one or more of these criteria, attempt to justify the following statements:
   a. Bidirectional search is preferred over Breath First Search. time complexity ($b^{d/2} + b^{d/2} < b^d$)
   b. Iterative deepening search is preferred over breadth-first search. space complexity

$\Downarrow$ $O(bd)$ $\Downarrow$ ~~$O(b^d)$~~ stores all nodes in memory

B) [/ 16.5 marks]

Consider the search graph drawn below where the numbers on the links are link costs and the numbers next to the states are heuristic estimates. Note that the arcs are undirected. Let A be the start state. For each of the following search strategies, indicate which goal state is reached (if any) and show the explored list, the frontier, the search tree, the solution path and the solution cost. Expand nodes in alphabetical order when you have more than one candidate for expansion.



Question 3: Uninformed Search [/ 6.5 marks]

a) Perform the search using **Breadth First Search** (BFS)

b) Perform the search using **Iterative Depth Search** (IDS).

Question 4: Informed Search [/ 10 marks]

Perform the search using A* algorithm.

$f(n) = g(n) + h(n)$

Question3 answer :

A) BFS

Frontier

~~A~~

~~B, C~~

~~C, D~~

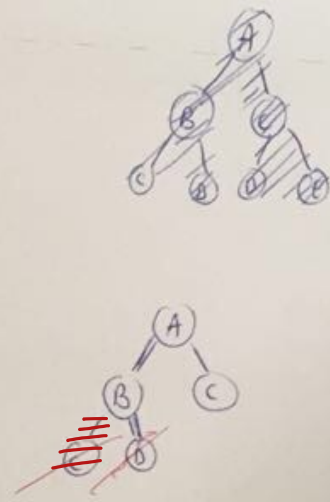
~~D, E~~

A

B, C

C

Search Tree:



Goal state reached: D

Cost: 10

Explored list: A, B,

Solution path: A, B, D

B) IDS

Frontier

d=0 A

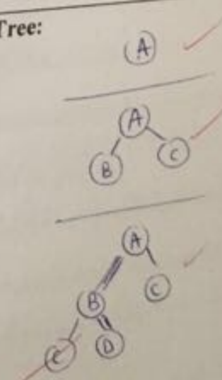
d=1 A
B, C
C

d=2 A
B, C
C, D, ~~E~~ R.S.
D, C

pop D => reached the goal

... 5 at each level

Search Tree:



Goal state reached: D

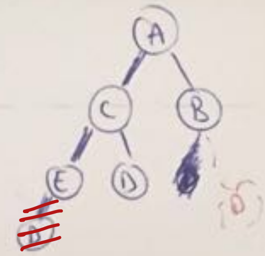
Cost: 10

Explored list: A, B, C

Solution path: A, B, D

Question 4 Answer: A* node(f(n), h(n), g(n))

8.75 ~~Well done~~

Frontier: ordered ascending	Search Tree:
A(5,5,0) C(4,1,3), B(5,4,1) B(5,4,1), E(6,1,5), D(8,0,8) E(6,1,5), D(8,0,8) D(6,0,6) Empty	
Explored list: A, C, B, E	**Goal state reached:** D (6,0,6)
Solution path: A, C, E, D	**Cost:** 6

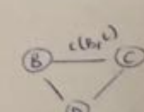
a) Is the heuristic given in the previous graph admissible? Explain. $h(n) \leq h^*(n)$

Yes, none of the nodes h(n) overestimate the true cost

$h(A) \leq 1+1+2+1$ (shortest path) & $h(B) \leq 1+2+1$ & $h(C) \leq 2+1$ & $h(D) \leq 0$ & $h(E) \leq 1$

b) Is the heuristic given in the previous graph consistent? Explain. $h(n) \leq h(n') + c(n,n')$

No, $h(B) = 4$, $h(C) = 1$, $c(B,C) = 1$



$h(B) \not\leq 1+1$

c) Did the A* algorithm find the optimal solution. Explain.

No, there is a shorter path cost = 5

A, B, C, E, D

Because graph search is used & h not consistent.

Graph search not consistent so not optimal

Good luck ☺

3) ~ Question 1. [7.5 points] Constraint Satisfaction Problems

7.5 / 7.5

(a) Assume that you are given a CSP over six variables, A, B, C, D, E and F, each having domains $\{1, 2, 3, 4, 5, 6\}$, with the following constraints:

1) $A \geq 4$
2) $A \geq E$
3) $A < D$
4) B is not 2 or 5
5) $B \neq D$
6) $|C-F| = 2$
7) D is either 1 or 6
8) $|E-D| \leq 1$
9) F is odd

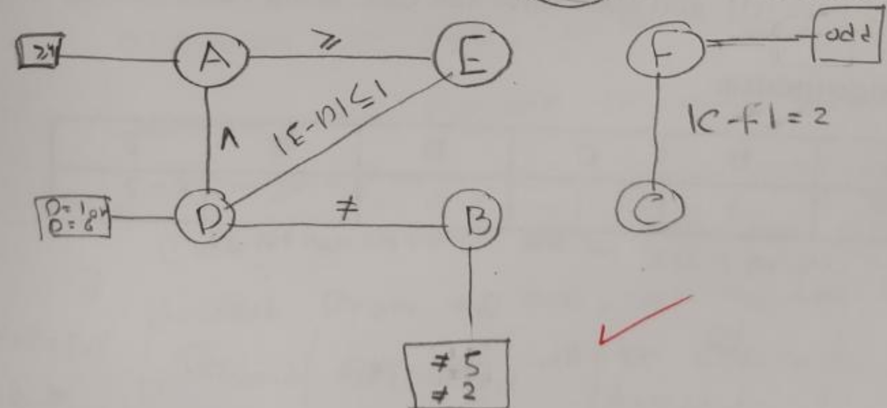
(i) On the grid below cross out the values from each domain that are eliminated by enforcing unary constraints.

0.75

A	B	C	D	E	F
~~1~~ ~~2~~ ~~3~~ 4 5 6	1 ~~2~~ 3 4 ~~5~~ 6	1 2 3 4 5 6	1 ~~2~~ ~~3~~ ~~4~~ ~~5~~ 6	1 2 3 4 5 6	1 ~~2~~ 3 ~~4~~ 5 ~~6~~

(ii) Draw the constraint graph after the unary constraints have been enforced.

1.25



(iii) If you were to use the MRV heuristic, which variable should you select for assignment first?

D Since it has the minimum remaining values in its domain

0.5

(iv) Apply the arc consistency algorithm (AC-3) after 3 is assigned to **F**.

Final Domains:

1.75

A	B	C	D	E	F
5	1,3,4	1,5	6	5	3

Steps:

Queue	A	B	C	D	E	F
	4,5,6	1,3,4,6	1,2,3,4,5,6	1,6	1,2,3,4,5,6	3
~~CF~~			1,5	1,6	1,2,3,4,5,6	3
~~CF~~	4,5,6	1,3,4,6		1,6	1,2,3,4,5,6	3
~~FE~~	4,5,6	1,3,4,6	1,5	1,6	1,2,3,4,5,6	3
~~AD~~	4,5	1,3,4,6	1,5	1,6	1,2,3,4,5,6	3
~~AE~~	4,5	1,3,4,6	1,5	6	1,2,3,4,5,6	3
~~DA~~	4,5	1,3,4,6	1,5	6	1,2,3,4,5,6	3
~~DB~~	4,5	1,3,4	1,5	6	1,2,3,4,5,6	3
~~DE~~	4,5	1,3,4	1,5	6	1,2,3,4,5,6	3
~~EA~~	4,5	1,3,4	1,5	6	1,2,3,4,5	3
~~ED~~	4,5	1,3,4	1,5	6	5	3
~~AD~~	4,5	1,3,4	1,5	6	5	3
	4,5	1,3,4	1,5	6	5	3
~~AE~~	5	1,3,4	1,5	6	5	3
~~DE~~	5	1,3,4	1,5	6	5	3

A DA
EA

(v) Assume no variables have been assigned yet, enforce unary constraints first (your answer from part (i)), and then solve the CSP using backtracking with forward checking.

Final Assignments:

1.75

A	B	C	D	E	F
5	1	1	6	5	3

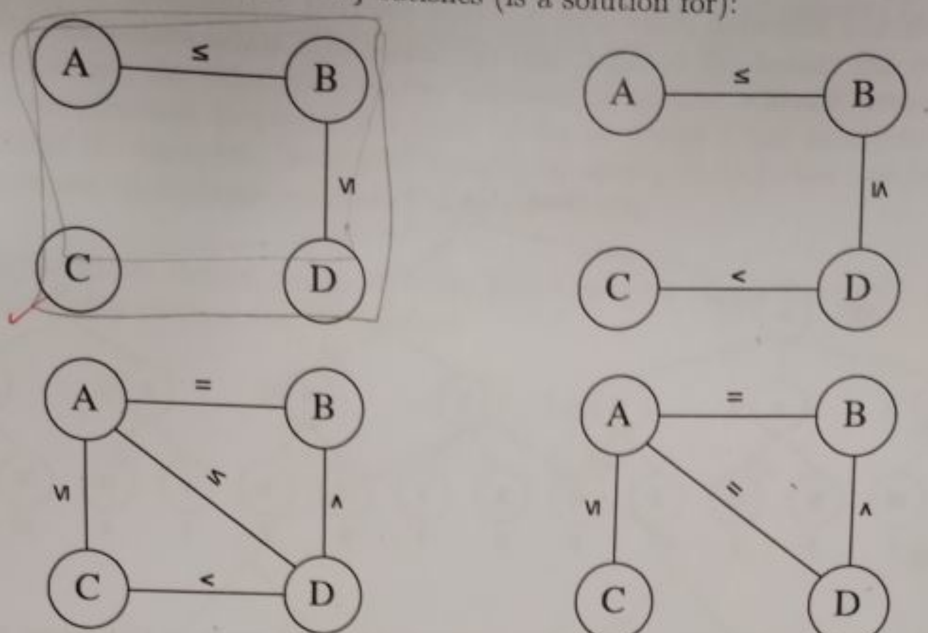
Using MRV we will start with D

Steps:

	A	B	C	D	E	F
	4,5,6	1,3,4,6	1,2,3,4,5,6	1,6	1,2,3,4,5,6	1,3,5
D = 6	4,5	1,3,4	1,2,3,4,5,6	6	5,6	1,3,5
A = 5	5	1,3,4	1,2,3,4,5,6	6	5	1,3,5
E = 5	5	1,3,4	1,2,3,4,5,6	6	5	1,3,5
B = 1	5	1	1,2,3,4,5,6	6	5	1,3,5
F = 3	5	1	1,5	6	5	3
C = 1	5	1	1	6	5	3

(b) For each of the following constraint-graphs, circle the graphs that this assignment $\{A = 5,\ B = 5,\ C = 5,\ D = 5\}$ satisfies (is a solution for):

0.5



(c) Forward checking and arc-consistency are both filtering approaches to detect failures early. Compare between the two in terms of effectiveness and computational cost.

arc-consistency is more effective that Forward Checking since it check all the constraint before assigning varibles, so ~~it~~ decreases the back tracking.

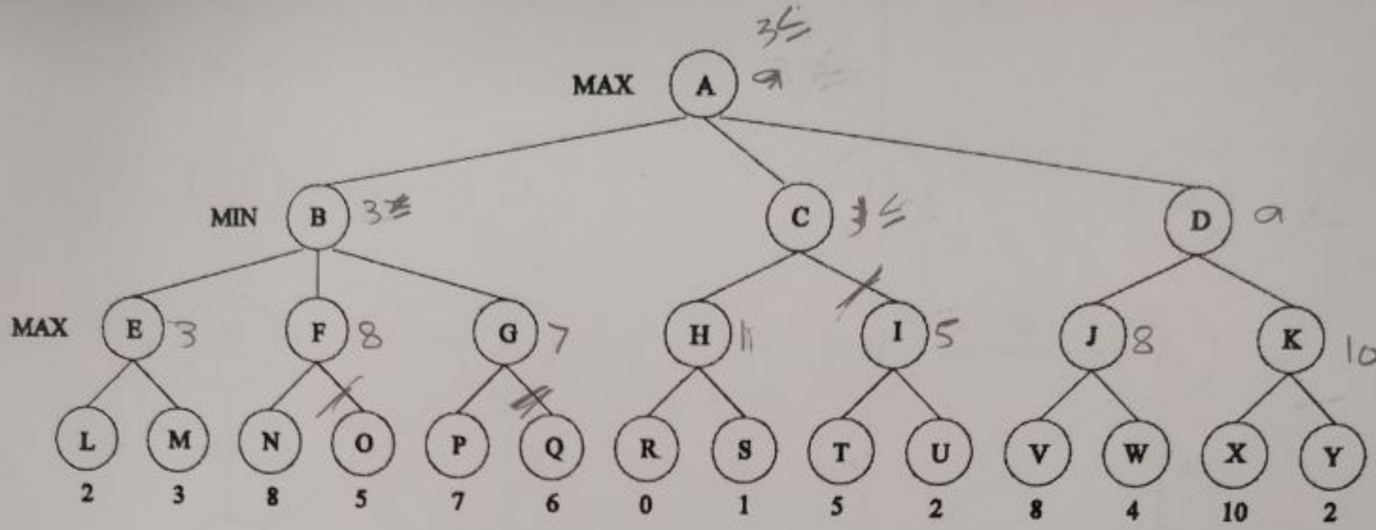
1

However, the Forward Checking has less cost than arc-consistency, because the arc consistency has to check each arc and when ever a value has been deleted from the tail, all the arc that the tail is head for them will be checked again which take time and memory reasources

78

~~Q~~uestion 2. [7.5 points]

(a) Consider the following game tree in which the root corresponds to a MAX node, children are visited left to right, and the values of a static evaluation function are given at the leaves.



(i) What are the **minimax values** computed at each node in this game tree?

2.25

A= 8 B= 3 C= 1 D= 8 E= 3 F= 8 G= 7 H= 1

I= 5 J= 8 K= 10

(ii) Which nodes would not be examined by Alpha-Beta Pruning algorithm?

O, Q, I (and its Children T and U), Y

1

(iii) In the game tree above assume the three MIN nodes are replaced by CHANCE nodes, and at a CHANCE node each successor move is equally likely. (For example, at node B there is a 1/3 chance of moving to each of its successors.) What are the **expectimax values** computed at each node in this game tree?

2.25

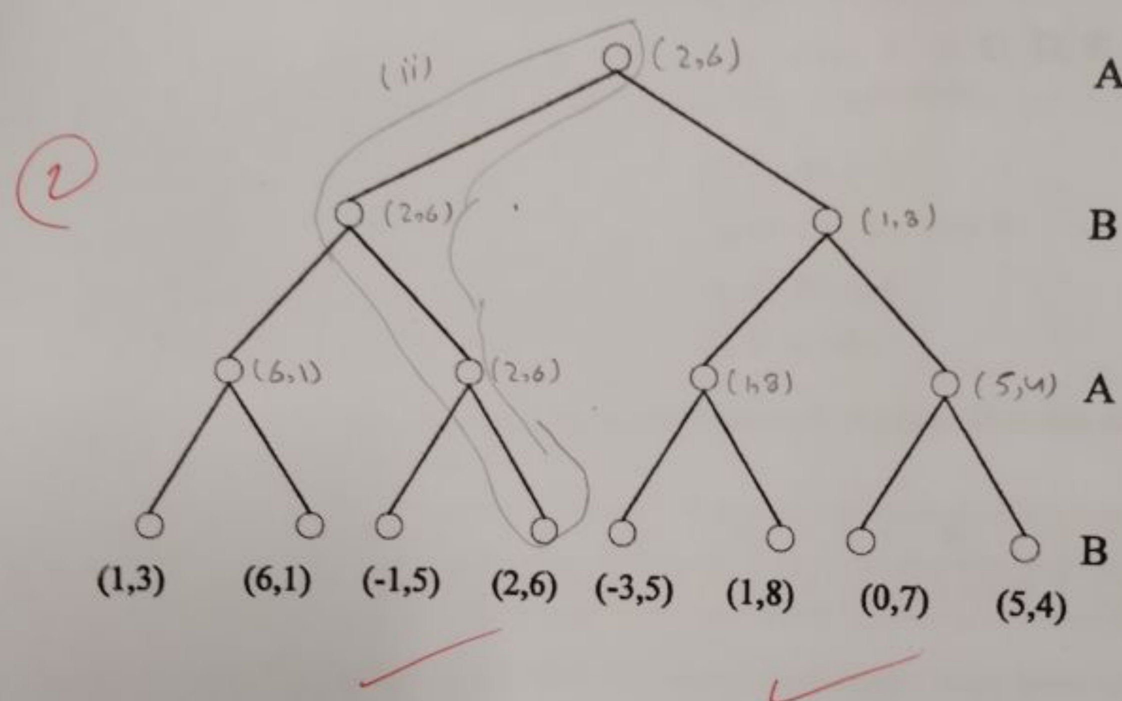
A= 9 B= 6 C= 3 D= 9 E= 3 F= 8 G= 7 H= 1

I= 5 J= 8 K= 10

(b) Consider a 2-player, non-zero-sum game in which players A and B alternate turns. At each leaf node, n, at the cutoff depth we compute a **pair of values** $(f_A(n), f_B(n))$, giving the value of that state from each players viewpoint.

(i) Propagate the value pairs up the following game tree, where the root (at depth 0) corresponds to player A's turn, nodes at depth 1 are positions where it's player B's turn, etc. Show your answers by adding them to the tree below. *Hint: Assume each player maximizes their own utility.*

(ii) What move should player **A** make based on your result from (i)? Show your answer by circling the selected arc. left



4) ~

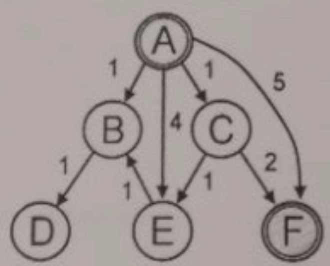
Question1: Please answer the following questions: [/9]

1. State whether each of the following statements is True or False: [3.5 / 4.5]

1. Blind Search uses the problem specific knowledge beyond the definition of the problem	[T | F]
2. Local beam search is similar to running K parallel hill climbing algorithms	[T | F]
3. The problem with the Hill Climbing algorithm is that it can get stuck in a ~~global~~ local maximum.	[T | F]
4. Depth First Search (DFS) keeps more nodes in memory than IDS.	[T | F]
5. Branching factor in a search tree is the number of actions available to the agent.	[T | F]
6. Breadth first search is not optimal in case actions have different cost.	[T | F]
7. If uniform cost search is complete, it is also optimal.	[T | F]
8. If a heuristic function $h()$ is admissible, A^* search is optimal.	[T | F]
9. Iterative Deeping Depth search (IDS) strategy is optimal when the step costs are all identical.	[T | F]

2. Choose the **BEST** answer for each question below: [2.5 / 4.5]

2.1. Consider the following search **GRAPH** in which **A is the start state** and **F is the goal state**. Assume that for each search method, the details are such that a state's children will be visited **in alphabetical order when possible**



a. In what **order** will the states be **expanded** by a depth-first tree search (no explored set)

a. ABECEF
b. ABDECF
c. ABDCEBDF
d. ABDCEF

ABECE

b. In what **order** will the states be **expanded** by a breadth-first graph search (with explored set)?

a. ABCDEF
b. ABCEF
c. ABCEDEF
d. ABCF

A
BCE

2.2. Local search is applied mainly for:

a. Rout finding problems
b. Optimization problems
c. Artificial problems.
d. Both a & b

2.3. On Thursday 18th October 2017, the United Arab of Emirates appoints the first Minister for Artificial Intelligence in the world because Artificial Intelligence concerns:

a. Understanding human intelligence
b. Building intelligent entities
c. Both a & b
d. None of the above

2.4. ______ is a test for intelligence in a computer, requiring that a human being should be unable to distinguish the machine from another human being by using the replies to questions put to both.

a. McCarthy Test
b. Turing Test
c. Goal Test
d. John Test

2.5. When solving a search problem, one should

a. Formulate the problem first, then the goal
b. Formulate the goal first, then the problem
c. Iterate between goal formulation and problem formulation
d. Iterate between goal formulation, problem formulation, and problem solving

2.6. The **time** complexity of ***DLS*** when branching factor is ***b***, ***L*** is the depth limit and the depth of goal is ***d*** is:

a. $O(b^d)$
b. $O(b+d)$
c. $O(b^L)$
d. $O(bd)$

2.7. In bidirectional search, the solution is found when:

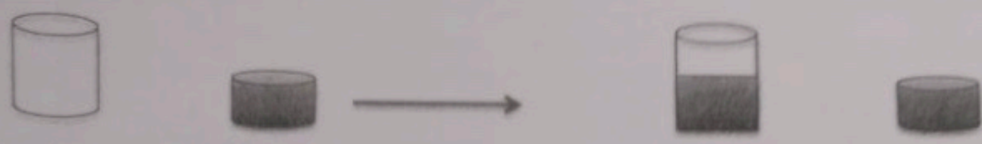
a. The goal test is satisfied.
b. The frontiers of the two searches intersect.
c. Both searches find different solutions.
d. One search finds the goal

2.8. A* complete and optimal provided that $h(n)$ is ad ______ (for tree search) or consis ____ (for graph search)

a. consistent, admissible
b. consistent, consistent
c. admissible, admissible
d. admissible, consistent

Question 2: Problem Formulation [12 /15]

A robot has an **empty** 5-liters jug and a **full** 2-liters jug. A water tap and a drain are available. The robot needs to get exactly **3** liters of water into the 5-liters jug and **2** liters of water into the 2-liters jug.



5-liters jug (empty) 2-liters jug(2 liters) 5-liters jug (3 liters) 2-liters jug (2 liters)

The robot can perform the following primitive actions only:

1. Completely fill a jug from the water tap (regardless of how much water is in it already);
2. Completely empty a jug down the drain;
3. Pour from one jug into the other until either
   (a) The first jug is empty, or
   (b) The second jug is full.

5 → 2

For example, if the big jug had 3 liters in it and the small jug had 1, the robot could pour 1 liter from the big jug into the small jug (filling the small jug), or could pour 1 liter from the small jug into the big jug (emptying the small jug), but could not pour any other amount from one into the other. The robot could also fill either jug to the brim, or empty either jug.

a) Propose a simple state representation: [1 /1]

x : will represent 5L jug & y : will represent 2L jug
(x,y) 2 Jugs, each could have (0-5)L

b) What is the initial state: [1 /1]

(0,2) Empty Jug, 2L Jug

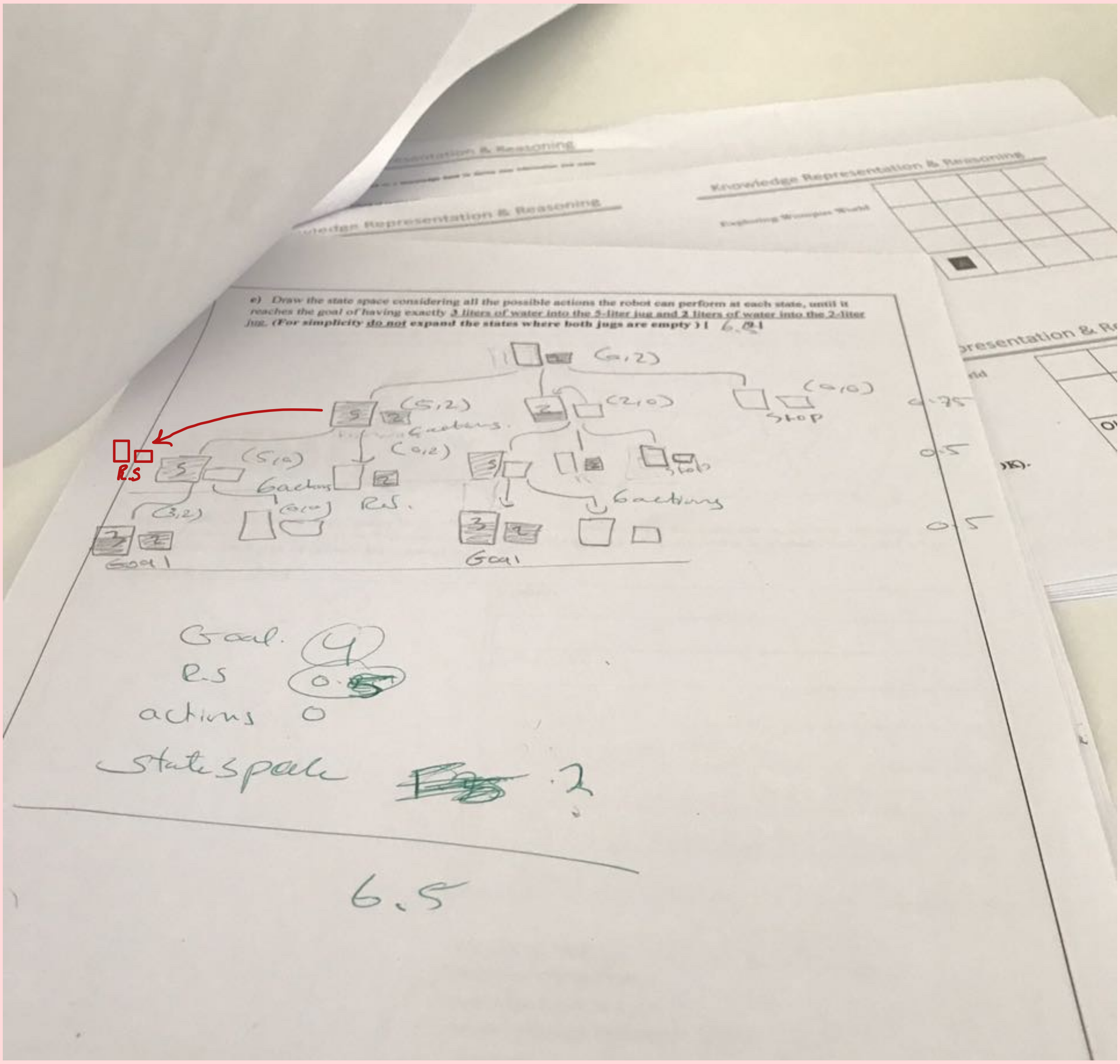
c) What is the goal state: [1 /1]

(3,2) 3L Jug, 2L Jug

d) What are the actions: [1.5/3]

① Filling jug to full
② Pouring jug until empty
③ Pouring on jug in the other

6 actions
one for each jug


Knowledge Representation & Reasoning

Exploring Wumpus World

e) Draw the state space considering all the possible actions the robot can perform at each state, until it reaches the goal of having exactly __3 liters of water into the 5-liter jug and 2 liters of water into the 2-liter jug.__ **(For simplicity __do not__ expand the states where both jugs are empty) [6.5]**

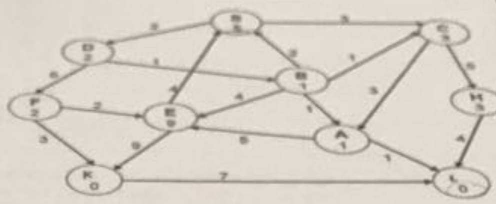
Goal. 4
R.S 0.5
actions 0
statespace ~~3~~ 2

6.5

Question 3: Search I /14

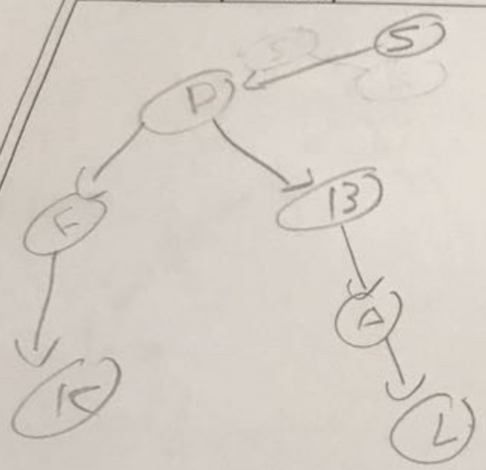
Part One - Uninformed and Informed Search (/9)

The search graph below represents the bicycle stations at the KSU female campus, where S (the start node) is the College of Computer and Information Sciences and the nodes K and L (the goals) are the two different gates for the campus sports center.



Find the path to the sports center using UCS, DLS, and A* graph search. Note that numbers on the arcs represent step costs and numbers in the nodes show heuristic cost to the goal of each node. **Expand nodes in alphabetical order when you have more than one candidate for expansion.**

a) UCS [1.75/3.25]



Frontier:

S
empty
D(2), C(3) A(4) 0.25
C(3), B(3), F(7) G(7) F(
B(3), A(6), F(7), H(8)
A(4), C(4), F(7), E(7), H(8)
C(4), L(5), F(7, E(7), H(8)

Explored List: S, D, C, B, ~~A~~, C

Solution Path, if any:

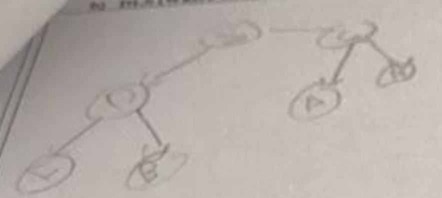
Solution Cost, if any: 5 for L and to K

Is the solution optimal? Yes

L : S, D, B, A, L

K = S, D, F, K

b) DLS (Where L=2) [/3.75]



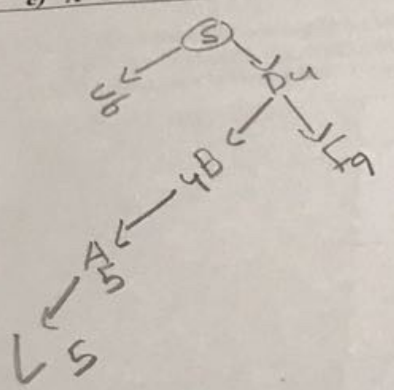
Frontier:

S
empty
G, D
A, H, D
H, D   (B), F
D   F
empty

0.5

Explored List: S, G, A, H, D, B, F
Solution Path, if any: NO
Solution Cost, if any: NO
Space Complexity, e.g. O(number) : $O(b^L)$ O(4)

c) A* Search [2.75 /3]



Frontier:

S(5)   empty
D(4), C(6)
B(4), C(6), F(9)
A(5), C(6), F(9)
L(5)

0.75

Explored List: S, D, B, A
Solution Path, if any: S, D, B, A, L
Solution Cost, if any: 5
Is h(n) admissible? yes

[illegible] arrived to the sports center, you decided to join a boot camp class to boost your metabolism and burn [illegible] on your Fitbit watch to monitor your heart rate and number of steps. Your goal is to maximize your [illegible]

Selected states	Metabolism rate in the current state	Metabolism rate in the next state	Temperature
1	50	70	60
2	75	100	45
3	100	80	30
4	90	90	15
5	150	200	5
6	250	270	0

≥ 80 current next

You applied a simulated annealing (SA) strategy to reach your goal, while your friend decided to go with just simple hill climbing (HC) one. Note that the probability drops when the temperature is less than 25, and the differences between the states is 50%. Compare between the two approaches in terms of:

25 Yes, No

Criteria	Simulated Annealing (SA)	Hill Climbing (HC)
How does the algorithm choose the next move?	randomly	depend of the value of ~~next,~~ neighbor if it more than current will take it
Is state 1 accepted?	yes	yes
Is state 3 accepted?	yes	No Highes neighbor Value
Is state 4 accepted?	No Yes	No

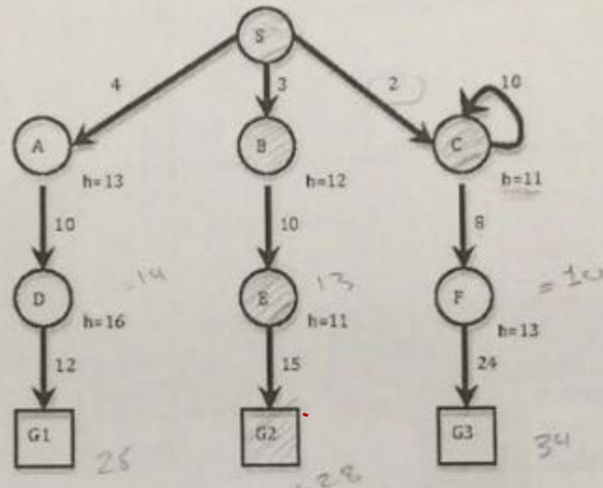
~

?

Exercise 2 [2 pts]

0.25 / 2

The figure shows the names of the nodes: G1, G2, and G3 are search-ending goal states, and S is the start state. The arcs are labeled with the cost of following them. Some searches may explore a state more than once. For each type of search, please list **in order the nodes that are explored (not the path).**



(1) Greedy Search (1pts)

(2) Uniform Cost Search (1pts)

1) nodes that are explored:-

S → C → B → E → G2 ✗ −1

~~S~~
~~C~~, B, A
~~B~~, A, F
~~E~~, A, F
~~G(2)~~, A, F

⇒ (UCS)

2) nodes that are explored:-

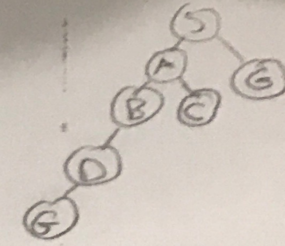
S - C - F - B - E - A - D - G1

−0.75

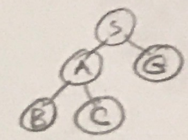
2/2

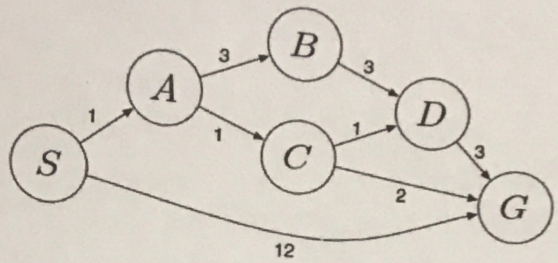
Question 3. [2 points] Consider the following graph:

DFS :



BFS.





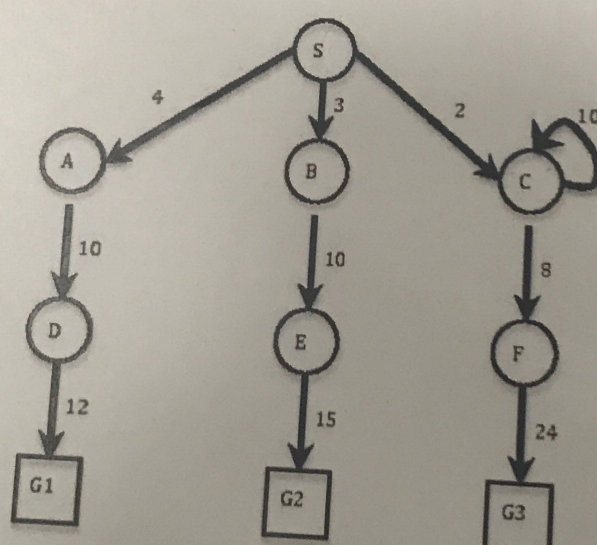
The start state is S and the only goal state is G. Assume that ties are broken alphabetically. For example, a partial plan $S \to X \to A$ would be expanded before $S \to X \to B$; similarly, $S \to A \to Z$ would be expanded before $S \to B \to A$.

a) What path will DFS tree search return? S – A – B – D – G

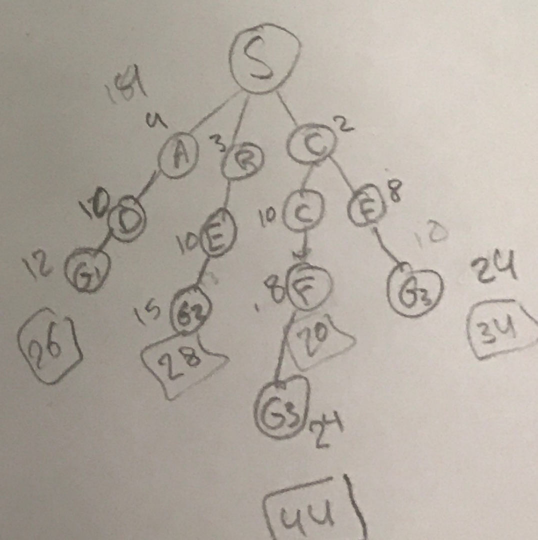
b) What path will BFS tree search return? S – G

2/2

Question 4. [2points] The figure shows the names of the nodes: G1, G2, and G3 are search-ending goal states, and S is the start state. The arcs are labeled with the cost of following them. Some searches may explore a state more than once. For **Uniform Cost Search**, please list **in order the nodes that are explored.**



S, C, B, A, F, C
, E, D, F, G1



SCBAFEDG1

S, C, B, A, F, C, E, D, F, G1

Cost $\boxed{26}$