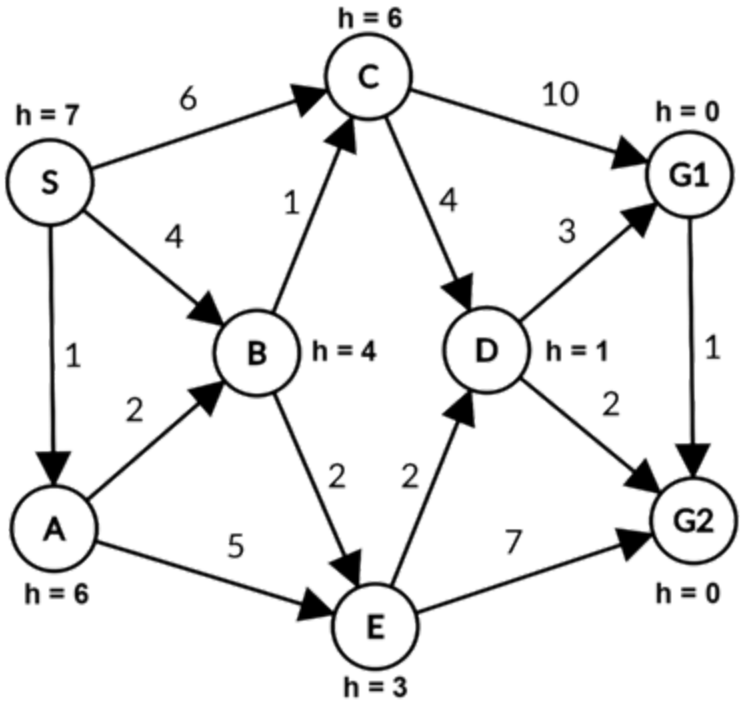
1. **TF [10 points, 1 per question]**

1. Genetic Algorithms have not been proven to always find the optimal solution. T
2. All learning agents are designed to measure and improve their way of thinking. T
3. Hill-Climbing is a local search method and completely deterministic. F
4. A Nondeterministic Polynomial (NP) Problem is a problem for which there exists an algorithm that can verify a given solution in a polynomial time, but that algorithm cannot always find a solution in polynomial time without any extra help. T
5. Rationality is nothing but to be successful. F
6. In the history of AI, there was a founder of AI who was also a Turing Award winner and a Nobel Prize winner. T
7. In game playing, the use of α-β pruning will change the results of minmax . F
8. Depth-First search will always find a goal state faster than Breadth-First search. F
9. The reward values of states can be used to represent the information of the goal states and/or the desired states. T
10. The utility values of states must be updated and propagated from other states' utility values before they can converge to some stable values. T

2. Search [20 points]

Consider the following graph. The start node is S, and the goal nodes are G1 and G2. The cost of each transition is shown on the corresponding edge and the heuristic value of each node is shown within that node.Using graph search, for each of the following search algorithms, show the order in which the nodes are expanded and the solution path.

When nodes are of equal depth and/or equal value, pop the nodes off the front of the open queue in alphabetical and numerical order. Each answer below should be a sequence of states, e.g., "S-A-B-C-D-E-G1". Note how the arcs are directed. Terminate a search only when a goal state is popped off the open queue, even for BFS and DFS. Loop detection: apply the "clean and robust algorithm" studied in class.



A. [6%] BFS **Rubric -1% for any error till zero**

[4%] Order of nodes popped off open queue	[2%] Solution Path
S - A - B - C - D - E - G1 Alternative Answer: S-A-B-C-E-D-G1	S - C - G1

B. [6%] DFS Rubric -1% for any error till zero

[4%] Order of nodes popped off open queue	[2%] Solution Path
S - A - B - C - D - G1 Alternate Ans: S-A-E-D-G1 (Alternate answer for the assumption when already enqueued node in the open list is not enqueued again)	S - A - B - C - D - G1 Alternate Ans: S-A-E-D-G1

C. [6%] A* Search Rubric -1% for any error till zero

[4%] Order of nodes popped off open queue	[2%] Solution Path
S - A - B - E - D - G2	S - A - B - E - D - G2

D. [2%] 2% for all correct, -1% for any wrong or missing

If h1 and h2 are admissible, which of the following are also guaranteed to be admissible? Circle all that apply:

(i) h1+h2

(ii) min(h1 , h2)

(iii) h1∗h2

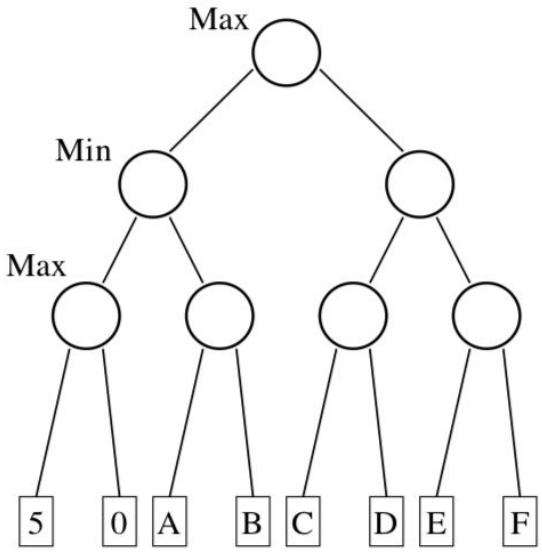
(iv) max(h1 , h2)

(v) (h1 + h2)/2

Ans: ii , iv, v

3. Game playing [20 points]

Consider the game tree picture below where the nodes are explored from left to right and standard alpha beta pruning is used.



a. [3%] Give a value of A such that B is pruned [5, inf]
   3 points for value between 5 and inf including 5
b. [3%] Give a value of A such that B is not pruned [-inf,5)
   3 points for value between inf and 5 for discluding 5
c. [3%] True or False: There are some values of A and B such that the subtree containing C and D is pruned. False

d. [5%] Assuming that B = 5 and A = 5, give a value of C and D such that the subtree containing E and F is pruned. Max (C and D) => [-inf, 5]
   5 points if Max (C,D) is between -inf and 5
e. [6%] If you are allowed to assign A-F arbitrarily, what is the MAXIMUM number of leaves that can be pruned, name the specific leaves ? 3 (B, E, and F)

   1.5 points for correct number, 1.5 points for each correct leaf

4. CSP [20 points]

You are in charge of scheduling for computer science classes that meet Mondays, Wednesdays and Fridays. There are 5 classes that meet on these days and 3 professors who will be teaching these classes. You are constrained by the fact that each professor can only teach one class at a time.
The classes are:
• Class 1 - Intro to Programming: meets from 9:00-11:00am
• Class 2 - Intro to Artificial Intelligence: meets from 9:00-1:00pm
• Class 3 - Natural Language Processing: meets from 10:30-12:00pm
• Class 4 - Computer Vision: meets from 11:00-12:30pm
• Class 5 - Machine Learning: meets from 12:00-1:00pm

The professors are:
• Professor A, who is available to teach Classes 2, 3 and 5.
• Professor B, who is available to teach Classes 1, 2, 3, 4, and 5.
• Professor C, who is available to teach Classes 3, 4, and 5.

a) [5%] Formulate this problem as a CSP problem in which there is one variable per class, stating the domains, and constraints. Constraints should be specified formally and precisely, but may be implicit rather than explicit.

Variables	**Domains**
C1	**B**
C2	**A,B**
C3	**A,B,C**
C4	**B, C**
C5	**A,B,C**

Constraints:

C1 != C2

C1 != C3

C2 != C3

C2 != C4

C2 != C5

C3 != C4

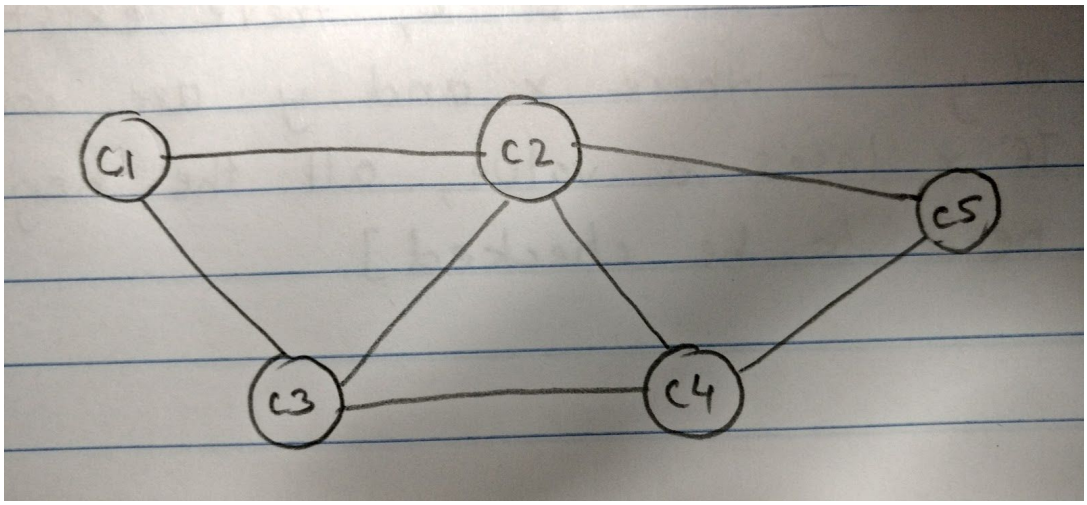
C4 != C5

Each error -1, until they got 0 points.
Miss one constraint -1, until they got 0 points.

b) [1%] Considering MRV [Minimum Remaining Values] as a heuristic, which of the variables will be chosen for assignment first? In case of a tie, list all such variables.

C1

c) [6%] Draw the constraint graph associated with your CSP.



Each error -1, until they got 0 points.
Miss one constraint -1, until they got 0 points.

d) [2%] Show the domains of the variables after running forward-checking on this initial graph considering Class 1 has been assigned Professor B and Class 2 has been assigned Professor A.

Variable	Domain
C1	B
C2	A

C3	**C**
C4	**B, C**
C5	**B, C**

Each error -1, until they got 0 points.
Miss one -1, until they got 0 points.

e) [3%] Show the domains of the variables after running arc-consistency on this initial graph. [This question is independent of d]

Variable	**Domain**
C1	**B**
C2	**A**
C3	**C**
C4	**B**
C5	**C**

Each error -1, until they got 0 points.
Miss one -1, until they got 0 points.

f) [3%] Give one solution to this CSP.

C1 = B, C2 = A, C3 = C, C4 = B, C5 = C.

Each error -1, until they got 0 points.

5. Reinforcement Learning [20 points]

Consider a system with two states and two actions. You perform actions and observe the rewards and transitions listed below. Each step lists the current state, reward, action, and resulting transition as $R_t(S_i) = r$; $a_k: S_i \rightarrow S_j$. Perform Q-Learning using a learning rate of $\alpha = 0.5$ and a discount factor of $\gamma = 0.6$ for each step. The tables below are the snapshots of the Q-table on each step. Initially, the table entries are all set to zero.

$$Q_{t+1}(s,a) = (1-\alpha)Q_t(s,a) + \alpha[R(s,a,s') + \gamma \max_{a'} Q_t(s',a')]$$

For each table, each wrong entry deduct 1 point, and 0 point for no correct entries.

1) $R_t(S_1) = 16$ $a_1: S_1 \rightarrow S_1$

Q	S_1	S_2
a_1	**8**	0
a_2	0	0

$$Q(S_1, a_1) = (1 - 0.5) * 0 + 0.5 * (16 + 0.6 * \max_{s'=S_1}(0,0)) = 8$$

2) $R_t(S_1) = 15$ $a_2: S_1 \rightarrow S_2$

Q	S_1	S_2
a_1	8	0
a_2	**7.5**	0

$$Q(S_1, a_2) = (1 - 0.5) * 0 + 0.5 * (15 + 0.6 * \max_{s'=S_2}(0,0)) = 7.5$$

3) $R_t(S_2) = -12$ $a_2: S_2 \rightarrow S_1$

Q	S_1	S_2
a_1	8	0
a_2	7.5	**-3.6**

$$Q(S_2, a_2) = (1 - 0.5) * 0 + 0.5 * (-12 + 0.6 * \max_{s'=S_1}(8,7.5)) = -3.6$$

4) $R_t(S_2) = -17$ $a_1: S_2 \rightarrow S_1$

Q	S_1	S_2
a_1	8	**-6.1**
a_2	7.5	-3.6

$$Q(S_2, a_1) = (1 - 0.5) * 0 + 0.5 * (-17 + 0.6 * \max_{s'=S_1}(8,7.5)) = -6.1$$

B) [4 points] What is the optimal policy at this point?

-2% for each error

$$\pi(S_1) = a_1$$

$$\pi(S_2) = a_2$$

6. MCQ [10 points, 2 per question]

1. In the discussions, we showed some remarkable AI accomplishments, please circle all that are true.

a. The DeepBlue chess player winning human chess master Kasparov. T
b. Space Shuttle has been successfully launched and returned. F
c. AlphaGo winning Go games against human Go masters. T
d. Nano technology inspired new materials and applications. F
e. The Grand Unified Theory for physics. F

2. In the discussions, we showed a set of common criteria for measuring and comparing search algorithms, please circle all that are true:

a. Completeness, admissibility, and consistency. F
b. Completeness, time complexity, space complexity, and optimality. T
c. The density of goal states and the branch factors.F
d. The representation of states in the search space.F
e. The location of goal states in the search space.F

3. In the discussions, we discussed the conditions for A* to guarantee optimality, please circle all that are true:

a. If the heuristic function for estimating the future cost is admissible T
b. If the heuristic function for estimating the future cost is consistent T
c. If the heuristic function for estimating the future cost is exactly correct T
d. If the heuristic function will always overestimates the future cost F
e. If the heuristic function treats all future possibilities as equal F

4. In the discussions, we showed that the α-β pruning method has a number characteristics, please circle all that are true:

a. Max will update α whenever $v < \alpha$ T
b. Min will update β whenever $v > \beta$ T
c. Using the α-β pruning will possibly speed up the minmax algorithm T
d. Using the α-β pruning will reduce the search space to be searched T
e. The α-β pruning method can also be used for depth-first search F

5. Simulated Annealing (SA) is designed to increase the chance to find the global extrema, please circle all that are true:

a. SA is an idea that was borrowed from nature. T
b. SA can guarantee finding the optimal solution no matter how it is applied. F
c. The higher the temperature, the more SA will behave like Hill-Climbing. F
d. It is always better to use SA than the Genetic Algorithm. F
e. The slower SA lowers the temperature, the more likely it will find a better solution. T