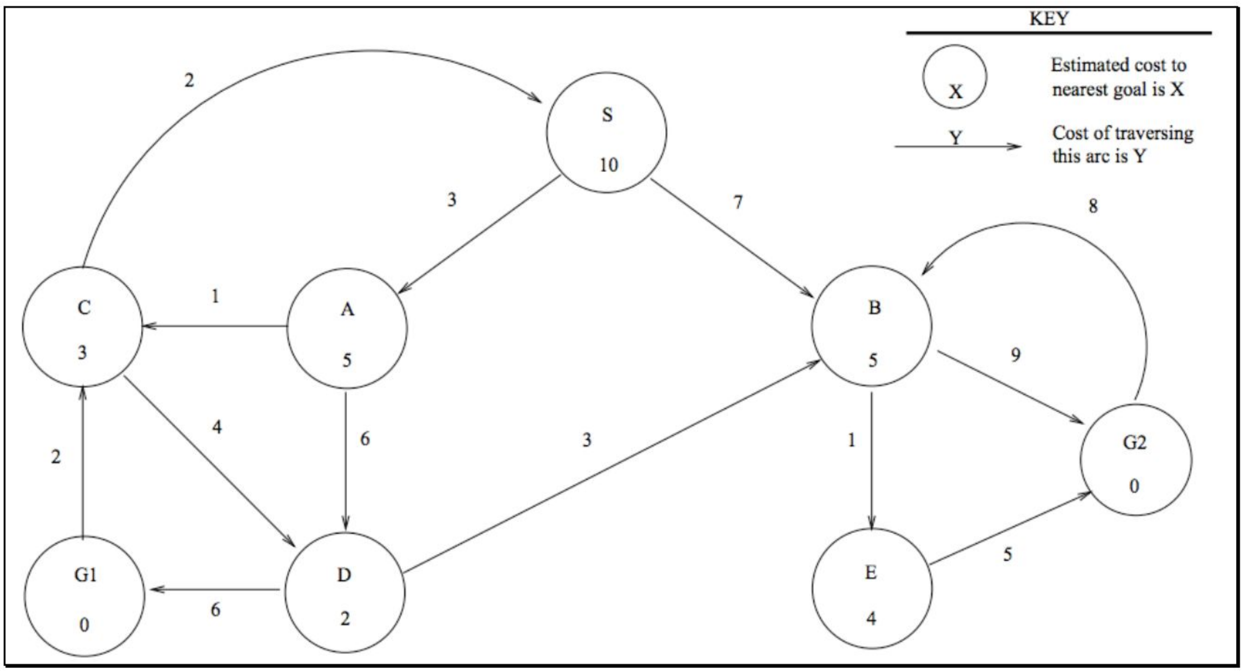
1. TF [10 points]

-1% per wrong answer

F	1. The study of intelligence is not a science but an art or engineering.
F	2. A rational agent can pass the basic Turing Test but not the total Turing Test.
T	3. Genetic Algorithms have not been proven to always find the optimal solution.
T	4. All learning agents are designed to measure and improve their way of thinking.
F	5. Hill-Climbing is a local search method and is completely deterministic.
T	6. An NP-Complete problem is a problem for which there exists an algorithm that can verify a given solution in a polynomial time, but for which there is no known algorithm that can find a solution in polynomial time.
F	7. Rationality is nothing but to be successful.
T	8. In the history of AI, there was a founder of AI who was also a Turing Award winner and a Nobel Prize winner.
F	9. In game playing, the use of α-β pruning will change the results of minimax.
F	10. Depth-First search will always find a goal state faster than Breadth-First search.

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 <u>only</u> 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.

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

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

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

[4%] Order of nodes popped off open queue	[2%] Solution Path
S-A-C-D-B-E-G2 Alternate Ans: S-A-C-D-G1 (Alternate answer for the assumption when already enqueued node in the open list is not enqueued again)	S-A-C-D-B-E-G2 Alternate Ans: S-A-C-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-C-D-B-E-G2	S-B-E-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) h1∗h2

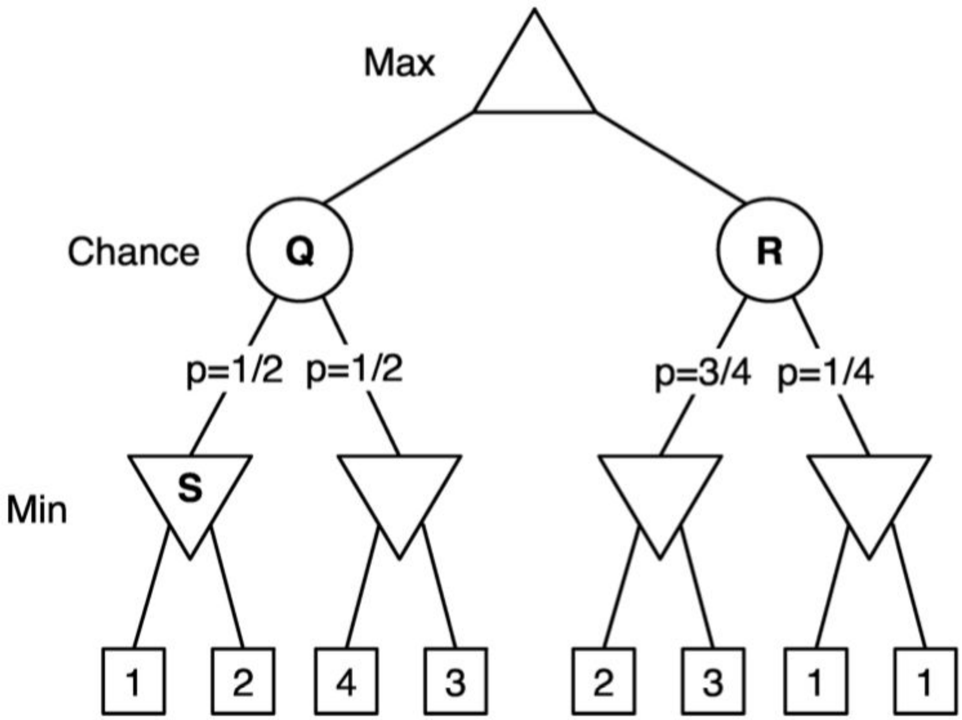
(iii) max(h1 , h2)

(iv) (α)h1 + (1−α)h2, for α∈[0,1]

Ans: iii , iv

3. Game playing [20 points]

The figure below shows the game tree of a two-player game; the first player is the maximizer and the second player is the minimizer. Use the tree to answer the following questions:



a. [4%] What is the value of the node labeled S?
   1
b. [4%] What is the expected value of the node labeled Q?
   2
c. [4%] What is the expected value of the node labeled R?
   7/4
d. [4%] What is the expected value of the game (root node)?
   2
e. [4%] True or False: You have been provided with enough information for you to be able to modify the alpha-beta pruning algorithm to work on this game tree.
   True

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 8:00-9:00am
- Class 2 - Intro to Artificial Intelligence: meets from 8:30-9:30am
- Class 3 - Natural Language Processing: meets from 9:00-10:00am
- Class 4 - Computer Vision: meets from 9:00-10:00am
- Class 5 - Machine Learning: meets from 9:30-10:30am

The professors are:
- Professor A, who is available to teach Classes 3 and 4.
- Professor B, who is available to teach Classes 2, 3, 4, and 5.
- Professor C, who is available to teach Classes 1, 2, 3, 4, 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	**C**
C2	**B,C**
C3	**A,B,C**
C4	**A,B,C**
C5	**B,C**

Constraints:

C1 != C2

C2 != C3

C3 != C4

C4 != C5

C2 != C4

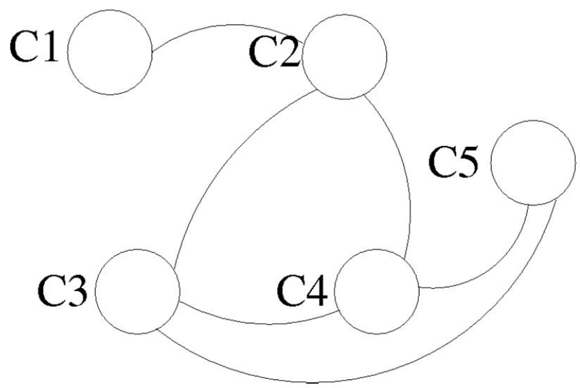
C3 != C5

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 constrain -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 C and Class 5 has been assigned Professor B.

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

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 part d].

Variable **Domain**

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

Note that C5 cannot possibly be C, but arc consistency does not rule it out.

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 = C, C2 = B, C3 = C, C4 = A, C5 = B. One other solution is possible (where C3 and C4 are switched).

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.

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

A) [16 points] Write down the results of Q-table entries for 4 consecutive steps.

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) $R_t(S_1) = -18$ a_2:$S_1 \rightarrow S_2$

Q	S_1	S_2
a_1	8	0
a_2	**-5.25**	-3.6

$$Q(S_1, a_2) = (1 - 0.5) * 7.5 + 0.5 * (-18 + 0.6 * \max_{s'=S_2}(0, -3.6)) = -5.25$$

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

-2% for each error

$$\pi(S_1) = a_1$$

$$\pi(S_2) = a_1$$

6. MCQ [10 points]

1. In the discussions, we showed the definition of arc-consistency. Please circle all that are true:
    a. (T) A variable X is arc-consistent with another variable Y, if for any valid value that is assigned to X, there will be a valid value for Y.
    b. (F) If X is arc-consistent with Y, then Y is arc-consistent with X.
    c. (T) Arc-consistency should be checked whenever the valid values of a variable are reduced.
    d. (F) Arc-consistency can only be applied to binary constraints.
    e. (F) The AC3 algorithm uses depth-first search but not arc-consistency.

2. In the discussions, we showed a number of DARPA grand challenges. Please circle all that are true:
    a. (T) One challenge is for self-driving cars to self-drive from LA to Las Vegas.
    b. (T) One challenge is for robots to perform tasks for fire fighting
    c. (F) One challenge is for computer chess players to win human chess masters
    d. (F) One challenge is for computer Go players to win human Go players
    e. (T) One challenge is for self-driving cars to safely go through a small town

3. In the discussions, we showed some remarkable AI accomplishments. Please circle all that are true:
    a. (T) The DeepBlue chess computer defeating human chess grandmaster Kasparov.
    b. (F) The Space Shuttle has been successfully launched and returned.
    c. (T) AlphaGo winning Go games against human Go masters.
    d. (F) Nanotechnology inspired new materials and applications.
    e. (F) The Grand Unified Theory for physics.

4. In the discussions, we showed a set of common criteria for measuring and comparing search algorithms. Please circle all that are true:
    a. (F) Completeness, admissibility, and consistency.
    b. (T) Completeness, time complexity, space complexity, and optimality.
    c. (F) The density of goal states and the branching factors.
    d. (F) The representation of states in the search space.
    e. (F) The location of goal states in the search space.

5. In the discussions, we discussed the conditions for A* to guarantee optimality. Please circle all the conditions under which A* is optimal:
    a. (T) If the heuristic function for estimating the future cost is admissible
    b. (T) If the heuristic function for estimating the future cost is consistent
    c. (T) If the heuristic function for estimating the future cost is exactly correct
    d. (F) If the heuristic function always overestimates the future cost
    e. (F) If the heuristic function treats all future possibilities as equal