CSCI 360 ♦ Introduction to Artificial Intelligence ♦ Mid-term Exam

Name (print): ______________________________

Student ID: ______________________________

I hereby confirm that (a) I will neither give nor receive unauthorized aid on this exam, and (b) I will neither record nor publicize the content of this exam.

Signature: ______________________________

Part I. Short Answer Questions (20 points)

1. Please use the relations such as Player(x), Star(y) and HighlyPaid(z) to express the following two sentences regarding the NBA players in first-order logic (2*3 = 6 points):

   - Some players are not stars. _________ $\exists x \;\; P(x) \wedge \neg E(x)$ _________________
   - Only stars are highly paid. _________ $\forall x \;\; H(x) \rightarrow E(x)$ _________________

2. Recall that "uniform-cost search" expands the node with the lowest path cost, and "best-first search" expands the node that appears to be closest to the goal. Please explain, in a short sentence, when each of the following statements is true (3*2 points = 6 points):

- Breadth-first search is a special case of uniform-cost search.

  _*when the step cost is always 1 (or always a constant value)*_______________________________

- Breadth-first, depth-first, and uniform-cost searches are special cases of "best-first" search.

  _*when the priority queue (defined based on the true cost to goal) happens to behave like a queue, stack, or priority queue based on step cost*_________________________________

- Uniform-cost search is a special case of A* search.

  __*when h(n) = 0 for all nodes in A* search*____

3. Recall that "unification" is needed to reason about first order logic. For each pair of sentences below, explain if they can be unified, and if the answer is yes, provide the corresponding unifier (4*2 = 8 points).

- $P(A,B,B), \quad P(x,y,z)$

  Can they be unified? ____YES_________ Unifier (if exists) ______x / A, y / B, z / B______________

- *P(x,A,g(x)),   P(f(y),y,z)*

  Can they be unified? ____YES______ Unifier (if exists) ___x / f(A), y / A, z / g(f(A))______

- *Knows(Father(y),y),   Knows(x,x)*

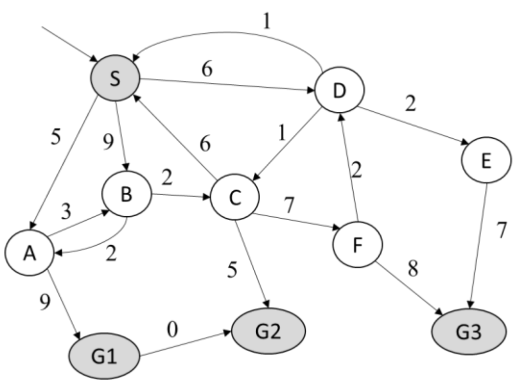
  Can they be unified? ______NO______ Unifier (if exists) ______________________________

- *Hates(A,B),   Loves(x,x)*

  Can they be unified? ______NO______ Unifier (if exists) ______________________________

Part II. Graph Search (20 points)

In "Graph Search" algorithms, the visited nodes are recorded so they will not be visited again. Please run these algorithms on the state space graph below, where the initial state is S, the goal states are G1, G2 and G3, the step costs are edge labels, and the heuristic function is given in the right-hand-side table.



State	*h(n)*
S	*5*
A	*7*
B	*3*
C	*4*
D	*6*
E	*5*
F	*6*

For each algorithm below, please show (1) which of the three goal states (G1, G2, and G3) is reached first, and (2) what is the sequence of "expanded" nodes (the sequence until a goal state is reached).

(a) Hill Climbing (2+4 = 6 points):

Goal reached: __G2________
Sequence of expanded nodes: _______S, B, C, G2____________________

(b) Iterative Deepening (2 + 4 = 6 points):

Goal reached: ___G1_______
Sequence of expanded nodes: ________S, S A B D, S A G1_____________

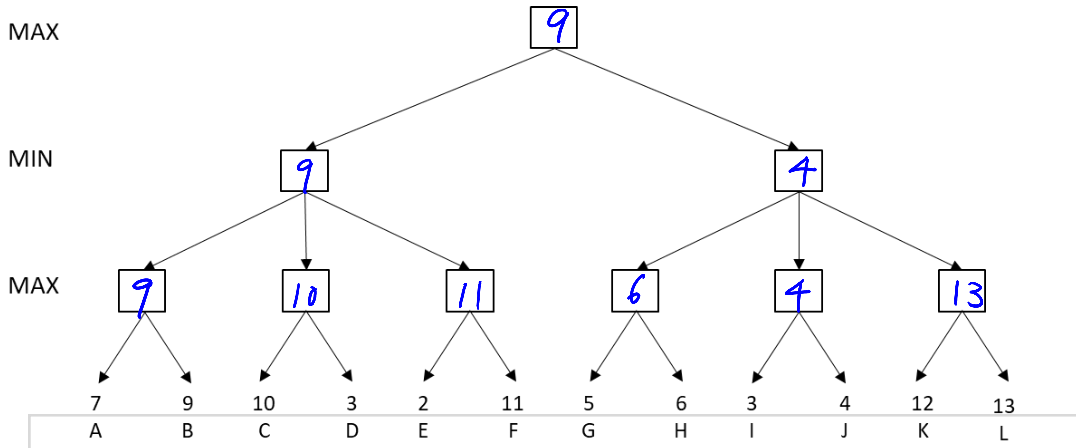
(c) A* Search (2 + 6 = 8 points):

Goal reached: _____G2______
Sequence of expanded nodes: _________S, A, B, D, C, G2____________

Note: use alphabetic order as tie-breaker (given equal cost in the priority queue, expand alphabetically).

Part IV. Adversarial Search (30 points)

In the game tree below, please first run the Minimax algorithm (without alpha-beta pruning) and compute the minimax values for all nodes.



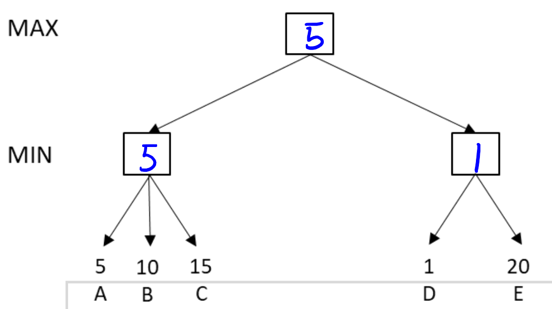
(1) Please compute the minimax values based on the utility values given at the bottom. (5 points)

Top (9), left (9), right (4), left-left (9), left-mid (10), left-right (11)
right-left (6), right-mid (4), right-right (13)

(2) Assume that bottom nodes are visited in alphabetic order (from A, B, C, … to J, K, L). Which of these nodes will be skipped by alpha-beta pruning? (10 points)

D, I, J, K, L

Below is another game tree generated by the Minimax search algorithm with alpha-beta pruning.



(1) Please write down the minimax values computed by the algorithm. (5 points)

Top (5), left (5), right (1)

(2) Do any nodes get pruned? And if the answer is yes, which nodes? (5 points)

'E'

(3) Is there an order to visit the nodes that achieves more pruning? If yes, which order? (5 points)

NO

Part VI. First Order Logic (30 points)

1. Translate the formula to Conjunctive Normal Form (CNF). Hint: you need to remove ($\exists$). (10 points)
   - $\forall x\ \exists y\ (\ P(x) \wedge A(y) \wedge D(F(x),y) \wedge R(x,y)\ )$

$\forall x\ (\ P(x) \wedge A(\ Q(x)\ ) \wedge D(F(x),\ Q(x)\ ) \wedge R(x,\ Q(x)\ )\ )$

2. Assume that all variables are natural numbers (0, 1, 2, ..., ∞) and ≥ means "greater than or equal to". Consider the following two sentences in first order logic:
   - (A) $\forall x\ \exists y\ (\ x \geq y\ )$
   - (B) $\exists y\ \forall x\ (\ x \geq y\ )$

Prove that (B) logically entails (A) using resolution.
Hint: transform (B)∧(¬A) to CNF and then show the CNF formula is unsatisfiable using resolution.

(1) Transform ($\exists y\ \forall x\ (\ x \geq y\ )$) ∧ ($\neg\ \forall x\ \exists y\ (\ x \geq y\ )$) to CNF. (10 points)

Push negation inside: ($\exists x \forall\ y \neg (\ x \geq y\ )$) ---- 2 points

Get rid of existential quantifiers: ---- 4 points

$\forall x\ (\ x \geq P\ )$

$\forall\ y \neg (\ Q \geq y\ )$ ---- 4 points

(2) Using "resolution" to prove the CNF formula is unsatisfiable. (10 points)

$\forall x\ (\ x \geq P\ )$ $\qquad$ $\forall\ y \neg (\ Q \geq y\ )$

They may be interpreted as two "unit" clauses (let GE denote ≥ for ease of comprehension)

($\forall x\ \ GE(x,P)$) $\qquad$ ($\forall\ y \neg\ GE(Q, y)$)

Find the unifier (x/Q, y/P) ---- 5 points

$(\ GE(Q,P)\ )$ $\qquad$ $(\ \neg\ GE(Q,P)\ )$

\ $\qquad$ /

$(\ )$ ---- 5 points

QED