CS-171, Intro to A.I. — Mid-term Exam — Fall Quarter, 2014

YOUR NAME: ____

YOUR ID: __________ ID TO RIGHT: __________ ROW: ________ SEAT: ________

The exam will begin on the next page. <u>Please, do not turn the page until told.</u>

When you are told to begin the exam, please check first to make sure that you have all ten pages, as numbered 1-10 in the bottom-right corner of each page. We wish to avoid copy problems. We will supply a new exam for any copy problems.

The exam is closed-notes, closed-book. No calculators, cell phones, electronics.

Please clear your desk entirely, except for pen, pencil, eraser, a blank piece of paper (for scratch pad use), and an optional water bottle. Please write your name and ID# on the blank piece of paper and turn it in with your exam.

<u>This page summarizes the points for each question, so you can plan your time.</u>

1. (10 pts total, -1 pt each wrong answer, but not negative) MINIMAX WITH ALPHA-BETA PRUNING.

2. (10 pts total, 2 pts each) CSP WITH BACKTRACKING SEARCH.

3. (6 pts total, 2 pts each) CONVERSION TO CNF.

4. (6 pts total, 2 pts each) RESOLUTION OF CLAUSES.

5. (10 pts total, 1 pt each) LOGIC.

6. (8 pts total, 2 pts each) TASK ENVIRONMENT.

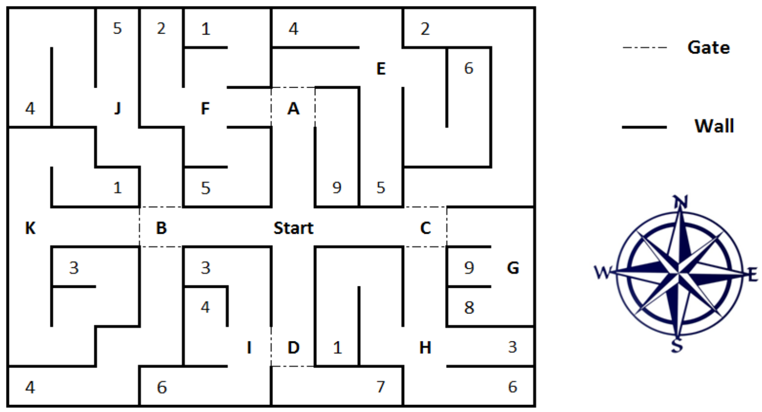
7. (10 pts total, 1/2 pt each) SEARCH PROPERTIES.

8. (15 points total, 3 pts each) CONSTRAINT SATISFACTION PROBLEMS.

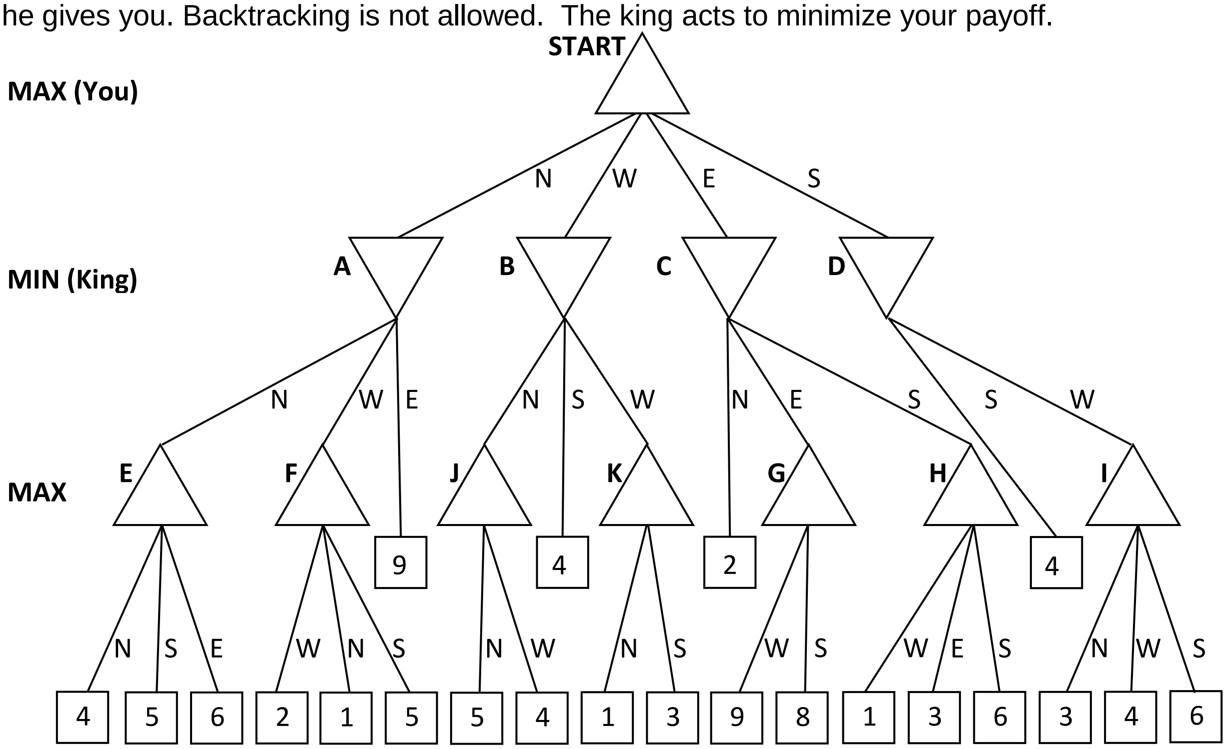
9. (10 pts total) RESOLUTION THEOREM PROVING.

10. (15 pts total, 3 pts each) STATE-SPACE SEARCH.

1. (10 pts total, -1 pt each wrong answer, but not negative) MINIMAX WITH ALPHA-BETA PRUNING. While visiting Crete, you are challenged by a passing king to what he calls the "Labyrinth Challenge". The rules are simple: you must make your way through a maze to find the largest prize for yourself. You are given the following map to plan your route:



You will start in the maze at the location labeled START and may travel North (N), South (S), East (E), or West (W). Your goal is to secure the largest, single prize for yourself, represented by the numbers spread across the maze. At four specific intersections (A, B, C, D), the king will be able to close off all but one pathway by closing gates around you, forcing you to take the path he gives you. Backtracking is not allowed. The king acts to minimize your payoff.



1.a. Fill in each blank triangle with its Mini-Max value. Process the game tree left-to-right.

1.b. Cross out each leaf node that will be pruned by Alpha-Beta pruning. Go left-to-right.

1.c. What is the best move for MAX? (write N, W, E, or S) _________

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2. (10 pts total, 2 pts each) CSP WITH BACKTRACKING SEARCH. This question will use CSP algorithms on a 6-queens problem. Variable Vi represents the row of the queen placed in column i. Each variable Vi has domain Di = {1,2,3,4,5,6}. The 6-queens problem requires that we place all 6 queens on the board such that none of them can attack each other; so we cannot have 2 queens in the same row, column, or diagonal. At this point we are part-way through the search, so one of the variables already has been assigned as V1 = 3 (see figure below).

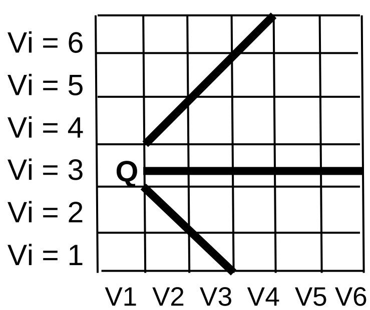
Show the search state after going all the way down the first branch in the search tree. Stop when you have either (1) found a solution, or (2) fail and need to backtrack.

Use (1) Forward Checking, (2) variable ordering by the Minimum Remaining Values (MRV) heuristic, (3) value ordering by the Least Constraining Value (LCV) heuristic. When there are ties on variable ordering from the MRV heuristic, break the tie by preferring the left-most tied variable. When there are ties on value ordering from the LCV heuristic, break ties by preferring the smallest value. At this point, you are part-way through the search, and you have just failed at V1 = 1 and V1 = 2, so V1 = 3 is the only assignment now. The first one (V1 = 3) is done for you as an example of what the problem asks for and how to fill it in ("Q" means queen).

2.a. Write the next selected variable, or "Fail" if you need to backtrack now: V1

Write the value assigned to the selected variable: 3

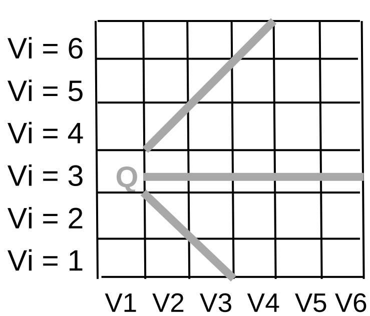
Write Q where you put your queen. Draw a line through values removed by Forward Checking. You will find it helpful to propagate your previous Qs and lines, but that is not required.



2.b. (2 pts) Write the next selected variable, or "Fail" if you need to backtrack now: ___________

Write the value assigned to the selected variable: _____________

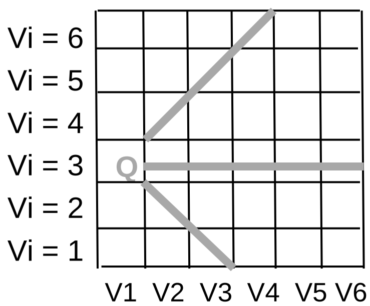
Write Q where you put your queen. Draw a line through values removed by Forward Checking. You will find it helpful to propagate your previous Qs and lines, but that is not required.



2.c. (2 pts) Write the next selected variable, or "Fail" if you need to backtrack now: ___________

Write the value assigned to the selected variable: ______________

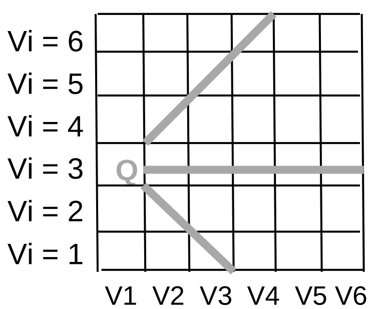
Write Q where you put your queen. Draw a line through values removed by Forward Checking. You will find it helpful to propagate your previous Qs and lines, but that is not required.



2.d. (2 pts) Write the next selected variable, or "Fail" if you need to backtrack now: ___________

Write the value assigned to the selected variable: ______________

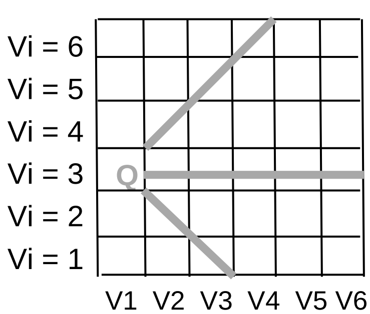
Write Q where you put your queen. Draw a line through values removed by Forward Checking. You will find it helpful to propagate your previous Qs and lines, but that is not required.



2.e. (2 pts) Write the next selected variable, or "Fail" if you need to backtrack now: ___________

Write the value assigned to the selected variable: ______________

Write Q where you put your queen. Draw a line through values removed by Forward Checking. You will find it helpful to propagate your previous Qs and lines, but that is not required.



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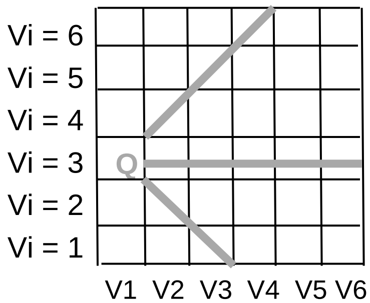
2.f. (2 pts) Write the next selected variable, or "Fail" if you need to backtrack now: ___________

Write the value assigned to the selected variable: _____________

Write Q where you put your queen. Draw a line through values removed by Forward Checking. You will find it helpful to propagate your previous Qs and lines, but that is not required.



3. (6 pts total, 2 pts each) CONVERSION TO CNF. Convert these expressions to CNF.

3.a. (2 pts) $(A \Leftrightarrow (B \vee C))$ ________________________________

3.b. (2 pts) $((C \wedge D) \Rightarrow \neg E)$ ________________________________

3.c. (2 pts) $((A \Rightarrow B) \Rightarrow C)$ ________________________________

4. (6 pts total, 2 pts each) RESOLUTION OF CLAUSES. Use resolution to resolve the following pairs of clauses, simplify, and write the resulting clause. If no resolution is possible write "None". If the resolvent simplifies to True write "True." If more than one resolution is possible, pick any one that you like, and write its simplified result.

4.a. (2 pts) Resolve (A B C) with (B $\neg$C $\neg$D) to yield ________________________

4.b. (2 pts) Resolve (A B C) with ($\neg$B $\neg$C $\neg$D) to yield ________________________

4.c. (2 pts) Resolve (A B C) with (B C $\neg$D) to yield ________________________

5. (10 pts total, 1 pt each) LOGIC. Which of the following are correct? **(T = True, F = False).** Recall that the symbol "|=" means "entails."

5.a. (1 pt) __________ *False |= True.*

5.b. (1 pt) __________ *True |= False.*

5.c. (1 pt) __________ $(A \wedge B) \models (A \Leftrightarrow B)$.

5.d. (1 pt) __________ $(A \Leftrightarrow B) \models (A \vee B)$.

5.e. (1 pt) __________ $(A \Leftrightarrow B) \models (\neg A \vee B)$.

5.f. (1 pt) __________ $((A \wedge B) \Rightarrow C) \models (A \Rightarrow C) \vee (B \Rightarrow C)$.

5.g. (1 pt) __________ $(A \vee B) \wedge (\neg C \vee \neg D \vee E) \models (A \vee B)$.

5.h. (1 pt) __________ $(A \vee B) \wedge (\neg C \vee \neg D \vee E) \models (A \vee B) \wedge (\neg D \vee E)$.

5.i. (1 pt) __________ $(A \vee B) \wedge \neg (A \Rightarrow B)$ is satisfiable.

5.j. (1 pt) __________ $(A \Leftrightarrow B) \wedge (\neg A \vee B)$ is satisfiable.

6. (8 pts total, 2 pts each) TASK ENVIRONMENT. Your book defines a task environment as a set of four things, with the acronym PEAS. Fill in the blanks with the names of the PEAS components.

P________________ E__________ A__________ S__________

7. (10 pts total, 1/2 pt each) SEARCH PROPERTIES.
Fill in the values of the four evaluation criteria for each search strategy shown. Assume a tree search where b is the finite branching factor; d is the depth to the shallowest goal node; m is the maximum depth of the search tree; C* is the cost of the optimal solution; step costs are identical and equal to some positive ε; and in Bidirectional search both directions using breadth-first search.

Note that these conditions satisfy all of the footnotes of Fig. 3.21 in your book.

Criterion	Complete?	Time complexity	Space complexity	Optimal?
Breadth-First				
Uniform-Cost				
Depth-First				
Iterative Deepening				
Bidirectional (if applicable)				

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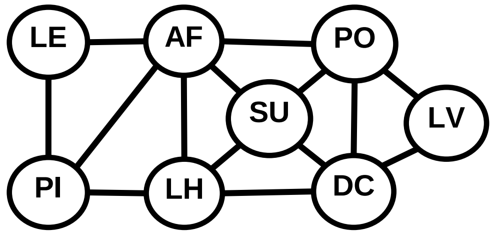
8. (15 points total, 3 pts each) CONSTRAINT SATISFACTION PROBLEMS.



AF = Allegheny Forest
DC = Dutch Country
LE = Lake Erie
LH = Laurel Highlands
LV = Lehigh Valley
PI = Pittsburgh
PO = Pocono Mountains
SU = Susquehanna Valleys

You are a map-coloring robot assigned to color this Pennsylvania region map. Adjacent regions must be colored a different color (R=Red, B=Blue, G=Green). The constraint graph is shown.

8.a. (3 pts total) FORWARD CHECKING. Cross out all values that would be eliminated by Forward Checking, after variable LH has just been assigned value G, as shown:

AF	DC	LE	LH	LV	PI	PO	SU
R G B	R G B	R G B	G	R G B	R G B	R G B	R G B

8.b. (3 pts total) ARC CONSISTENCY.
AF and LE have been assigned values, but no constraint propagation has been done. Cross out all values that would be eliminated by Arc Consistency (AC-4 in your book).

AF	DC	LE	LH	LV	PI	PO	SU
B	R G B	R	R G B	R G B	R G B	R G B	R G B

8.c. (3 pts total) MINIMUM-REMAINING-VALUES HEURISTIC. Consider the assignment below. PO is assigned and constraint propagation has been done. List all unassigned variables that might be selected by the Minimum-Remaining-Values (MRV) Heuristic:________________________.

AF	DC	LE	LH	LV	PI	PO	SU
G B	G B	R G B	R G B	G B	R G B	R	G B

8.d. (3 pts total) DEGREE HEURISTIC. Consider the assignment below. (It is the same assignment as in problem 8.c. above.) PO is assigned and constraint propagation has been done. List all unassigned variables that might be selected by the Degree Heuristic:______________________.

AF	DC	LE	LH	LV	PI	PO	SU
G B	G B	R G B	R G B	G B	R G B	R	G B

8.e. (3 pts total) MIN-CONFLICTS HEURISTIC. Consider the complete but inconsistent assignment below. AF has just been selected to be assigned a new value during local search for a complete and consistent assignment. What new value would be chosen below for AF by the Min-Conflicts Heuristic?_______________________________.

AF	DC	LE	LH	LV	PI	PO	SU
?	G	G	R	G	B	B	G

9. (10 pts total) RESOLUTION THEOREM PROVING. Solve this puzzle as a logic agent.

"Three girls took part in a race. Alison (A) finished before Betty (B) but behind Clare (C). What was the finishing order?"

Obviously, the finishing order was C, A, B. You will use resolution to prove this fact.

You create 9 propositional variables, A/B/C1/2/3, to indicate that A, B, or C finished in place 1, 2, or 3. Your Knowledge Base is:

Alison (A) finished before Betty (B): $((A1 \wedge B2) \vee (A1 \wedge B3) \vee (A2 \wedge B3))$

Alison (A) finished behind Clare (C): $((C1 \wedge A2) \vee (C1 \wedge A3) \vee (C2 \wedge A3))$

Each contestant finished exactly one of first, second, or third:

$((A1 \Rightarrow \neg(A2 \vee A3)) \wedge ((A2 \Rightarrow \neg(A1 \vee A3)) \wedge ((A3 \Rightarrow \neg(A1 \vee A2))$
$((B1 \Rightarrow \neg(B2 \vee B3)) \wedge ((B2 \Rightarrow \neg(B1 \vee B3)) \wedge ((B3 \Rightarrow \neg(B1 \vee B2))$
$((C1 \Rightarrow \neg(C2 \vee C3)) \wedge ((C2 \Rightarrow \neg(C1 \vee C3)) \wedge ((C3 \Rightarrow \neg(C1 \vee C2))$

Finishing first, second, or third is mutually exclusive among contestants:

$((A1 \Rightarrow \neg(B1 \vee C1)) \wedge ((B1 \Rightarrow \neg(A1 \vee C1)) \wedge ((C1 \Rightarrow \neg(A1 \vee B1))$
$((A2 \Rightarrow \neg(B2 \vee C2)) \wedge ((B2 \Rightarrow \neg(A2 \vee C2)) \wedge ((C2 \Rightarrow \neg(A2 \vee B2))$
$((A3 \Rightarrow \neg(B3 \vee C3)) \wedge ((B3 \Rightarrow \neg(A3 \vee C3)) \wedge ((C3 \Rightarrow \neg(A3 \vee B3))$

Thus, your Knowledge Base after conversion to CNF is:

(A1 A2)	(A1 B3)	(B2 B3)
(A2 A3)	(A3 C1)	(C1 C2)
($\neg$A1 $\neg$A2)	($\neg$ A1 $\neg$A3)	($\neg$ A2 $\neg$A3)
($\neg$B1 $\neg$B2)	($\neg$ B1 $\neg$B3)	($\neg$ B2 $\neg$B3)
($\neg$C1 $\neg$C2)	($\neg$ C1 $\neg$C3)	($\neg$ C2 $\neg$C3)
($\neg$A1 $\neg$B1)	($\neg$ A1 $\neg$C1)	($\neg$ B1 $\neg$C1)
($\neg$A2 $\neg$B2)	($\neg$ A2 $\neg$C2)	($\neg$ B2 $\neg$C2)
($\neg$A3 $\neg$B3)	($\neg$ A3 $\neg$C3)	($\neg$ B3 $\neg$C3)

Your goal sentence is (C1 $\wedge$ A2 $\wedge$ B3) so your negated goal sentence is:

($\neg$C1 $\neg$A2 $\neg$B3)

Produce a resolution proof that the finishing order was (C1 $\wedge$ A2 $\wedge$ B3).

Repeatedly choose two clauses, write one clause in the first blank space on a line, and the other clause in the second. Apply resolution to them. Write the resulting clause in the third blank space, and insert it into the knowledge base. Continue until ( ). Use more lines if needed.

The first one is done for you as an example.

Resolve ____(A1 A2)____ and ____($\neg$ A1 $\neg$A3)____ to give ____(A2 $\neg$A3)____

Resolve ____________________ and ____________________ to give ____________________

Resolve ____________________ and ____________________ to give ____________________

Resolve ____________________ and ____________________ to give ____________________

Resolve ____________________ and ____________________ to give ____________________

Resolve ____________________ and ____________________ to give ____________________

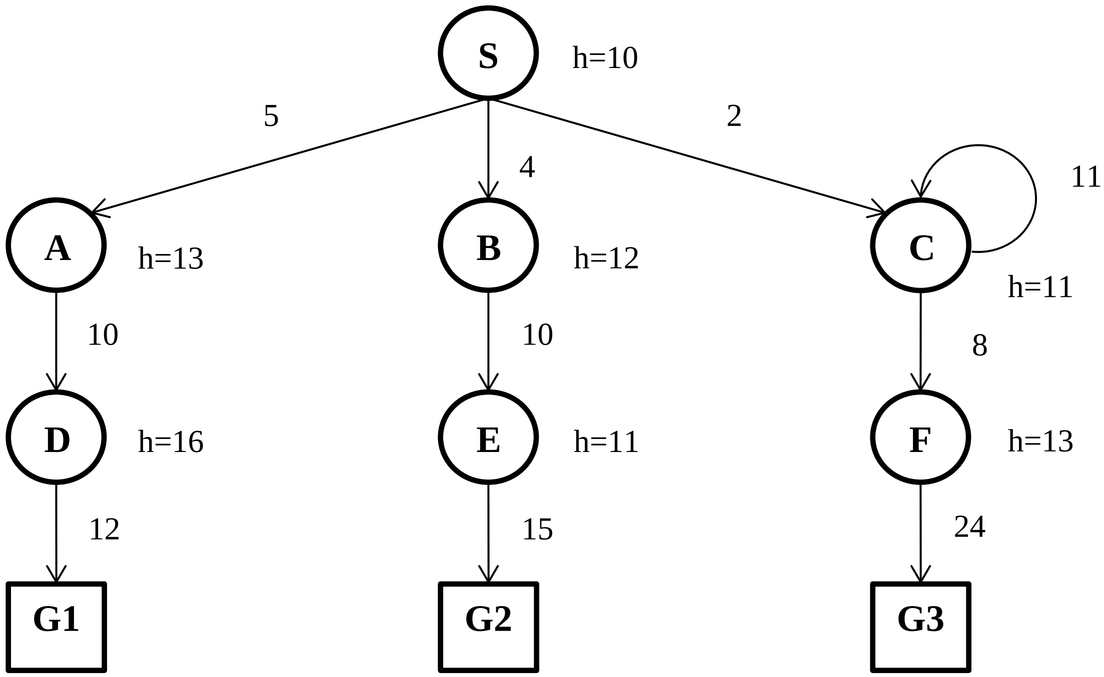
Resolve ____________________ and ____________________ to give ____________________

Resolve ____________________ and ____________________ to give ____________________

Resolve ____________________ and ____________________ to give ____( )____

10. (15 pts total, 3 pts each) STATE-SPACE SEARCH. Execute Tree Search through this graph (i.e., do not remember visited nodes, so repeated nodes are possible). It is not a tree, but pretend you don't know that. Step costs are given next to each arc. Heuristic values are given next to each node (as h=x). The successors of each node are indicated by the arrows out of that node. <u>Successors are returned in left-to-right order. The successors of S are A/B/C, and of C are F/C, in that order. C is a successor of itself.</u>

For each search strategy below, indicate the order in which nodes are expanded (i.e, its children are generated), ending with the goal node that is found. The first one is done for you as an example.



10.a. DEPTH FIRST SEARCH.

S A D G1 ____

10.b. (3 pts, -1 for each wrong answer, but not negative) UNIFORM COST SEARCH.

____

10.c. (3 pts, -1 for each wrong answer, but not negative) GREEDY (BEST-FIRST) SEARCH.

____

10.d. (3 pts, -1 for each wrong answer, but not negative) ITERATED DEEPENING SEARCH.

____

10.e. (3 pts, -1 for each wrong answer, but not negative) A* SEARCH.

____

10.f. (3 pts, -1 for each wrong answer, but not negative) OPTIMALITY.

Did Uniform Cost Search find the optimal goal?________ Why or why not?__________________________

Did A* Search find the optimal goal?__________ Why or why not?__________________________________

****** THIS IS THE END OF THE MID-TERM EXAM ******