You have 50 minutes to complete this midterm. You are only allowed to use your textbook, your notes, your assignments and solutions to those assignments during this midterm. If you find that you are spending a large amount of time on a difficult question, skip it and return to it when you’ve finished some of the easier questions. Total marks for this midterm is 46.

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Section I: Agents (8 points)
1. Consider an agent designed to solve instances of the 8-tile puzzle described in class. Recall that the 8-tile puzzle is a 3x3 grid with 8 numbered tiles and one blank square, and the objective is to get from an initial configuration of the tiles to a specified configuration (usually with the tiles in numeric order).

For each part below, circle the choice which best describes the environment for this agent:

a) Fully observable or Partially observable [1 point]

b) Deterministic or Stochastic [1 point]

c) Episodic or Sequential [1 point]

d) Static or Dynamic [1 point]

e) Discrete or Continuous [1 point]

f) Single agent or Multi-agent [1 point]

2. What type of agent is the 8-tile puzzle solver from question 1? Choose from simple reflex agent, model-based reflex agent, goal-based agent and utility-based agent. Give a one or two sentence justification of your answer. [2 points]

Goal or utility based, since there is clearly a goal state to be reached. Intermediate states could be modeled as having utility values or not.
II. Search [10 points]

4. Consider formulating the 8-tile puzzle as a local search problem and representing a state as an array of 9 symbols corresponding to the tile positions. For example,

```
6 4 3
1 2 7
8 B 5
```

would be represented as [6 4 3 1 2 7 8 B 5], with B for blank.

a) List the neighbors for the state shown above in this representation? [2 points]

- [6 4 3 1 2 7 8 5 B]
- [6 4 3 1 B 7 8 2 5]
- [6 4 3 1 2 B 8 5]

b) Propose an evaluation function for this problem. [2 points]

Any of the heuristics we used for A* on this problem would serve here. E.g. number of misplaced tiles, Manhattan distance.

c) Using this state representation, would genetic algorithms be a promising approach to this problem? Why or why not? [2 points]

No. The crossover operation applied to this state representation would not necessarily correspond to legal moves for the game.
5. In the tree-search algorithm, the goal test is applied after a node is removed from the queue. We saw that breadth-first search (BFS) and uniform cost search (UCS) are optimal tree-search strategies. Consider a variant of tree-search in which the goal test occurs when nodes are expanded instead, right before they are inserted into the queue.

a) Is BFS (with uniform step costs) still optimal in this variant? Why or why not? [2 points]

Yes. The nodes would be checked in the same order. Computationally, this would save us from having to generate nodes in the last level of the tree.

b) Is UCS (with non-uniform step costs) still optimal in this variant? Why or why not? [2 points]

No. Like in A*, it is possible to explore a sub-optimal path to the goal before we find the optimal one. (In graph search, where we keep track of explored nodes, the goal test can be moved earlier as long as we do the extra bookkeeping to make sure we keep the best path to each node.)

III. Games [13 points]

6. Below is a portion of a game tree. At this point, MAX is choosing between a guaranteed utility of 10 versus tossing a series of coins. Which action should MAX choose (left or right)? Use the expectiminimax algorithm to decide, and show your work. [7 points]

MAX should take the left (chance) action.
7. Consider the following game tree, in which the terminal nodes have utilities W through Z, and the edges are labeled with A through F.

\[ \text{MAX} \]

\[ \text{MIN} \]

a) Give a mathematical expression for the minimax value at the root node in terms of the utilities. (Hint: you can use \( \min() \) and \( \max() \) functions that return the minimum or maximum of their arguments, respectively.) [2 points]

\[ \max(\min(W,X), \min(Y,Z)) \]

b) Suppose \( W = 3, X = 6, Y = 4 \), and \( Z = 5 \). Are any of the edges pruned by the alpha-beta algorithm? If so, which ones? [2 points]

None are pruned.

c) Suppose \( W = 7 \) and \( X = 2 \). Give a value for \( Y \) such that edge F is pruned by the alpha-beta algorithm. [2 points]

Any value less than or equal to 2 works.
IV. Propositional Logic [16 points]
8. Is the following sentence valid, unsatisfiable, or neither? Justify your answer. [2 points]

\[ ((A \land B) \Rightarrow C) \iff ((A \Rightarrow C) \lor (B \Rightarrow C)) \]

\[ \text{LHS: } \neg(A \land B) \lor C \]
\[ \neg A \lor \neg B \lor C \]

\[ \text{RHS: } (\neg A \lor C) \lor (\neg B \lor C) \]
\[ \neg A \lor \neg B \lor C \]

Let \( P = \neg A \lor \neg B \lor C \). The original sentence is \( P \iff P \). By the definition of the biconditional operator, this is valid.

9. Convert the following English sentences into propositional logic.
   If I study and I get enough sleep, then I will pass the exam.
   If my homework is not late, then I will get full credit for it.
   I can study or I can get enough sleep, but not both.

   [3 points]

\[ (\text{Study} \land \text{Sleep}) \Rightarrow \text{Exam} \]
\[ \neg \text{Late} \Rightarrow \text{Credit} \]
\[ \neg(\text{Study} \iff \text{Sleep}) \]
10. Convert the following KB into CNF. [5 points]

\[ P \iff Q \]
\[ (Q \land R) \Rightarrow S \]
\[ (R \land S) \lor T \]

\[ \neg P \lor Q \]
\[ \neg Q \lor P \]
\[ \neg Q \lor \neg R \lor S \]
\[ R \lor T \]
\[ S \lor T \]

11. Use the resolution algorithm to determine whether the following KB entails B. [5 points]

1. \( A \lor B \)
2. \( \neg B \lor \neg C \)
3. \( \neg C \lor D \)
4. \( B \lor E \)
5. \( D \lor F \)
6. \( E \lor \neg F \)

7. \( \neg B \)
8. \( A (7 + 1) \)
9. \( E (4 + 7) \)
10. \( A \lor \neg C (1 + 2) \)
11. \( \neg C \lor E (2 + 4) \)
12. \( D \lor E (5 + 6) \)

No new clauses can be generated, so the KB does not entail B.