Write your answers on these pages and show your work. If you feel that a question is not fully specified, state any assumptions you need to make in order to solve the problem. You may use the backs of these sheets for scratch work.

Write your name on this page and initial all other pages of this exam (in case a page comes loose during grading). Make sure your exam contains eight problems on ten pages.

Name

Student ID

<table>
<thead>
<tr>
<th>Problem</th>
<th>Score</th>
<th>Max Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>_____</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>_____</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>_____</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>_____</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>_____</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>_____</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>_____</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>_____</td>
<td>9</td>
</tr>
</tbody>
</table>

TOTAL _____ 100
Problem 1 – Decision Trees (20 points)

Assume that you are given the set of labeled training examples below, where each feature is binary valued and a ‘name’ field is included for convenience. You choose to learn a decision tree and select ‘+’ as the default output if there are ties.

<table>
<thead>
<tr>
<th>Name</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex1</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>+</td>
</tr>
<tr>
<td>Ex2</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>+</td>
</tr>
<tr>
<td>Ex3</td>
<td>F</td>
<td>T</td>
<td>T</td>
<td>+</td>
</tr>
<tr>
<td>Ex4</td>
<td>T</td>
<td>T</td>
<td>F</td>
<td>+</td>
</tr>
<tr>
<td>Ex5</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>-</td>
</tr>
<tr>
<td>Ex6</td>
<td>F</td>
<td>F</td>
<td>T</td>
<td>-</td>
</tr>
</tbody>
</table>

a) What score would the information gain calculation assign to each of the features? 
   *Be sure to show all your work* (use the back of this or the previous sheet if needed).

b) Which feature would be chosen as the root of the decision tree being built? ____________
   (Break ties in favor of F1 over F2 over F3, i.e., in alphabetic order.)
c) In bagging, one creates copies of the training set by uniformly drawing with replacement. Show a possible copy below; be sure to explain your work. Just show the examples’ NAMEs for simplicity.

Assume you have a six-sided die that you use in this process and that the first dozen tosses of this die produce these numbers in this left-to-right order: 5, 6, 1, 4, 3, 6, 1, 5, 2, 2, 5, 3.

d) Your friend Ida Smart suggests

We should add the following feature to our dataset:
the number of the first three features that have value T

Describe below what the ‘real’ ID3 would do with this numeric feature, including showing information-gain calculations. Even though this new feature has a small number of different values, you need to treat it like a numeric-valued feature. (You only need to discuss what ID3 would do on the first call to it; you need not show recursive steps, if any.)

Does your answer to Part (b) change? ______

Why or why not?

<table>
<thead>
<tr>
<th>Name</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex1</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>+</td>
</tr>
<tr>
<td>Ex2</td>
<td>T</td>
<td>F</td>
<td>T</td>
<td>+</td>
</tr>
<tr>
<td>Ex3</td>
<td>F</td>
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<td>Ex4</td>
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<td>T</td>
<td>F</td>
<td>+</td>
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<td>Ex5</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>-</td>
</tr>
<tr>
<td>Ex6</td>
<td>F</td>
<td>F</td>
<td>T</td>
<td>-</td>
</tr>
</tbody>
</table>
Problem 2 – Search (15 points)

Consider the search space below, where $S$ is the start node and $G1$ and $G2$ satisfy the goal test. Arcs are labeled with the cost of traversing them (so lower is better) and the estimated cost to a goal is reported inside nodes.

For each of the following search strategies, indicate which goal state is reached (if any) and list, in order, all the states popped off of the OPEN list. When all else is equal, nodes should be removed from OPEN in alphabetical order.

You can show your work (for cases of partial credit), using the notation presented in class, on the back of the previous page.

**Hill-climbing**

Goal state reached: ______ States popped off OPEN: ________________________________

**Iterative Deepening**

Goal state reached: ______ States popped off OPEN: ________________________________

**A* ($f = g + h$)**

Goal state reached: ______ States popped off OPEN: ________________________________
Problem 3 – Probabilistic Reasoning (8 points)

Using the probability table below, answer the following questions. Write your numeric answer on the line provided and show your work in the space below each question.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>false</td>
<td>false</td>
<td>false</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>false</td>
<td>false</td>
<td>true</td>
<td>0.20</td>
</tr>
<tr>
<td>3</td>
<td>false</td>
<td>true</td>
<td>false</td>
<td>0.15</td>
</tr>
<tr>
<td>4</td>
<td>false</td>
<td>true</td>
<td>true</td>
<td>0.04</td>
</tr>
<tr>
<td>5</td>
<td>true</td>
<td>false</td>
<td>false</td>
<td>0.25</td>
</tr>
<tr>
<td>6</td>
<td>true</td>
<td>false</td>
<td>true</td>
<td>0.10</td>
</tr>
<tr>
<td>7</td>
<td>true</td>
<td>true</td>
<td>false</td>
<td>0.18</td>
</tr>
<tr>
<td>8</td>
<td>true</td>
<td>true</td>
<td>true</td>
<td>0.07</td>
</tr>
</tbody>
</table>

a) \( \text{Prob}(A=\text{true} \land B=\text{true}) \) ? ______________________

b) \( \text{Prob}(A=\text{false}) \) ? ______________________

c) \( \text{Prob}(A=\text{true} \lor C = \text{true}) \) ? ______________________

d) \( \text{Prob}(B = \text{false} \land C=\text{true} \mid A=\text{false}) \) ? ______________________
Problem 4 – Game Playing (12 points)

a) Apply the mini-max algorithm to the partial game tree below, where it is the maximizer’s turn to play and the game does not involve randomness. The values estimated by the static-board evaluator (SBE) are indicated in the leaf nodes (higher scores are better for the maximizer).

Write the estimated values of the intermediate nodes inside their circles and indicate the proper move of the maximizer by circling one of the root’s outgoing arcs. Process this game tree working left-to-right.

b) List the first leaf node (if any) in the above game tree whose SBE score need not be computed: the node whose score = ________

Explain why:

c) Assume we wanted to create software that that solves one-player games that do not involve randomness. Which of the following algorithms would be the best to include in your solution? Circle one and briefly explain your answer.

   i. Alpha-beta Pruning
   ii. Fitness Slicing
   iii. Iterative Deepening
Problem 5 – Multiple-Choice Questions (18 points)

For each question, circle your answer(s). Unless stated otherwise, choose the one best answer.

a) Simulated Annealing never makes ‘downhill’ (i.e., bad) moves unless at a local maximum.  
   TRUE   FALSE

b) If we have an admissible heuristic function, then when a goal node is expanded and placed in CLOSED, we have always reached it via the shortest possible path.  
   TRUE   FALSE

c) If BFS finds a solution, is A* guaranteed to find a solution as well?  
   YES   NO

d) Beam search suffers from the overfitting problem.  
   TRUE   FALSE

e) Which of the following are true about using tune sets (ok to circle none or more than one):
   i) they are likely to produce models with worse accuracy on the train set
   ii) they are likely to produce models with better accuracy on the test set
   iii) they are not needed in the k-NN algorithm

f) The ID3 pruning algorithm searches feature space.  
   TRUE   FALSE

g) Circle (zero or more) correct completions to the following:

   Minimax and alpha-beta pruning will always choose the same move
   i) if the number of nodes consided is the same for the two algorithms.
   ii) if the maximum lookahead depth is the same for the two algorithms.
   iii) if neither ever needs to call the SBE.

h) \( \text{Prob}(A \mid B) \) is always larger than \( \min(\text{Prob}(A), \text{Prob}(B)) \).  
   TRUE   FALSE

i) Joint probabilities result from making independence assumptions.  
   TRUE   FALSE
Problem 6 – Key AI Concepts (9 points)

Briefly describe each of the following AI concepts and explain each’s significance. (Write your answers to the right of and below the phrases and clearly separate your description and significance.)

Fitness-proportional Reproduction

description:

significance:

Parameter Tuning

description:

significance:

The Coming Singularity

description:

significance:
Problem 7 – Miscellaneous Questions (9 points)

a) Consider the following game. You spend your last $10 to play. How much money do you expect to have after playing the game? Show your work.

First, you flip a fair coin.

If heads, you flip the fair coin again.
   If the second flip of the coin comes up heads you win $5 otherwise you win nothing.

If tails, 1% of the time you win $100 else you win $10.

b) For each of the search algorithms below, briefly provide one strength and one weakness compared to breadth-first search. No need to explain your answers.

i. A*

Strength: ________________________________________________________________

Weakness: ______________________________________________________________

ii. Beam search

Strength: ______________________________________________________________

Weakness: ______________________________________________________________
Problem 8 – More Miscellaneous Questions (9 points)

a) Is it accurate to view Uniform Cost Search as a special case of the A* algorithm? ________
   Justify your answer below.

b) Assume Entity A = 100010 and Entity B = 010101 are crossed over to form two children in a
genetic algorithm. Show two possible children and explain your answer by illustrating the
process of generating them via cross over.

c) Draw a search space where heuristic search (i.e., \( f=h \)) finds a different answer than A* (i.e.,
\( f=g+h \), where \( h \) is admissible). Use no more than four nodes and explain your answer.