1. [12 pts] Match the terms below with their definitions by writing the letter of the term beside its definition or description:

a. Genetic algorithm  
   b. Simulated annealing  
   c. AND-OR tree  
   d. PDDL  
   e. Partial order plan  
   f. Conformant planner  
   g. Kalman Filter  
   h. Atomic event  
   i. Hamming  
   j. Online search

[ g ] Robot location defined as a multidimensional Gaussian distribution.
[ c ] Used to find plans in non-deterministic environments.
[ j ] Agents using this kind of search can only sense the current state of the environment.
[ a ] A form of beam search that uses crossover events and point mutation.
[ i ] Distance metric used for discrete values.
[ h ] A single point in the state space of possibilities.
[ e ] Created as a DAG rather than a linear sequence of actions.
[ d ] A language to describe planning problems.
[ f ] Tries to find a plan to reach a goal without sensing the environment.
[ b ] Uses a temperature parameter to control randomness.
[ h ] Can occur when the algorithm attempts to fit the data exactly.
[ g ] Created by rearranging the terms of the product rule.

2. [3 pts] (T / F) A decision-theoretic agent will always play the lottery because the maximum payout is greater than the ticket price.
   
   False - DT agent uses expected payout to choose action.
3. [6 pts] Suppose that you have a 1D dataset with the following values:
[1, 2, 5, 8, 11, 12, 18]
You initialize the K-means algorithm with two means at m1=0 and m2=4. Compute m1 and m2 for the next iteration of the algorithm.

\[
\begin{align*}
m1 &= (1+2)/2 = 1.5 \\
m2 &= (5+8+11+12+18)/5 = 10.8
\end{align*}
\]

4. [6 pts] You are researching soil samples, and discover a discoloration that indicates the soil might contain a certain bacterium. The prior probability that the bacterium is in the soil is P(b)=0.002. The probability that a random soil sample is discolored is P(d)=0.1, and the probability of seeing the discoloration if the bacterium is in the soil is P(d|b)=0.95. Based on this, what is the probability that your soil sample contains the bacterium?

\[
P(b|d) = \frac{0.95 \times 0.002}{0.1} = 0.019
\]

(about 19 times higher than a random sample, but still a low probability)

5. [4 pts] Suppose that at one point while running A* that you have the three nodes A, B, and C on the frontier with h() and g() values given as follows:

<table>
<thead>
<tr>
<th></th>
<th>g(A)</th>
<th>h(A)</th>
<th>f(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>18</td>
<td>20</td>
<td>38</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>25</td>
<td>29</td>
</tr>
</tbody>
</table>

Which node will A* expand next?

**It will expand A, since it has the smallest f value.**

6. [3 pts] (T / F) A* search only produces an approximate solution, and this is why it is faster than iterative deepening search.

**False.** A* search finds the optimal solution, but does not need to explore all of the branches of the tree.

7. [3 pts] ADP agents attach utility to states in the state space. To what do Q-learning agents attach utility?

**Q-learning agents attach utility to state-action pairs:** Q(S,A)
8. [4 pts] Suppose that a particular search tree has a branching factor of 7. If level 0 is the root, how many nodes are on level 2 of the search tree.

$$7^2 = 49$$

9. [6 pts] Suppose that a given state S has 3 possible successor states, A, B, C, and that the current utilities of S and the neighbor states are given below:

S: 4, A: 5, B: 7, C: 2

Let the discount rate be 0.8. If the current policy will transition to each of the successor states with the following probabilities:

P(A|S)=0.2, P(B|S)=0.3, P(C|S)=0.5

Perform one update of value iteration, giving the resulting utility for state S: U(S).

**Ignore current value of P(S), and perform update as follows:**

$$U(S) = 0.2 \times 5 + 0.3 \times 7 + 0.5 \times 2 = 4.1$$

10. [3 pts] (T / F) To quickly find the optimal policy and state values, an adaptive dynamic programming agent must balance exploration of new actions and exploitation of high value paths that have already been found.

**True**

11. [8 pts] Trace the execution of the printFun function below, writing everything that is printed. Start with the call `recFunc(4," > ")`.

```java
void recFunc(int x, String s)
    println(s + " + " + x)
    if (x > 2)
        printFun(1 + x/2, s + " * ") // integer divide
        printFun(x-1, s + " + ")

> 4
> * 3
> * * 2
> * + 2
> + 3
> + * 2
> + + 2
```

12. [3 pts] (T / F) A robot can never have more effective degrees of freedom than it has controllable degrees of freedom.

**False. This happens quite frequently.**

13. [3 pts] (T / F) Hill climbing always finds a global maximum.

**False. Hill climbing finds a local maximum since it is a local search method.**
Perform alpha-beta pruning on the following tree. Show the final value of alpha and beta for each node that is evaluated, as well as the calculated value of the node. Circle nodes that are pruned by the algorithm.

```
\begin{tabular}{c c c c c c c c}
8 & 2 & 10 & 4 & 9 & 1 & 6 & 3 \\
\end{tabular}
```

```
\begin{tabular}{c c c c c c c c}
[alpha, beta] value \\
[8, inf] 8 \\
[-inf, 8] 8 & [8, 6] 6 \\
8 & 2 & 10 & 4 (prune) & 9 & 1 (prune) & 6 & 3 \\
\end{tabular}
```
15. [6 pts] Suppose that you are running the decision tree learning algorithm. A particular training set has 50 positive, and 50 negative samples. Feature F will split the training set into 3 groups, one with 30 positive and 0 negative samples, one with 10 positive and 40 negative, and one with 10 positive and 10 negative samples. Compute the information gain using feature F.

\[
\text{entropy of original dataset} = -(0.5 \times \log_2(0.5) + 0.5 \times \log_2(0.5)) = 1
\]

\[
\text{entropy of split dataset} = (30/100) \times -(1 \times \log_2(1)) + (50/100) \times -(0.2 \times \log_2(0.2) + 0.8 \times \log_2(0.8)) + (20/100) \times -(0.5 \times \log_2(0.5) + 0.5 \times \log_2(0.5)) = 0.3610 + 0.2 = 0.5610
\]

\[
\text{Information gain} = 1 - 0.5610 = 0.439
\]

16. [6 pts] For this problem, use the joint probability table below (where ~ means negation):

<table>
<thead>
<tr>
<th></th>
<th>earthquake</th>
<th>~earthquake</th>
</tr>
</thead>
<tbody>
<tr>
<td>burglary</td>
<td>~burglary</td>
<td>burglary</td>
</tr>
<tr>
<td>alarm</td>
<td>0.010</td>
<td>0.020</td>
</tr>
<tr>
<td>~alarm</td>
<td>0.001</td>
<td>0.070</td>
</tr>
</tbody>
</table>

a) What is the probability that there is an alarm?

\[
P(\text{alarm}) = 0.010 + 0.020 + 0.010 + 0.002 = 0.042
\]

b) What is the probability that there is a burglary or an earthquake?

\[
P(\text{burglary} \lor \text{earthquake}) = 0.010 + 0.020 + 0.001 + 0.070 + 0.01 + 0.10 = 0.211
\]

c) What is probability that there is an burglary given that there is an alarm?

\[
P(\text{burglary} \mid \text{alarm}) = \frac{0.010 + 0.010}{0.042} = 0.476
\]