Q1:

A milkman has a full bottle containing 12 litres of milk and two empty bottles with capacities of 8 litres and 5 litres respectively. He needs to deliver exactly 6 litres to a customer in one of these bottles without wasting any milk. That is, he can only pour milk between the bottles, and he has no means of measuring except knowing when a bottle is full.

(a) Formulate this problem as a search problem by specifying how you would represent:   
  
(i) a general state,   
(ii) the initial state,   
(iii) the operators (actions that can be performed, and how they change the state),   
(iv) the goal test and   
(v) the path cost. [10 marks]

(b) Estimate the size of the search space and the maximum branching factor, explaining your reasoning. [4 marks]

(c) What are the first 3 nodes expanded in searching for a solution using breadth-first search? Show the initial agenda and the resulting agenda after each node expansion. You may assume that nodes that have already been expanded are never added to the agenda again. [7 marks]

(d) Would uniform cost search be better than breadth-first search for this problem? Give a reason for your answer. [2 marks] (e) Why is depth-first search not suitable for this problem? How can depth-first search be modified to make it suitable for this problem? [2 marks]

Q2:

(a) What is meant by the term “local search”? [2 marks]

(b) Which of the following are local search problems:   
  
(i) route-finding;   
(ii) crossword generation from a fixed list of words;   
(iii) efficient layout of components on a circuit board;   
(iv) planning in robotics? [4 marks]

(c) Explain the purpose and use of the “temperature” variable in simulated annealing. [3 marks]

(d) Define and give examples (one each) of the crossover and mutation operations for genetic algorithms. [6 marks]

(e) Explain the difference between a terminal-test and a cutoff-test for minimax search? What values are returned in each case if the test returns true? [4 marks]

(f) (NOTE: Same as the CW)   
  
Consider the game tree in Figure 1 with values generated using the minimax algorithm. Simulate the execution of alpha-beta pruning, searching from left to right. Which branches are pruned and why? Refer to nodes by (depth, position) where depth is counted from the root (depth 1), and position from the left (also starting from 1). For example, node (5,4) has the value 5.

Q3:

a) Using the training data in the table below, execute the ID3 algorithm to build a decision tree classifier to shed light on the relationship between sales (represented by the variable Sale) and the attributes Price, Change (of price), Quality and Ads. Show all of your working and represent the final solution by drawing the decision tree. [12 marks]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Price** | **Change** | **Quality** | **Ads** | **Sale** |
| Low | None | Poor | Radio | No |
| Low | None | Good | Radio | No |
| Low | Positive | Good | Radio | No |
| High | Negative | Poor | Web | No |
| High | Positive | Poor | Radio | No |
| Low | Negative | Good | Web | Yes |
| Low | Positive | Poor | Web | Yes |
| Medium | Negative | Poor | Web | Yes |
| Medium | None | Good | Radio | Yes |
| Medium | None | Good | Web | Yes |
| Medium | Positive | Poor | Radio | Yes |
| High | Negative | Good | Radio | Yes |
| High | Negative | Good | Web | Yes |
| High | Positive | Good | Web | Yes |

(b) What is the advantage of having one or more hidden layers in an artificial neural network? Illustrate your answer with an example. [3 marks]

(c) How do you choose the number of units in each hidden layer of an artificial neural network? Is there an algorithm for this? What is the danger of having too many units? [3 marks]

(d) Given a single perceptron with inputs xi for 1 ≤ i < 3, where x3 = 1 is the bias, initial weights w1 = w2 = w3 = 1, learning rate α = 0.8 and non-linear activation function:   
  
g(s) = 0, s <= 0.5; 1, s > 0.5  
use the perceptron training algorithm to learn the function specified by the following table of training examples. Show all working, including training example, weights, output and action performed for each step. [7 marks]

|  |  |  |
| --- | --- | --- |
| X1 | X2 | Output |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

Q4:

(a) Give an English language translation of the following logical statements:   
  
(i) ∃c Cat(c) ∧ Owns(Amy, c)   
(ii) ∀c Cat(c) → Likes(Bob, c)   
(iii) ∀x.∀c (Cat(c) ∧ Owns(Amy, c) ∧ Likes(x, c) → Likes(Amy, x)) [4 marks]

(b) Convert the 3 logical sentences above, give a resolution proof, showing and explaining your working, of the sentence: Likes(Amy, Bob) [13 marks]

(c) Given two fair 6-sided dice with the digits 1 to 6 on their faces, what is the probability of rolling:   
  
(i) a 6 with the first die   
(ii) a sum of 7 on the two dice   
(iii) a double (both dice show the same number)   
(iv) a double after you have seen the result of one die   
  
Use the correct notation for expressing the probability. [4 marks]

(d) Suppose you are given a bag containing equal numbers of three types of coins. The first type have heads on both sides, the second type have tails on both sides, and the third type have heads and one side and tails on the other. The coins are otherwise identical and the only way to investigate the coins is by tossing them. Suppose you choose a coin randomly from the bag and toss it twice and obtain heads both times. What are the probabilities of the coin belonging to each of the three types of coin? Show all working. [4 marks]