This question paper consists of 5 printed pages, each of which is identified by the Code Number COMP2611.

This is a closed book examination. No material is permitted.

School of Computing

May/June 2018

COMP2611

Artificial Intelligence

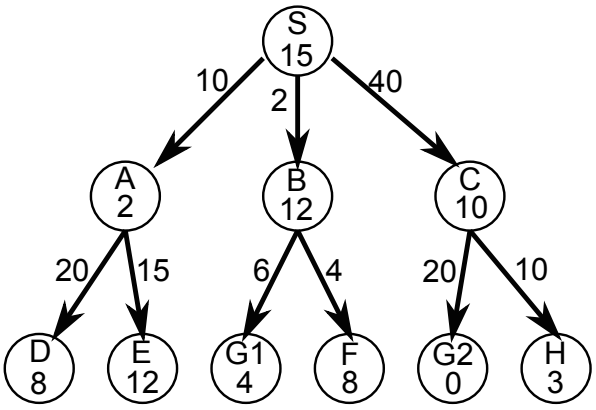
Answer ALL THREE Questions

Time allowed: Two hours

TURN OVER FOR QUESTIONS

Question 1

(a) Consider the following graph diagram of a search space. Each circle represents a state and the arrows represent possible action transitions. S is the start state and there are two goal states: G1 and G2. The cost of each action is given by the number next to the arrow. Each state is labelled by an identifying name (S, A–F, G1, G2, H) and also a number. The number is the value of a heuristic function at that node.



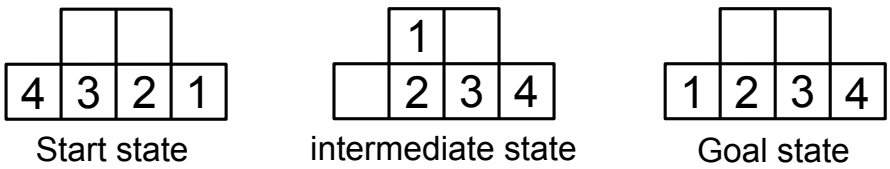
(i) Write down the optimal path from S to one of the goals **[1 mark]**

(ii) Write down the sequence in which nodes will be expanded until one of the goal states is reached, while performing a best first search (also known as greedy search). **[2 marks]**

(iii) Write down the sequence in which nodes will be expanded, until one of the goal states is reached, while performing a uniform cost search. **[2 marks]**

(iv) Write down the sequence in which nodes will be expanded until one of the goal states is reached, while performing an A* (A-star) search. **[2 marks]**

(b) A version of the sliding tile puzzle consist of four tiles that can slide horizontally or vertically between six positions as in the following picture.



The aim of the puzzle is to get from the start to the goal in as few moves as possible. Sliding one tile counts as one move.

(i) Draw the part of the search tree starting from the start state and showing all states one or two moves from the start. You need not show cases where the second move is just the reverse of the first one. You can use the number zero to indicate

a space not occupied by one of the four tiles. For example the start state and the intermediate state in the above picture can be drawn as follows.

$$\begin{array}{cccc} & 0 & 0 & \\ 4 & 3 & 2 & 1 \end{array} \qquad\qquad \begin{array}{cccc} & 1 & 0 & \\ 0 & 2 & 3 & 4 \end{array}$$

[5 marks]

(ii) One possible heuristic function for this problem would be to count the number of misplaced tiles. That is, you count how many of the four tiles are not in the position they need to be for the goal.

What estimate would this heuristic give to the intermediate state shown in the above picture? By comparing this situation with a state in which the number 2 tile was the only one out of place, comment on the accuracy of the estimate provided by the heuristic. **[4 marks]**

(iii) Explain why the function defined in (b)ii never over-estimates the cost of reaching a goal state. **[4 marks]**

[question 1 total: 20 marks]

Question 2

(a) Express the logical content of each of the following sentences by a formula in propositional calculus. If the sentence is ambiguous, full marks can be gained by a formula expressing just one of the possible meanings.

(i) If it is warm and dry we will walk to the park, but if not we will stay at home.
[2 marks]

(ii) If the burglar was tall then she didn't both wear sandals and leave by helicopter.
[2 marks]

(b) Express the logical content of the following sentence by a first-order logic formula using both the quantifiers $\forall$ and $\exists$. Your answer should use a binary predicate symbol $Likes$, with the intended interpretation that $Likes(x, y)$ holds when x likes y. You should also use a constant symbol $music$. Explain the intended meaning of any further predicate symbols that you use.

Everyone likes some kind of music.

[3 marks]

(c) A first-order language contains a binary predicate symbol R, and the language is to be interpreted using a domain with exactly three elements.

Give two interpretations: one in which the following formula is false, and one in which it is true.

$$\forall x \; \exists y \; (R(x, y) \wedge \neg R(y, x))$$

[4 marks]

(d) In the following expressions, f is a binary function symbol, x, y, z are variables, and a, b are constant symbols.

Find the most general unifier of the following two expressions.

$$f(f(x, y), f(x, z)) \qquad f(z, f(a, f(y, x)))$$

Your answer should show clearly how you calculated the most general unifier and the unified expression. **[4 marks]**

(e) Consider the set of formulas $\Delta = \{p \wedge \neg q, \;\; r \rightarrow (q \vee \neg p)\}$.

Show how the resolution refutation procedure works by using it to deduce $\neg r$ from the set Δ. **[5 marks]**

[question 2 total: 20 marks]

Question 3

Imagine you have been asked to help a supermarket determine what features of the ice cream products they stock make them profitable for the supermarket. You are given the following training set which records the combinations of features in nine examples. The features considered were: Manufacturer of the ice cream, Flavour, Price to the customer. The supermarket has calculated whether it found each example profitable or not. Note that a given manufacturer may produce the same flavour in both an expensive high-quality version and in a cheaper more basic version.

Example	Manufacturer	Price	Flavour	Profitable?
1	Alfred	high	Chocolate	yes
2	Alfred	low	Vanilla	no
3	Alfred	low	Chocolate	yes
4	Cauldron	low	Vanilla	no
5	Blossom	low	Chocolate	yes
6	Blossom	high	Chocolate	no
7	Cauldron	high	Vanilla	yes
8	Delicious	low	Chocolate	yes
9	Delicious	low	Vanilla	no

(a) Suppose you are asked to calculate from the given data whether a Vanilla ice cream made by Blossom with a high price would be profitable.

(i) One idea would be to calculate each of the following two probabilities and see which is the greater.

$$P(yes|Blossom, high, Vanilla) \qquad P(no|Blossom, high, Vanilla)$$

Explain why this is not possible.

The Naive Bayes approach involves the comparing two alternative expressions and seeing which is greater. State what these two expressions are, and state what assumption about the attributes is made in the Naive Bayes approach. **[4 marks]**

(ii) Carry out the Naive Bayes classification in this case and state clearly which conclusion (profitable or not profitable) you come to for the example **[5 marks]**

(b) This part of the question asks about building a decision tree from the above examples

(i) The first step in constructing a decision tree would be to find the **entropy** of the set of all examples. Calculate the entropy of this set of examples, stating clearly the formula for entropy you use. What would the entropy be if all examples had the same classification? **[3 marks]**

(ii) Calculate the **information gain** for each of the attributes Price and Flavour. You should state clearly the formula used. **[6 marks]**

(iii) Which of the attributes Price and Flavour would be better to split on in constructing the decision tree? Explain the reason for your answer. **[2 marks]**

[question 3 total: 20 marks]
[grand total: 60 marks]

END