King's College London

This paper is part of an examination of the College counting towards the award of a degree. Examinations are governed by the College Regulations under the authority of the Academic Board.

Degree Programmes	MSc
Module Code	7CCSMAIN
Module Title	Artificial Intelligence
Examination Period	January 2017 (Period 1)
Time Allowed	Two hours
Rubric	ANSWER FOUR OF FIVE QUESTIONS.
	All questions carry equal marks. If more than four questions are answered, the answers to the first four questions in exam paper order will count.
Calculators	Calculators may be used. The following models are permitted: Casio fx83 / Casio fx85.
Notes	Books, notes or other written material may not be brought into this examination

PLEASE DO NOT REMOVE THIS PAPER FROM THE EXAMINATION ROOM

1.

a. Write down the truth table for the formula:

$$\neg(p \wedge q) \rightarrow (q \vee r)$$

and use your answer to write the formula in Conjunctive Normal Form and in Disjunctive Normal Form.

[10 marks]

b. Is $\neg(p \wedge q) \rightarrow (q \vee r)$ a logical consequence of $p \wedge q$? Why?

[3 marks]

c. Write down another logical consequence of $\neg(p \wedge q) \rightarrow (q \vee r)$.

[2 marks]

d. Represent the following sentences in first order logic where $W(x)$ denotes x is a winter day, $C(x)$ denotes x is cold, $S(x)$ denotes x is snowy, $R(x)$ denotes x is rainy.

i. Winter days are cold.

ii. Winter days are snowy or rainy.

iii. Some winter days are snowy.

iv. Days that are snowy are not rainy.

v. No winter day is both warm and rainy.

[5 marks]

e. Reformulate two of your answers to the previous question using default logic and explain why these reformulations better capture what happens in the real world.

[5 marks]

2.

a. In the context of game theory, explain what it means for one strategy to *dominate* another.

[2 marks]

b. Simplify the following normal form game by iteratively removing dominated strategies:

	L	C	R
T	1 0	2 1	3 2
M	0 2	3 0	3 1
B	1 3	2 4	3 1

[8 marks]

c. In the context of game theory, explain what it means for two strategies to be in Nash equilibrium.

[2 marks]

d. Identify any pure strategy Nash equilibria and Pareto optimal outcomes in the following normal form game. Explain your answer.

	L	R
U	4 2	1 3
D	3 1	2 4

[8 marks]

e. In the context of game theory, explain the concept of social welfare.

[2 marks]

f. Which outcome in the game in 2.b maximises social welfare? Comment on this with respect to your solution to 2.b.

[3 marks]

3.

a. Write down Bayes' Rule, and explain each element of the rule.

[4 marks]

b. You are programming a demining robot. As the robot drives along, the prior probability of a mine being in its immediate vicinity is 0.001 (the mines are not very close together).

The robot is equipped with a mine detecting sensor which sounds a bell if it detects a mine nearby. If there is a mine nearby, then the probability of the sensor ringing the bell is 0.95 (the sensor is pretty accurate). If there is no mine nearby, the probability of the sensor ringing the bell is 0.01 (the sensor is rather reliable).

If the bell rings, what is the probability that there is a mine nearby? Discuss your answer.

[8 marks]

c. The mine detecting sensor sweeps the area around the robot every second, generating a new measurement each time. You program the demining robot to stop as soon as the bell rings. If the bell rings again, one second after the robot stops, what is the probability that there is a mine nearby?

[4 marks]

QUESTION 3 CONTINUES ON NEXT PAGE

d. You now fit a new sensor to the robot. This uses a completely different method to detect mines from that used by the first sensor, and if it does detect a mine, it sounds a buzzer. If there is a mine nearby, then the probability of the new sensor sounding the buzzer is 0.90, and if there is no mine nearby, the probability of the sensor ringing the bell is 0.02. How would you use the information from the two sensors to compute the probability of there being a mine nearby?

[4 marks]

e. Explain the concept of a Noisy-OR model and give an example of its use.

[5 marks]

4.

a. In the context of sequential decision making, explain what a *policy* is. Why is this an important concept?

[2 marks]

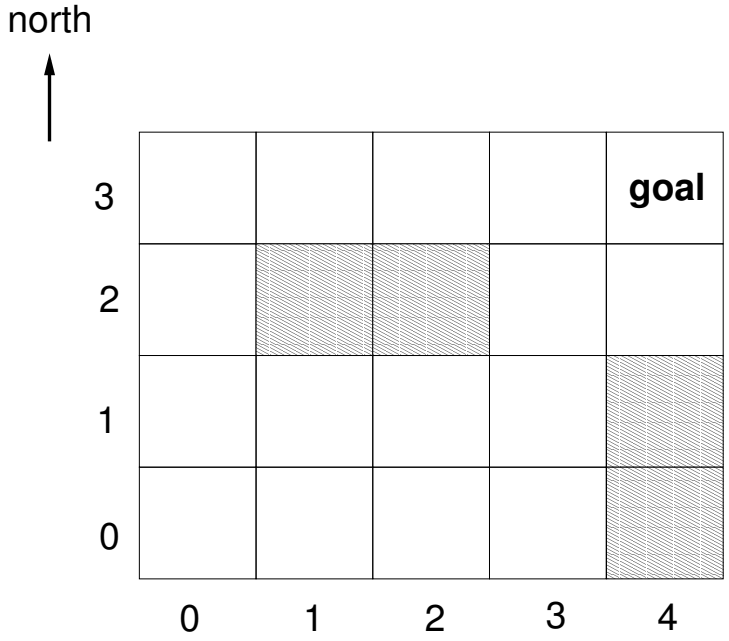
b. Explain the intuition behind the Bellman equation:

$$U(s) = R(s) + \gamma \max_{a \in A(s)} \sum_{s'} P(s'|s, a) U(s')$$

and how it can be used to derive a policy.

[4 marks]

c. The following picture shows the environment that an agent has to act in:



Obstacles are shaded. The agent can move north, south, east and west. The cost of each action is 1, the agent receives a reward of 10 for being in the goal state, and the discount factor is 1.

In this example, the agent's movement is deterministic.

i. Give an example of a run in this environment. What is the utility of this run?

[4 marks]

ii. Show how value iteration can be used to establish how to best act in this environment. Be sure to show the results for several iterations to make it clear what the final outcome of value iteration is in this case.

[8 marks]

iii. Explain how your answer to 4.c.ii would alter if the agent's movement was non-deterministic.

[2 marks]

d. A robot is at a crossroads where it has a choice between turning left, turning right, or going straight ahead.

If the robot turns left, it has an 80% chance of reaching a state with a utility of 10, a 10% chance of reaching a state with a utility of 20, and a 10% chance of reaching a state with a utility of -5.

If the robot turns right, it has a 50% chance of reaching a state with a utility of 30 and a 50% chance of reaching a state with utility of 5.

If the robot goes straight ahead, it has a 60% chance of reaching a state with utility 5, a 10% chance of reaching a state with utility 30, and a 30% chance of reaching a state with utility 10.

What is the expected utility of each choice, and which choice should the robot make? Explain the reason behind the choice the robot should make.

[5 marks]

5. The following table gives some examples of recent films I have browsed using the WebMooviz app:

Examples	Attributes			Stream?
	New	Lang	Type	
X_1	N	Eng	Action	Y
X_2	N	Sp	Comedy	Y
X_3	Y	Eng	Drama	N
X_4	Y	Sp	Comedy	Y
X_5	N	Sp	Action	Y
X_6	N	Sp	Drama	Y
X_7	N	Fr	Comedy	N
X_8	Y	Sp	Action	N
X_9	Y	Eng	Drama	Y
X_{10}	Y	Fr	Action	N

This records whether or not the film is a *New* release, what *Lang*uage the film is in (English, French or Spanish), and what *type* film is (Action, Comedy, Drama). The app also records whether or not I actually streamed the film (or just browsed it).

a. Write down an algorithm for learning a decision tree from a dataset like the WebMooviz dataset.

[6 marks]

QUESTION 5 CONTINUES ON NEXT PAGE

b. In the context of information, what is *entropy*? How could you use the concept of entropy to inform the way that your algorithm works?

[4 marks]

c. Illustrate your answer to 5.b by showing how entropy could be used to make the choice of the first attribute to test in a decision tree constructed from the WebMooviz dataset.

For full marks, you should complete the relevant entropy calculations.

[10 marks]

d. With reference to the WebMooviz data, explain the process of n-fold cross-validation. What is the advantage of using n-fold cross-validation?

[5 marks]