—— DRAFT VERSION ——

King's College London

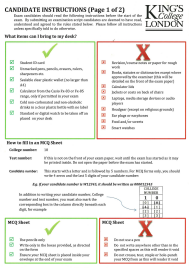
This paper is part of an examination of the College counting towards the award of a degree. Examinations are governed by the College Regulations under the authority of the Academic Board.

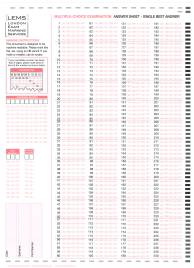
Degree Programmes	BSc, MSci, BEng, MEng
Module Code	6CCS3AIN
Module Title	Artificial Intelligence Reasoning and Decision Making
Examination Period	August 2020 (Period 3)
Time Allowed	Two hours
Rubric	ANSWER ALL QUESTIONS. A correct choice will give marks. However, marks will be deducted for incorrect choices, but no question can yield a negative overall number of points. That is each question gives at least 0 points, regardless of the answers. The answers to questions need to be clearly made by pen on the appropriate grid on the **answer sheet** provided at **the back of the exam paper.**
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

How to correctly use your Answer Sheet

- You must provide the answers to all questions on the **answer sheet** by making the appropriate choice selections when ready to commit them.
- Please make your choice selections on the **answer sheet** (**at the back of the exam paper**) by filling out the corresponding box using a **pen**.
- If you find the following 'Candidate Instructions' and 'LEMS answer sheet' on your desk, **please ignore them:**

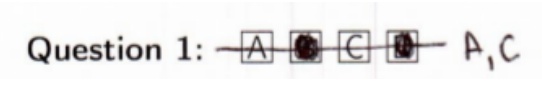




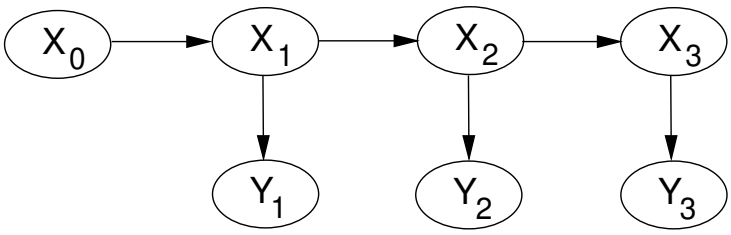
- Below are examples of how to correctly and incorrectly make your choice selections on the answer sheet.

Correct	Incorrect
Question 1: ● B C D	Question 1: ~~A~~ B C D

- Only one answer sheet per exam will be provided so make your choice selections carefully.
- If for any reason you make a mistake making your choice selection, put a line over the choice boxes of the question item and provide the correction in writing next to the question item. In the example below, the selections A and C will be considered instead of B and D.



1. The following network is a Hidden Markov Model:



If we have evidence about Y_1 and Y_2, and we establish the probability of X_1, what kind of inference is this?

[4 marks]

A. Prediction

B. Filtering

C. Smoothing

D. Flattening

E. None of the above

2. The random variables Y and Z are non-interacting causes of X. Given the conditional probability values $P(\neg x|y) = 0.1$ and $P(x|z) = 0.3$, what does the Noisy Or model give as the value of $P(x|y, z)$?

[4 marks]

A. 0.9

B. 0.93

C. 0.27

D. 0.6

E. 0.28

3. Consider the joint probability table for the three binary variables P, Q and R:

	p		¬ p	
	q	¬ q	q	¬ q
r	0.108	0.082	0.152	0.328
¬ r	0.069	0.044	0.181	0.036

What is $P(\neg p \wedge \neg r)$?

[4 marks]

A. 0.113

B. 0.217

C. 0.51

D. 0.636

E. None of the above

4. Consider the joint probability table for the three binary variables P, Q and R:

	p		¬ p	
	q	¬ q	q	¬ q
r	0.108	0.082	0.152	0.328
¬ r	0.069	0.044	0.181	0.036

What is $P((p \wedge q) \vee \neg r)$?

[4 marks]

A. 0.212

B. 0.493

C. 0.438

D. 0.514

E. None of the above

5. Consider the joint probability table for the three binary variables P, Q and R:

	p		¬ p	
	q	¬ q	q	¬ q
r	0.108	0.082	0.152	0.328
¬ r	0.069	0.044	0.181	0.036

What is $P(\neg q|p, r)$?

[4 marks]

A. a number in $(0, 0.1]$

B. a number in $(0.1, 0.2]$

C. a number in $(0.2, 0.3]$

D. a number in $(0.4, 0.5]$

E. None of the above

6. Consider the following normal form game:

	L	R
U	8 8	9 1
D	9 1	8 8

Identify any Pareto optimal outcomes:

[4 marks]

A. (U, L)

B. (U, R)

C. (D, L)

D. (D, R)

E. There are none

7. Consider the following normal form game:

	L	R
U	4 4	7 3
D	7 3	4 4

Identify the outcomes that minimize social welfare:

[4 marks]

A. (U, L)

B. (U, R)

C. (D, L)

D. (D, R)

E. There are none

8. Consider the following normal form game:

	L	R
U	3 3	6 2
D	5 2	3 3

Identify any pure strategy Nash equilibria:

[4 marks]

A. (U, L)

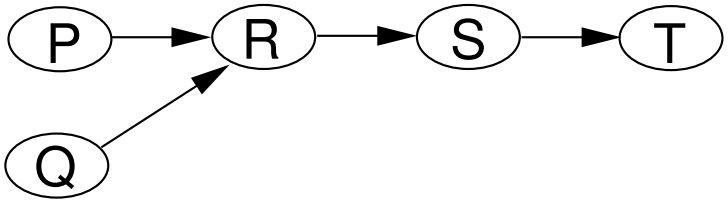
B. (U, R)

C. (D, L)

D. (D, R)

E. There are none

9. Given the Bayesian network:



Which variables are in the Markov blanket of Q?

[2 marks]

A. P

B. R

C. T

D. S

E. None of the above

10. In the Bellman equation:

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

which elements represent the sensor model?

[2 marks]

A. $U(s)$

B. $R(s)$

C. $P(s'|s,a)$

D. $U(s')$

E. None of the above

11. Given the probability distribution $\mathbf{P}(U, V, W, X, Y)$, and the query $P(\neg w|\neg x, y)$, which of the following are hidden variables:

[2 marks]

A. U

B. V

C. W

D. X

E. Y

12. A variable X has values $x_1, \ldots, x_n$, and there is a probability distribution $\mathbf{P}(X)$ over X. $\mathbf{P}(X)$ is such that:

[4 marks]

A. There is at least one $P(x_i)$ with value 1.

B. $E[x_1 + x_2] = x_1 + x_2$

C. The values of $P(x_i)$ add up to 1.

D. There exists i and j such that $P(x_i)$ and $P(x_j)$, $P(x_i) + P(x_j) = 1$.

E. For all $i \in \{1, 2, \ldots, n\}$, x_i has to be an integer.

13. In the context of Markov decision processes, a policy:

[2 marks]

A. Generates the maximum expected utility.

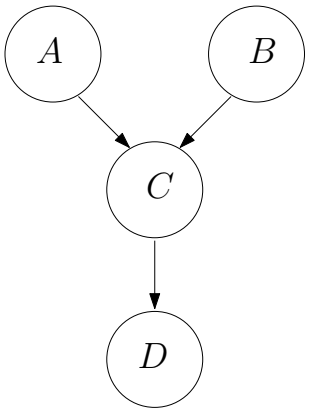
B. Tells an agent what to do.

C. Ensures that the agents always ends up in a terminal state eventually.

D. Is a mapping from actions to states.

E. None of he above.

14. Use prior sampling to create an estimate of $P(a, \neg b, c, d)$ based on three sampled events from the following network and its associated probabilities.



$$
\begin{aligned}
P(a) &= 0.5 \\
P(b) &= 0.4 \\
P(c \mid a, b) &= 0.11 \\
P(c \mid a, \neg b) &= 0.51 \\
P(c \mid \neg a, b) &= 0.41 \\
P(c \mid \neg a, \neg b) &= 0.61 \\
P(d \mid c) &= 0.8
\end{aligned}
$$

When generating sampled events, use the following list of random numbers picked from a uniform distribution between 0 and 1:

#	1	2	3	4	5	6	7	8	9	10	11	12
random number	0.23	0.5	0.5	0.2	0.2	0.42	0.3	0.2	0.1	0.1	0.23	0.4

[4 marks]

A. The first samples returns the event $a, \neg b, c, d$.

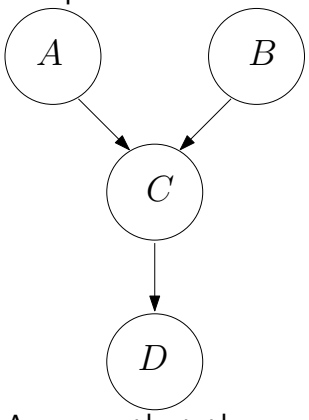
B. The second sample returns the event $a, \neg b, c, d$.

C. The third sample returns the event $a, \neg b, c, d$.

D. There exists no sequence of random numbers such that the sample returns the event $a, \neg b, c, d$.

E. None of he above.

15. Use rejection sampling to create an estimate of $P(a \mid b, \neg d)$ based on five sampled events from the following network and its associated probabilities.



$$
\begin{aligned}
P(a) &= 0.5 \\
P(b) &= 0.5 \\
P(c \mid a, b) &= 0.5 \\
P(c \mid a, \neg b) &= 0.5 \\
P(c \mid \neg a, b) &= 0.5 \\
P(c \mid \neg a, \neg b) &= 0.5 \\
P(d \mid c) &= 0.5
\end{aligned}
$$

Assume that the sampled events from the prior sampling sub-routine are

1. $\neg a, b, \neg c, \neg d$
2. $a, b, c, \neg d$
3. $\neg a, b, c, \neg d$
4. a, b, c, d
5. $\neg a, b, c, \neg d$

Then, rejection sample yields the following estimate

[4 marks]

A. $\hat{P}(a \mid b, \neg d) = 1/3$

B. $\hat{P}(a \mid b, \neg d) = 1/4$

C. $\hat{P}(a \mid b, \neg d) = 0$

D. $\hat{P}(a \mid b, \neg d) = 1$

E. None of the above

16. Consider n binary random variables $X_1, X_2, \ldots X_n$. Which of the following statements are correct.

[4 marks]

A. Assume n is even and you and you are promised that all X_i for $i \leq n/2$ are independent and identically distributed random variables. Then the joint probability distribution $P(X_1, X_2, \ldots, X_n)$ can always be stored using $O(n)$ space.

B. There always exists i, j such that X_i and X_j have the same distribution.

C. There are distributions such that it is required to store at least $2^{n-2} - 1$ different values.

D. There are cases where the joint distribution can be stored in $o(\sqrt{n})$ space.

E. None of the above

17. A diagnostic test has a probability 0.95 of giving a positive result when applied to a person suffering from a certain disease, and a probability 0.10 of giving a (false) positive when applied to a non-sufferer. It is estimated that 0.5% of the population are sufferers. Suppose that the test is now administered to a person about whom we have no relevant information relating to the disease (apart from the fact that he/she comes from this population). Which of the following statements is correct:

[4 marks]

A. The probability that the test result will be positive is 0.20425;

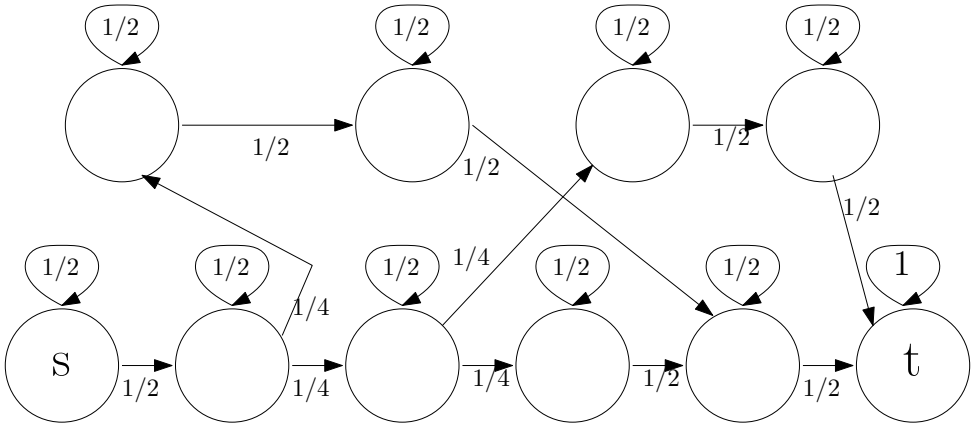
B. The probability that, given a positive result, the person is a sufferer is 0.0495;

C. The probability that, given a negative result, the person is a non-sufferer is 0.9997;

D. The probability that the person will be misclassified (i.e., they get an incorrect diagnose) is 0.09975.

E. None of the above.

18. Consider the following graph. An agent starts at node s and in every round it follows an edge with the probability given by the weight of the edge. For example, if the agent is at node s, it stays at s with probability $1/2$ and it moves to the next node with probability $1/2$. Let X be the random variable denoting the number of rounds it takes to get from s to t.



Which of the following statements are correct.

[4 marks]

A. $E[X] = 12$

B. $E[X] < 10$

C. $Pr(X > 1000) > 0$

D. $Pr(X = 5) = 1/32$

E. None of the above

19. Which of the following statements are correct.

[4 marks]

A. A Pareto optimal solution can **minimise** social welfare, but it doesn't have to.

B. A Nash equilibrium can **minimise** social welfare, but it doesn't have to.

C. A Nash equilibrium can be a Pareto optimal solution, but it doesn't have to be.

D. Consider the case with two players. A pair of strategies (i, j) can be such that it a) is not Pareto optimal, b) it is not a Nash equilibrium and c) it does not optimise social welfare.

E. None of the above.

20. Consider a game with payoff matrices A (to i) and B (to j). Let (x^*, y^*) be a mixed strategy that is a Nash equilibrium. Which of the following statements are correct

A. It is possible (depending on A and B) that there exists an $x' \neq x^*$ such that

$$\forall x, x' A y'^T \geq x A y^{*T}$$

B. It is possible (depending on A and B) that there exists an $x' \neq x^*$ and $y' \neq y^*$ such that

$$x' A y' > x^* A y^{*T} \text{ and}$$
$$x' B y' > x^* B y^{*T}$$

C. It holds that

$$\forall x, x^* A y^{*T} > x A y^{*T} \text{ and}$$
$$\forall y, x^* B y^{*T} > x^* B y^T$$

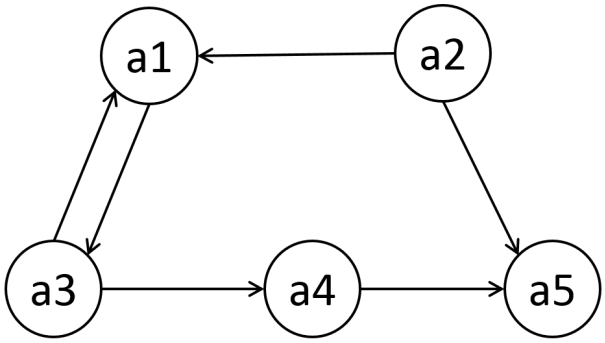
D. It is possible (depending on A) that there exists an $x' \neq x^*$ such that

$$x' A y^{*T} > x^* A y^{*T}$$

E. None of the above.

[4 marks]

21. Consider the argumentation framework shown below.



Identify all complete extensions from the options below:

[4 marks]

A. $\{\}$

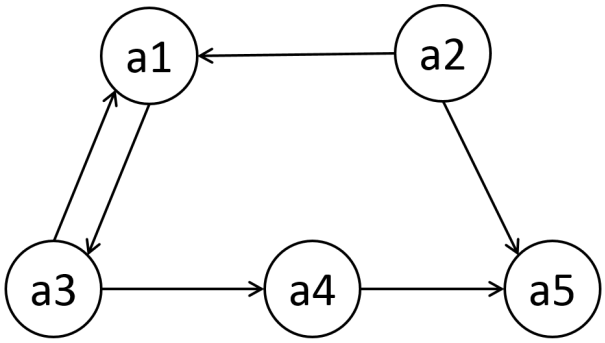
B. $\{a3, a5\}$

C. $\{a2, a3\}$

D. $\{a2, a3, a5\}$

E. $\{a2\}$

22. Consider the argumentation framework shown below.



Identify all of the **false** statements from the options below.

[4 marks]

A. The empty set does not defend any arguments.

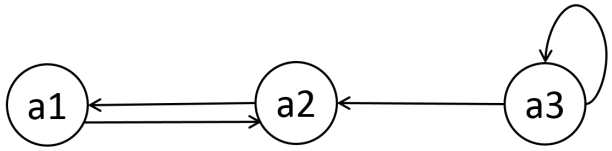
B. The only argument that is defended by the set $\{a1\}$ is $a4$.

C. The set $\{a3\}$ is admissible.

D. The set $\{a2, a4\}$ is conflict-free.

E. The set $\{a1, a2, a3, a4, a5\}$ is conflict free.

23. Consider the argumentation framework shown below.



Identify all of the true statements from the options below.

[4 marks]

A. The set $\{\}$ is a complete extension.

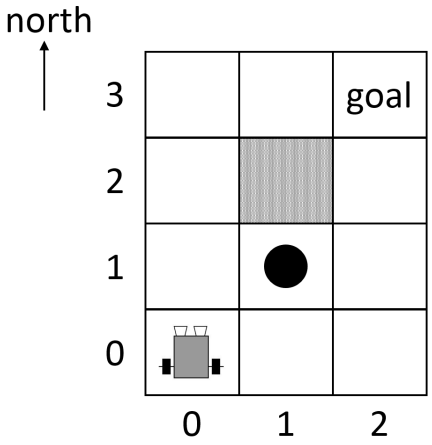
B. The set $\{a1, a3\}$ defends all of its elements.

C. The set $\{a1, a3\}$ is conflict-free.

D. The grounded extension is $\{a1\}$.

E. The set $\{a2\}$ is a complete extension.

24. The figure below shows an agent situated in a *static* environment. The environment E is made up of 12 states: $e_{0,0}$, $e_{0,1}$, ..., $e_{2,2}$, $e_{2,3}$. The current state is determined by the square that the agent is located in, so if the agent is currently in the square (i, j) then the current state is $e_{i,j}$. The state shown in the figure below is $e_{0,0}$.



The agent can move north, south, east and west, which we write as: α_n, α_s, α_e, α_w, and these have the effects you would expect. If the agent is in state $e_{0,0}$ and takes action α_n, it will end up in state $e_{0,1}$, while if the agent is in state $e_{1,1}$ and takes action α_e it will end up in $e_{2,1}$. If the agent tries to move outside the grid then it does not move (for example if the agent is in $e_{0,3}$ and tries to do α_n then it stays in $e_{0,3}$).

If the agent enters the state $e_{2,3}$, marked with the word goal, then it gets a reward of 10. If it enters state $e_{1,1}$, marked with a dark circle, it gets a reward of -10 (i.e. it takes a loss).

The filled square $(1, 2)$ is an obstacle, the agent cannot enter this square. If it tries to move into this square its action will fail and it will stay where it is.

QUESTION CONTINUES ON THE NEXT PAGE

Consider the following control program:

```
counter = 0
while ((counter < 10) and (not in state e_{2,3})){
     randomly pick either α_n, α_s, α_e or α_w
        (each with probability 0.25)
     execute the action that was selected
     counter = counter + 1
}
```

Select all of the true statements from the options below.

[6 marks]

A. The maximum reward the agent may receive is 10.

B. The environment is not deterministic.

C. The agent is guaranteed to reach the goal state at some point.

D. It is possible to determine the minimum reward that the agent may receive.

E. None of the above.

25. You are the lead AI software developer for a company which designs, builds and sells autonomous (self-driving) cars. One of the cars sold by your company is involved in a road accident, where the vehicle was faced with a sudden difficult choice. The owner of the self-driving car was in the passenger seat of the car at the time, and she had the power to stop the car in an emergency.

The choice faced by the self-driving car was either to keep driving straight ahead and face a head-on collision with an oncoming car driven by a human that was driving in the wrong lane OR to move onto the footpath where there was a risk of killing some pedestrians who were there. The self-driving vehicle stayed in its current lane and crashed into the oncoming vehicle, killing the family that was in the car.

The insurance company that had insured the driver of the oncoming vehicle has now taken action in court to sue you and your employer for damages, saying that you were responsible for the actions of the self-driving car.

Which one of the following arguments do you think a court would find the most acceptable?

[5 marks]

QUESTION CONTINUES ON THE NEXT PAGE

A. This is the responsibility of my employer, not me. I was just doing what I was told by my boss.

B. The choice made by the self-driving car was a difficult ethical trade-off, with potential negative consequences no matter what choice was made.

C. The owner of the self-driving car was a passenger in the car at the time, so she should have over-ruled the AI driving the car and stopped it.

D. Any driver, whether they be human or an AI program, has to make such a decision on the spur of the moment,and so neither myself nor my company can be held responsible for a decision made so quickly. The AI should be judged by the same standards as would apply if a human were driving the car.

E. As part of the software development for the car design, my team had run extensive game theory simulations. Based on these simulations, we expected the other driver to chicken out and swerve aside before the two vehicles crashed. It is not our fault that the human driver did not behave according to our simulations.

26. The technology company you work for has tasked you with developing an AI application which searches social media, such as Facebook and LinkedIn, for information and photos of potential recruits and then matches this information against profiles of the company's best-performing existing staff to identify the best potential recruits. The plan is that the Human Resources Department will contact the potential recruits to invite them for an interview.

After developing the system but before putting it into production, you notice that almost all the recommended potential recruits are men. Your realize that this may be because most of the staff in the technology sector, including most of company's existing staff and most potential recruits, are men.

You also notice that the system seems to reject any potential recruits whose photos show them wearing a hat or other headgear. You do not know why the AI system does this, but it may just be some trivial quirk of a machine learning system.

What do you do?

[5 marks]

A. Nothing. All AI systems have quirks, and it is best to leave them alone.

B. This decision is the responsibility of my employer, so I will just follow orders.

C. Try to eliminate the bias against both women and hat-wearers.

D. Try to eliminate the bias against women but ignore the issue of the hat-wearers, as this is trivial.

E. Try to eliminate the bias against hat-wearers but ignore the issue of gender bias, because this is a problem across the entire technology sector which one company cannot solve.