—— SOLUTIONS ——

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, MSci
Module Code	7CCSMAMS (Mock)
Module Title	Agents and Multiagent Systems
Examination Period	December 2019

Time Allowed Two hours

Rubric ANSWER ALL QUESTIONS.

All questions have ONE or MORE correct choices. In order to obtain full marks you must select all correct choices and only those.

Marks will be deducted for incorrect choices selected in questions.

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

Your exam in Jan will be open book.

PLEASE DO NOT REMOVE THIS PAPER FROM THE EXAMINATION ROOM

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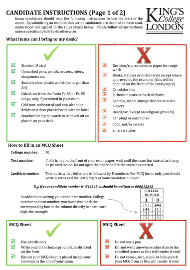
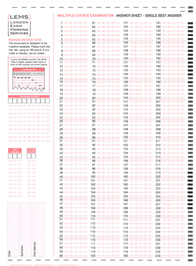
Your exam in Jan will be on KEATS, so you won't need to fill in an answer sheet.

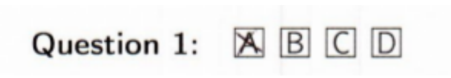
How to correctly use your Answer Sheet and Answer Book

- You must provide the answers to all questions on the **answer sheet** by making the appropriate choice selections when ready to commit them.
- Only the answers provided in the answer sheet will be considered.
- 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:**

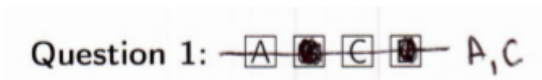




- Below are examples of how to correctly and incorrectly make your choice selections on the answer sheet.

Correct	Incorrect
	

- 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.



SEE NEXT PAGE

1. Consider the partial BDI agent algorithm below for executing the plan `pi`. Which of the following statements are true?

```
1  while not empty(pi)
2          or succeeded(I, B)
3          or impossible(I, B) do
4    a := head(pi);
5    execute(a);
6    pi := tail(pi);
7    get next percept p;
8    B := brf(B, p);
9    if reconsider(I, B) then
10     D := options(B, I)
11     I := filter(B, D, I)
12   end-if
13   if not sound(pi, I, B) then
14     pi := plan(B, I)
15   end-if
16 end-while
```

[6 marks]

A. If we removed lines 9 and 12, the agent would not be reactive to changes in its environment.

B. If we removed lines 9 and 12, the agent could repeatedly reconsider its intentions and be at risk of never actually achieving them.

C. Without lines 10 and 11, the agent could continue to pursue intentions it no longer had a reason to desire.

D. Without lines 10 and 11, the agent may not be aware that its plan is unachievable in the current environment.

E. Without lines 10 and 11, the agent would not replan should its plan ever become unsound to commit to under the current environment.

Answer

B, C .

Syllabus: Practical reasoning

This tests students understanding of BDI reasoning algorithms.

Marking scheme

A. -3

B. 3

C. 3

D. -3

E. -3

no negative overall mark

2. A utility function over runs of an agent embedded in an environment is defined by the function $u^r : \mathcal{R}^E \rightarrow \mathbb{R}$. A utility function over environment states is defined by the function $u^e : E \rightarrow \mathbb{R}$. Recall that E is the set of all possible environment states; Ac is the set of all possible actions; $\mathcal{R}^E$ is the set of all possible runs over E and Ac that end with an environment state; $\mathbb{R}$ is the set of real numbers. Which of the following are true?

[6 marks]

A. Every utility function defined over runs can be expressed by a utility function defined over states.

B. Every utility function defined over states can be expressed by a utility function defined over runs.

C. The utility of a run is always the sum of utilities of the states within that run.

D. The expected utility of a run in a system is the product of the probability that the run occurs and the utility of that run.

E. If the environment and the agent's decision making are deterministic, then the expected utility of a particular agent is equal to the utility of one run of the system.

Answer

B, D, E .
Syllabus: Embedded agents
This tests students understanding of the utility obtained by agents executing in an environment, and the distinction between states and runs.

Marking scheme

A. -2

B. 2

C. -2

D. 2

E. 2

no negative overall mark

3. Which of the following temporal logic formulae is one way to formalise the statement "you will be allowed to drive from the day after you get your licence" using the predicates $hasLicence(you)$ and $allowedToDrive(you)$? As a reminder, $\Diamond$ means 'true now or at some point in the future', $\blacksquare$ means 'true at every point in the past', $\Box$ means 'true now and at all points in the future', $\circ$ means 'true in next state' (in this case, the next day), $\circledcirc$ means 'true in previous state' (previous day), $\phi \mathcal{U} \psi$ means 'ψ true at some point in the future and ϕ true at all points until then', $\phi \mathcal{S} \psi$ means 'ψ true at some point in the past and ϕ true at all points since then'.

[4 marks]

A. $\circledcirc hasLicence(you) \rightarrow allowedToDrive(you)$

B. $\neg allowedToDrive(you)\ \mathcal{U}\ (\circledcirc\ hasLicence(you))$

C. $allowedToDrive(you)\ \mathcal{S}\ (\circ\ hasLicence(you))$

D. $\circ\ hasLicence(you) \rightarrow allowedToDrive(you)$

Answer

A .

Syllabus: Agent architectures

This tests students understanding of temporal logic, learnt for expressing agent behaviour.

- The second option is nearly right but doesn't actually say that you are allowed to drive after getting license, only that you can't before having the licence
- The third option is wrong both because it talks about the past not future and because it says you were allowed to drive the day before getting the licence
- The fourth option is wrong because it says that you are allowed to drive the day before getting a licence

Marking scheme

A. 4

B. -4

C. -4

D. -4

no negative overall mark

4. Consider the use of agent-based models (ABM) for studying emergent properties of a society. Which of the following are true?

Ignore this question, we won't cover ABM this year. [6 marks]

A. If a society has emergent properties, this is because the number of people in that society is large.

B. An ABM in which agents do not directly interact with each other could not be used to study emergent properties.

C. If a property of a society is emergent, we cannot study it just through analysing the behaviour of an individual in that society, even if every individual behaved the same.

D. If agents with the same individual behaviour and attributes comprise two societies, and the societies are entirely deterministic in their behaviour, then different properties could still emerge due to differences in the agent's links to each other (e.g. neighbourhoods).

E. A cellular automata model could not be used to investigate emergent properties because the cells are not as behaviourally complex as ABM agents.

Answer

C, D .
Syllabus: Agent-based modelling
This tests students knowledge of understanding of studying emergent properties through agent-based simulation.

Marking scheme

A. -3

B. -3

C. 3

D. 3

E. -3

no negative overall mark

5. Comparing approaches to coordination, which of the following are true?

[6 marks]

Ignore answers B and C, we won't cover coordination through joint intentions this year.

A. Centralised multi-agent planning differs from merging of individual plans because the merging of individual plans requires no centralisation.

B. Partial global multi-agent planning differs from coordination through joint intentions because coordination through joint intentions requires no sharing of plans only communication on the status of the shared goal.

C. The use of prescriptive norms differs from coordination through joint intentions because once prescriptive norms are set and known, no communication may be required to coordinate on a particular goal.

D. Partial global planning differs from merging of individual plans because partial global planning requires no centralisation.

E. Both multi-agent planning and the use of prescriptive norms require the agents to share private information about their goals with other agents.

Answer

B, C, D .

Syllabus: Coordination

The student needs to understand and be able to contrast different mechanisms described in class.

Marking scheme

A. -2

B. 2

C. 2

D. 2

E. -2

no negative overall mark

6. Consider a game in which two players each have four possible moves, A, B, C and D.

- If one player plays B and the other plays A, C or D, then the B player receives 2 utility and the other player receives 1 utility.
- In all other outcomes, both players receive 0 utility.

Which of the following are true?

[6 marks]

A. There is no Nash equilibrium in this game.

B. There is a dominant strategy by either agent to play B because this gives the highest potential utility.

C. An outcome in which one player plays B and the other plays C is Pareto optimal.

D. An outcome in which both players plays B is Pareto optimal.

E. There is more than one outcome that maximises social welfare.

Answer

C, E .

Syllabus: Negotiation

The student needs to apply their knowledge of game theory properties to a novel negotiation case study.

- There are 6 outcomes that are a Nash equilibrium: every option where one player plays B and the other does not. In these cases, the B player receives the maximum possible, and the other player can only reduce their utility to 0 by changing to B or remain at 1 through any other change.
- The Nash equilibrium outcomes are also Pareto optimal (any change reduces the utility of the B agent from 2 to 1 or both agents to 0) and maximise social welfare (they all produce the highest social welfare of 3).

Marking scheme

A. -3

B. -3

C. 3

D. -3

E. 3

no negative overall mark

7. Consider the following voter profile and select the options that are true.

5 voters:	$A \succ B \succ C \succ D$
6 voters:	$B \succ D \succ A \succ C$
7 voters:	$C \succ B \succ D \succ A$
8 voters:	$D \succ A \succ C \succ B$

[6 marks]

A. The winner under plurality voting is the same as if using instant run-off.

B. The winner under plurality voting is the same as if using the Copeland rule.

C. If using linear sequence majority voting with agenda (D, A, B, C), then C would win.

D. The winner under plurality voting is the same as if using a Borda count.

E. There exists a positional scoring rule (a choice of scores per position) that would cause A to be the winner (hint: first look at whether there are scores that allow A to beat D).

Answer

B, C, D .

Syllabus: Social choice

The student will need to understand different voting systems and calculate the outcomes by applying each to this scenario.

- Under plurality voting, A has 5 votes, B has 6, C has 7, and D has 8. So D wins.
- In instant run-off, the first eliminated candidate is A because of the scores given for plurality voting above. In the second round, B's votes increase to 11 so C is out. B's votes increase to 18, compared to D's 8. So B wins.
- Under Copeland rule, A draws 13/13 with B, A beats C 19/7, D beats A by 21/5, C beats B by 15/11, B beats D 18/8, D beats C 14/12. A and B have 0 points overall, C has -1, D has 1. So D wins.
- In the linear sequential voting agenda shown, we can use the same votes as for Copeland rule above, so D would beat A 21/5, B would beat D 18/8, and C would beat B 15/11. So C wins.
- In the Borda count, A receives $5 \times 3 + 8 \times 2 + 6 = 37$, B receives $6 \times 3 + 12 \times 2 + 24 = 42$, C receives $7 \times 3 + 0 \times 2 + 13 = 34$, D receives $8 \times 3 + 6 \times 2 + 7 = 43$. So D wins.
- A cannot win under PSRs. If we say the score for 1st place is w, for 2nd is x, for 3rd is y, and for 4th is z, then for A to beat D, $5w+8x+6y+7z > 8w + 6x + 7y + 5z$. This simplifies to $2x + 2z > 3w + y$. Because $z <= y$ by the PSR rules, $2x + 2z > 3w + z$ or $2x + z > 3w$. Because $w >= x >= z$ by the PSR rules, $3w > 3w$, which is impossible, so A can never beat D regardless of the scoring rules.

Marking scheme

A. -3

B. $\boxed{2}$

C. $\boxed{2}$

D. $\boxed{2}$

E. -3

no negative overall mark

8. Three agents (A, B and C) bid for two goods (x and y) in a combinatorial auction. A Vickrey-Clarke-Groves mechanism is used to allocate and set the pricing for the goods. They are honest in declaring their valuation functions specified below.

- Agent A values receiving both goods, x and y, at 3. Receiving only one good is of zero value to the agent.
- Agent B values receiving either or both goods at 2.
- Agent C values receiving any bundle containing good y at 2, but x alone has no value to the agent.

Which of the following are true?

[6 marks]

A. Good x is allocated to agent A.

B. Agent B pays more for their allocated bundle than agent C.

C. Agent C pays more for their allocated bundle than agent A.

D. Agent A receives 0 utility from the allocation.

E. Agent C receives 2 utility from the allocation.

Answer

C, D .

Syllabus: Social choice

The student will need to understand how to apply the specified auction mechanism to a concrete case.

- Allocating x to B and y to C gives maximum social welfare of 4. Allocating both goods t o A would only give welfare of 3. Allocating both goods to either B or C, or just y to B, would give a welfare of 2. All other combinations give 0 welfare.
- Without A in the auction, the outcome would be no different.
- Without B or C in the auction, allocating both goods to A would produce maximum welfare of 3.

- A pays $4 - 4 = 0$. B pays $3 - 2 = 1$. C pays $3 - 2 = 1$.
- A's utility is $0 - 0 = 0$. B's utility is $2 - 1 = 1$. C's utility is $2 - 1 = 1$.

Marking scheme

A. -3

B. -3

C. 3

D. 3

E. -3

no negative overall mark

9. An agent has created the following arguments from its database of knowledge: $(\{a\}, a)$, $(\{\neg b\}, \neg b)$, $(\{a \rightarrow b\}, a \rightarrow b)$, $(\{a, a \rightarrow b\}, b)$, $(\{a \rightarrow b, \neg b\}, \neg a)$. It creates an argumentation graph, where one argument attacks another wherever it *rebuts* or *undercuts* the other argument. The agent labels the arguments In or Out according to abstract argumentation rules to determine labellings under the grounded and preferred semantics. Which of the following are true?

[6 marks]

A. Only argument $(\{a \rightarrow b\}, a \rightarrow b)$ is In under the grounded semantics.

B. In all preferred semantics labellings, 2 arguments are labelled In.

C. There are 4 possible preferred semantics labellings.

D. All the arguments are acceptable under preferred credulous semantics.

E. All of the attacks in the argumentation graph are due to undercuts.

Answer

A, D .

Syllabus: Argumentation

The student will need to understand how argumentations can be constructed from classical logic and how abstract argument labelling works.

- The possible arguments from the database are as follows. (A): $(\{a\}, a)$, (B): $(\{a \rightarrow b, \neg b\}, \neg a)$, (C): $(\{a, a \rightarrow b\}, b)$, (D): $(\{\neg b\}, \neg b)$, (E): $(\{a \rightarrow b\}, a \rightarrow b)$
- A and B attack each other by rebuttal, B and C attack each other by undercutting, C and D attack each other by rebuttal. E is neither attacked nor attacks.
- E is the only argument In under all semantics because it is not attacked.
- There are three possible preferred semantics. If A is In, then either C or D can also be In. If D is In, then either A or B can also be In. These two have one case overlapping.

Marking scheme

A. 3

B. -3

C. -3

D. 3

E. -3

no negative overall mark