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THE UNIVERSITY
of LIVERPOOL

JANUARY 2006 EXAMINATIONS

Bachelor of Arts: Year 3
Bachelor of Engineering: Year 3
Bachelor of Science: Year 3
Bachelor of Science: Year 4
No qualification aimed for: Year 1

Knowledge Representation and Reasoning

TIME ALLOWED : Two Hours and a half

INSTRUCTIONS TO CANDIDATES

Answer **four** questions only.

If you attempt to answer more questions than the required number of questions (in any section), the marks awarded for the excess questions will be discarded (starting with your lowest mark).

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1. (Knowledge Representation and Reasoning)

   (a) In relation to Newell and Simon's physical symbol system hypothesis, what *three* parts does a physical symbol system consists of? (3 marks)

   (b) Knowledge representation and reasoning takes techniques from and contributes to several areas of computer science. Discuss, with reference to *three* areas. (9 marks)

   (c) (i) State the so-called *knowledge principle* as discussed, for example, by Feigenbaum. (7 marks)

   (ii) Give a critical account of the knowledge principle discussing at least *three* critical points. (6 marks)

2. (Modal Logic)

   Let the Kripke model $\mathcal{M} = ((W, R), I)$ be given by

$$W = \{1, 2, 3, 4, 5\}$$
$$R = \{(1, 2), (1, 3), (2, 3), (3, 4), (4, 5)\}$$
$$I = \{(p, \{1, 2, 4\}), (q, \{2, 4\})\}$$

   (a) Draw the labelled directed graph corresponding to $\mathcal{M}$. (5 marks)

   (b) Give formal derivations which determine at which worlds in the Kripke model $\mathcal{M}$, defined above, the formula $p \wedge q$ is true. (6 marks)

   (c) Give a formal derivation which determines whether the following is true in the Kripke model $\mathcal{M}$ defined above: $\mathcal{M}, 3 \models q \vee \Box\Diamond p$ (14 marks)

3. (Probability Theory)

(a) (i) What is the multiplication rule? (4 marks)

(ii) What is Bayes' rule? (4 marks)

(b) A box contains four balls labelled A, B, C and D. Two balls are drawn one after the other, the first ball being replaced before the second is drawn.

(i) Give the sample space for this scenario. (2 marks)

(ii) Given that the same ball does not appear on both draws, give the new sample space for this scenario. (2 marks)

(iii) Again, given that the same ball does not appear on both draws, what is the probability that neither of the two balls drawn is C? Explain your answer. (5 marks)

(c) A student who previously passed Software Development (abbreviated to SD) has a 0.5 chance of passing Knowledge Representation (abbreviated to KR); and,

a student who previously passed Artificial Intelligence (abbreviated to AI) has a 0.8 chance of passing KR.

Suppose I have information about 100 students who have taken the KR course last year. Every student who takes KR previously has to take either SD or AI. Of the 100 students for whom I have information, 30 took SD and 70 took AI.

(i) What is the prior probability that a student taking KR will pass? (4 marks)

(ii) If I know that a student has passed KR, what is the posterior probability that the student passed AI? (4 marks)

4. (Epistemic Logic)

   (a) Describe what is meant by the term *logical omniscience* and give two reasons as to why logical omniscience could be considered unrealistic. (7 marks)

   (b) In the card game Indian poker players are dealt a playing card by the dealer which they place on their forehead and so cannot see it, though the other players can. Suppose that a player wins the game if he correctly claims that his card is an Ace. We can model this puzzle for the case of three players. Use as states $(x, y, z) \in \{0, 1\}^3$, where for instance $(1, 1, 0)$ denotes the (hypothetical) situation in which players 1 and 2 both have Aces, but player 3 does not.

   Draw the Kripke model that represents this situation. Clearly indicate the accessibility relations. Explain why your drawing represents the situation. (9 marks)

   (c) Now the dealer announces that at least one player has an Ace.

   (i) Draw the Kripke model that represents this new situation. (4 marks)

   (ii) Clearly label the node which shows the situation where player 3 is the only player holding an Ace. (1 mark)

   (d) After the dealer has announced that one player holds an Ace, it may be possible for one of the players to know that he holds an Ace. Use the Kripke diagram you gave in part (c) to explain in which situations a win can be claimed with certainty. (4 marks)

5. (Description Logic)

   Let $\mathcal{K}$ be the knowledge base below

$$\begin{array}{rl} \text{male} \doteq \neg\text{female} & \qquad \text{john} : \text{person} \\ \text{marriedPerson} \doteq \text{person} \sqcap \exists\text{hasSpouse.person} & \qquad \text{john} : \neg\text{female} \\ \text{wife} \doteq \text{marriedPerson} \sqcap \text{female} & \qquad \text{mary} : \text{person} \\ \text{husband} \doteq \text{marriedPerson} \sqcap \text{male} & \qquad (\text{john}, \text{mary}) : \text{hasSpouse} \end{array}$$

   (a) Give the expanded TBox of the knowledge base $\mathcal{K}$. (4 marks)

   (b) Compute the negation normal form of the concept $\neg$husband with respect to the TBox of the knowledge base $\mathcal{K}$. (8 marks)

   (c) Give a tableau derivation which determines whether john is an element of the concept husband. (13 marks)