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THE UNIVERSITY
of LIVERPOOL

JANUARY 2007 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) Russell and Norvig (1995) have given a classification of the opposing ends of five different types of environment that a computer agent can inhabit. Name both ends for each of the *five* different types of environment. (5 marks)

   (b) Name the *five* desirable features of knowledge representation for computer manipulation. (5 marks)

   (c) (i) In relation to the so-called *knowledge principle*, explain what is meant by the phrase "Physicians, not logicians, treat patients". (6 marks)

   (ii) Give a critical account of the knowledge principle discussing at least *three* critical points. (9 marks)

2. (Modal Logic)

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

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

   (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: $M, 1 \models \neg q \vee \Diamond\Box p$ (14 marks)

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3. (Modal and Epistemic Logic)

(a) Explain what is meant by an *equivalence relation* in the logic S5. (4 marks)

(b) Describe what is meant by the term *logical omniscience* and give two reasons as to why logical omniscience could be considered unrealistic. (8 marks)

(c) Consider the situation where there are two students, Bob and Alice, each going to a computer laboratory to do some work. Suppose Bob goes into laboratory 1 and Alice goes into laboratory 2. Let p represent the proposition 'the heating is on in laboratory 1' and let q represent the proposition 'the heating is on in laboratory 2'.

(i) Draw the Kripke model that represents this situation, clearly indicating the accessibility relations. Explain why your drawing represents the situation. (8 marks)

(ii) Bob telephones Alice to tell her that the heating is on in laboratory 1. This is the only information exchanged during the phone call. Update the Kripke model given this new information and explain why your drawing represents the new situation. (5 marks)

4. (Description Logic.)

(a) One auxiliary inferential service of description logic is "*Checking the consistency of an ABox (with respect to a TBox)*". The test for this procedure proceeds in *five* steps. State all *five*. (5 marks)

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

$$\begin{array}{rl} \text{staff} \doteq \neg\text{student} & \qquad \text{logicProj} : \text{project} \\ \text{tutor} \doteq \text{staff} \sqcap \exists\text{hasTutee.student} & \qquad \text{tom} : \neg\text{student} \\ \text{researcher} \doteq \text{staff} \sqcap \exists\text{worksOn.project} & \qquad \text{sally} : \text{student} \\ \text{lecturer} \doteq \text{tutor} \sqcup \text{researcher} & \qquad (\text{tom}, \text{sally}) : \text{hasTutee} \end{array}$$

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

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

(iii) Give a tableau derivation through the application of the appropriate completion rules which determines whether tom is an element of the concept tutor.(8 marks)

5. (Probability Theory)

(a) (i) State the addition law for two non-mutually exclusive events. (4 marks)

(ii) State Bayes' rule. (4 marks)

(b) Consider a random experiment that involves a bag containing four coins as follows: a pound coin (P), a fifty pence coin (F), a ten pence coin (T) and a one pence coin (O). Suppose we independently choose two coins from the bag and replace the first coin before choosing the second one.

Also, consider two random variables associated with the experiment, which both have the value set $\{0, 1, 2\}$:

X = Number of times a silver coin appears.
Y = Number of times a coin with the value less than one pound appears.

Note that P is gold coloured, F and T are silver coloured and O is copper coloured.

(i) Draw the sample space for this experiment as a table using only the types of coin (P, F, T and O) to describe the sample space. Draw the table with the outcome of the first choice of coin across the rows and the outcome of the second choice of coin down the columns. (10 marks)

(ii) In relation to the table you have drawn above for (i), state all sample points where X = 1 and Y = 2. (4 marks)

(iii) From your answer to (ii) above, state the joint probability distribution of X and Y (i.e. the joint probability distribution where X = 1 and Y = 2). (3 marks)