PAPER CODE NO.	EXAMINER : Dr. Rafael H. Bordini
COMP230	DEPARTMENT : Computer Science Tel. No. (0151) 794 3792

THE UNIVERSITY
of LIVERPOOL

MAY 2003 EXAMINATIONS

Bachelor of Arts : Year 3
Bachelor of Arts : Year 4
Bachelor of Science : Year 2
Bachelor of Science : Year 3

INTRODUCTION TO ARTIFICIAL INTELLIGENCE

TIME ALLOWED : Two Hours

INSTRUCTIONS TO CANDIDATES

Section A: Answer exactly 5 questions, one from each of the 5 subsections. If there is more than one question in a subsection, you can choose any one of those questions.

Section B: Credit will be given for the best 2 answers 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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Section A

Each of the following questions is worth **10 marks**. Answer exactly one question from each of the 5 subsections.

Section A.1

1. Which are the two dimensions along which the four main definitions of Artificial Intelligence (AI) vary? Chose one of these four definitions and identify the main concerns of AI from that point of view.

Section A.2

2. What is necessary for defining a real problem as a search problem? What is meant by *abstraction* in the process of defining a search problem?

3. Explain how breadth-first search works and discuss its main characteristics. Recall that examples of evaluation criteria for search procedures are whether they are complete, optimal, as well as their time and space complexity.

4. In the context of problem solving as search in a state-space, what is the notion of a *heuristic function*? Why is the use of heuristic functions important in search problems?

Section A.3

5. Give two desirable properties of a knowledge representation scheme, saying briefly what they mean.

6. Mention some advantages and disadvantages of frames and semantic networks.

Section A.4

7. What is an expert system? Give examples of applications of expert systems.

8. Explain how *backward chaining* works in a rule based system.

Section A.5

9. In the context of mathematical logics, what is meant by the term *logical consequence*?

10. How does first order logic differ from propositional logic?

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Section B

Answer any two (2) questions from this section. Marks will be given to at most two of the questions below. If you answer more than two questions, only the two questions with higher marks will be considered. Each of the following questions is worth **25 marks**.

1. The vacuum world, as depicted in Figure 1, consists of an agent that is supposed to clean two rooms. The agent can move to the room to the left (**L**) or the right (**R**), and it can operate the vacuum cleaner, producing a suction action (**S**). The suction action is assumed to be an action whose outcome is to have the whole room cleaned. Figure 1 shows the whole state space of the problem where the goal states are the ones in the bottom (i.e., the goal test is true whenever both rooms clean in a given world).

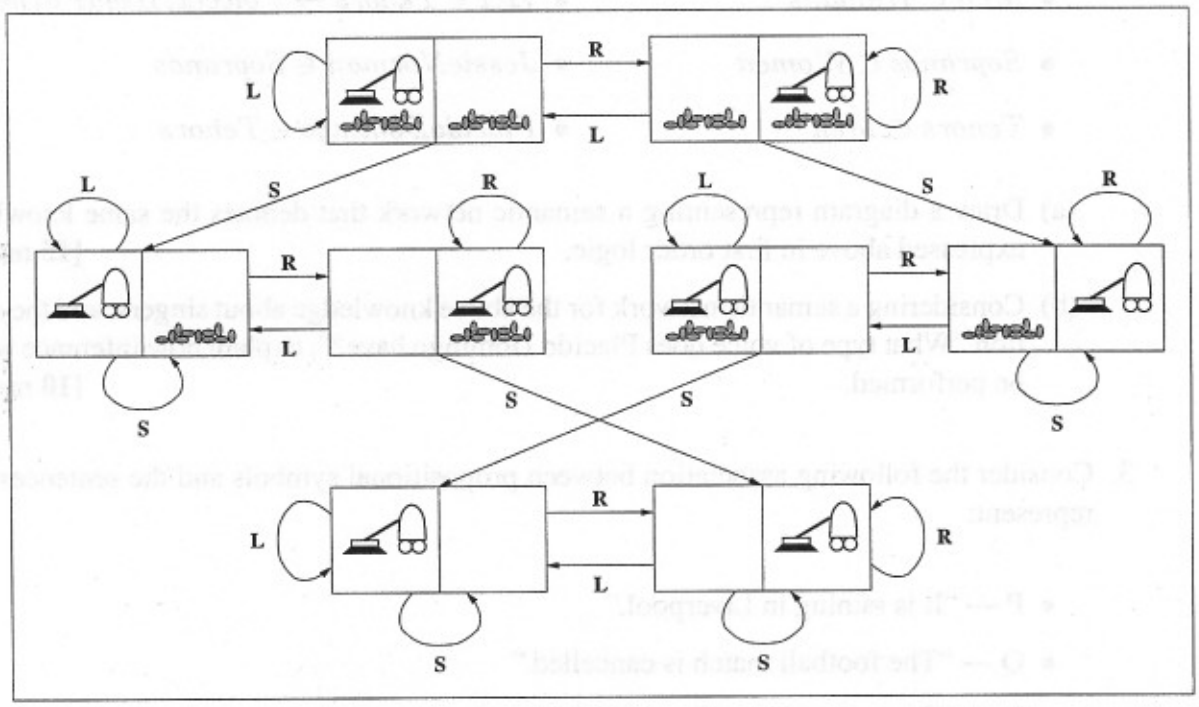
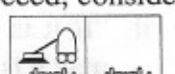
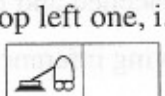
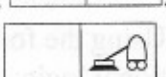


Figure 1: *The Vacuum World State Space. Arcs denote actions:* ***L*** *= moving left;* ***R*** *= moving right;* ***S*** *= suction action.*

(a) Draw a sequence of diagrams showing how the depth-limited search procedure would find a solution to the problem. Whenever a state is expanded the operators are always considered in this order: **S**, **R**, and then **L**. This is to say that the leftmost arc should be labelled **S**, the middle one **R**, and, accordingly, the rightmost arc should be labelled **L**.

When showing how the depth-limited search would proceed, consider that the depth limit is **3** and that the initial state is the top left one, i.e.,  .

Remember that the goal states are either  or  . **[15 marks]**

(b) How would depth-limited search compare to breadth-first for the problem described in this question? **[5 marks]**

(c) If A* search were to be performed in a problem described as above, two functions would need to be defined. Describe what these functions are, how A* would proceed, and give some of its characteristics. **[5 marks]**

2. Consider the following representation in first order logic of known facts in the domain of human singers. The logical representation is given by the conjunction of the following eight (8) formulæ:

- $Women \subset Humans$
- $Men \subset Humans$
- $Sopranos \subset Women$
- $Tenors \subset Men$
- $\forall x.x \in Sopranos \rightarrow Voice(x, HighPitched)$
- $\forall x.x \in Tenors \rightarrow Voice(x, HighPitched)$
- $JessieNorman \in Sopranos$
- $PlacidoDomingo \in Tenors$

(a) Draw a diagram representing a semantic network that denotes the same knowledge expressed above in first order logic. **[15 marks]**

(b) Considering a semantic network for the above knowledge about singers, and the question "What type of voice does Placido Domingo have?", explain how inference would be performed. **[10 marks]**

3. Consider the following association between propositional symbols and the sentences they represent:

- P — "It is raining in Liverpool."
- Q — "The football match is cancelled."
- R — "Fans go to the rugby match."

(a) Express the following formulæ in words:

i. $P \vee R \rightarrow Q$
ii. $P \wedge \neg Q \rightarrow \neg R$ **[5 marks]**

(b) Express the following sentences as well-formed formulæ of propositional logic:

i. "Fans go to the rugby match if, and only if, it is raining in Liverpool and the football match is cancelled."
ii. "If it is not raining in Liverpool, then it is not the case that both the football match is cancelled and fans go the rugby match." **[8 marks]**

(c) Using the following inference rules from the Natural Deduction calculus for propositional logic:

$$\frac{\alpha \wedge \beta}{\alpha} \qquad \frac{\alpha \wedge \beta}{\beta} \qquad (\wedge E),$$

$$\frac{\alpha}{\alpha \vee \beta} \qquad \frac{\beta}{\alpha \vee \beta} \qquad (\vee I),$$

$$\frac{\alpha \rightarrow \beta \qquad \alpha}{\beta} \qquad (\rightarrow E),$$

show that $\{P \rightarrow (Q \rightarrow R), P \wedge Q\} \vdash R \vee \neg P$. **[12 marks]**

4. A robotic agent is to be implemented for a simplified version of the "blocks world". In this world, there is a table with boxes on its top (but boxes are not piled), and there is a wastebasket where the boxes are to be moved. The robot can pick up one box at a time with its arm. Once a box is picked, the robot moves itself to the wastebasket, drops the box there, and returns to the table, repeating the procedure until the table is cleared.

   (a) Suggest a way of representing this world, and show the actions that the robot will need in order to operate in this world. This should be done according to the conventions of STRIPS-like languages. **[15 marks]**

   (b) Show a particular plan the robot may execute in order to move box A from the table to the wastebasket, then return to the table. Show the resulting state of the world, considering that, originally, boxes A and B were on the table. **[10 marks]**