SOLUTIONS

TECHNICAL UNIVERSITY OF DENMARK

Written examination, 22 May 2019

Course name: Introduction to Artificial Intelligence

Course number: 02180

Aids allowed: Alle written aids allowed.

Exam duration: 2 hours.

Weighting:

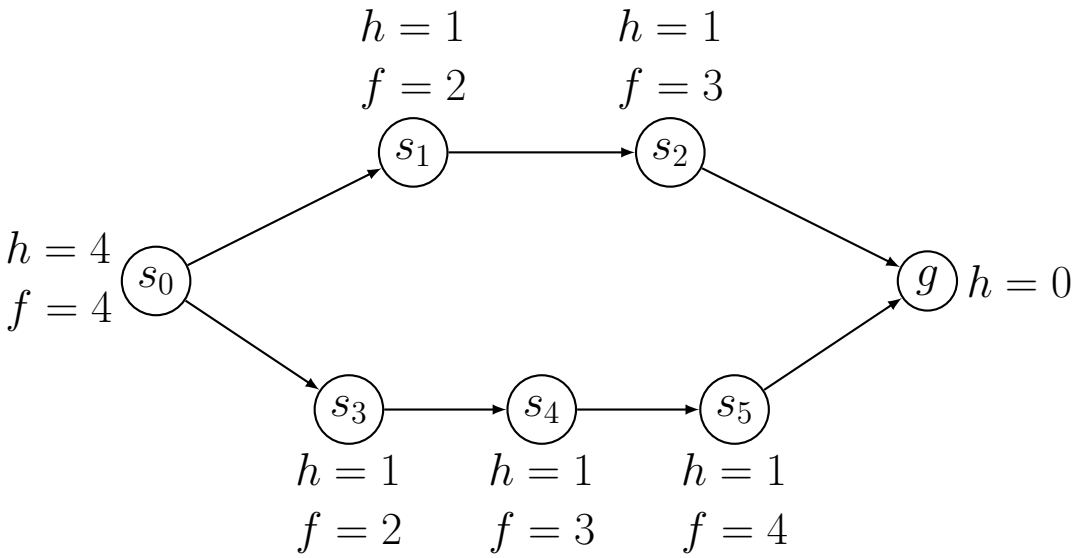
Opgave 1: 20%
Opgave 2: 30%
Opgave 3: 16%
Opgave 4: 12%
Opgave 5: 10%
Opgave 6: 12%

All exercises should be answered by filling in the designated blank spaces on the following pages.

Table no.	Course no.: 02180 Date: 22 May 2019 Course name Introduction to Artificial Intelligence Study Number: _____ Birth Date: _____ Name: _____	Sheet no.

Problem 1 (Informed search) 20 %

Consider the search problem with the following state space:



All step costs are 1, the initial state is s_0 and the goal state is g. A heuristics h for the problem is given above.

a. Add the f-values to the nodes above as they would be added by the $A^\star$ Graph-Search algorithm.

b. Answer the questions below. Wrong answers count negatively.

	yes	no
Is the heuristics admissible?		x
Is the heuristics consistent?		x
Will $A^\star$ Graph-Search necessarily find the optimal solution to this problem?	x	
Will greedy best-first Graph-Search necessarily find the optimal solution to this problem?		x

Problem 2 (Searching with nondeterministic actions) 30 %

Consider the following search problem with nondeterminism. The state space has three states, s_0, h and t. The state s_0 represents the situation in which you are holding a coin in your hand. This is the initial state of the problem. The state h represents the situation in which the coin lies

on the table facing heads up. The state t represents the situation in which the coin lies on the table facing tails up.

In any of the three states of the problem, it is possible to toss the coin. The action of tossing the coin is denoted *toss*. The *toss* action has two possible outcome states, h and t. In other words, when you toss the coin, it will afterwards be on the table facing either heads or tails up. Note that the action *toss* is applicable independently of whether you are currently holding it in your hand (you are in state s_0) or it is currently on the table (you are in state h or t).

When the coin is on the table, it is possible to turn it over. We denote this action by *turn*. Executing the *turn* action in state h will result in state t, and executing it in state t will result in state h.

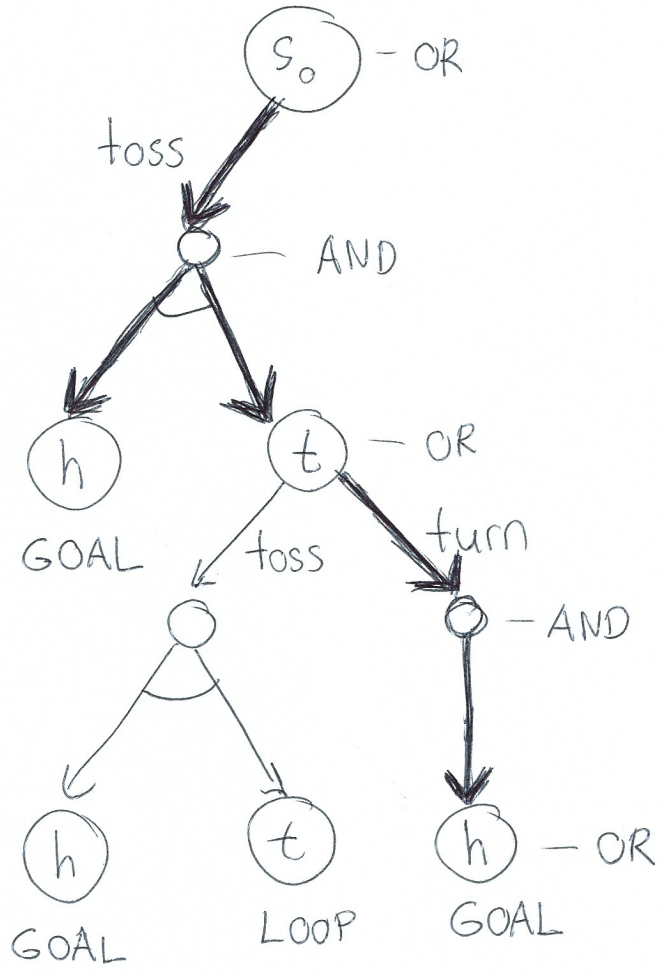
The goal of the problem is to be in state h.

a. Provide part of the formal description of this search problem by filling in the function values below:

$$\textsc{Actions}(s_0) = \{toss\}$$
$$\textsc{Actions}(h) = \{toss, turn\}$$
$$\textsc{Results}(s_0, toss) = \{h, t\}$$
$$\textsc{Results}(h, toss) = \{h, t\}$$
$$\textsc{Results}(h, turn) = \{t\}$$

b. Draw below the full And-Or search tree of the problem. The root node should contain the initial state s_0. Nodes containing goal states should be marked with *GOAL* and loop nodes with *LOOP*. Note that a node n containing a state s is only a loop node if state s occurs in an earlier node on the path from the root to n.

c. Mark an acyclic solution to the search problem as a subtree of your And-Or search tree. The subtree should be highlighted by making the edges of the subtree boldface (significantly thicker than the other edges).



d. Describe in words the solution (conditional plan) found in c, that is, describe how to reach the goal h from the initial state s_0 via the actions *toss* and *turn*. **SOLUTION**. Toss the coin. If it lands tails, turn it, otherwise stop.

e. Answer the question below. Wrong answer counts negatively.

	yes	no
Would the problem still have a solution if we removed the *turn* action?		x

Problem 3 (Propositional Logic) 16 %

a. Convert the following propositional logic formula into conjunctive normal form (CNF):

$$(q \rightarrow p) \wedge ((p \wedge r) \rightarrow s)$$

by providing a step-by-step rewriting in the table below. You might not need all lines.

step	formula
1	$(q \to p) \wedge ((p \wedge r) \to s)$
2	$(\neg q \vee p) \wedge ((p \wedge r) \to s)$
3	$(\neg q \vee p) \wedge (\neg(p \wedge r) \vee s)$
4	$(\neg q \vee p) \wedge (\neg p \vee \neg r \vee s)$

b. Answer the following questions about the CNF formula you obtained above. Wrong answers count negatively.

	yes	no
Is the resulting formula in Horn normal form (consisting only of Horn clauses)?	x	
Does the resulting formula contain a definite clause?	x	
Does the resulting formula contain a goal clause?		x

Problem 4 (Belief Revision) 12 %

Let $A = \{p, q, p \wedge q, p \vee q, p \to q\}$ be a belief base. Which of the following sets are elements of $A \perp q$? Wrong answers count negatively.

set of formulas	yes	no
$\{p, p \vee q\}$	x	
$\{p \to q\}$	x	
$\{p \vee q, p \to q\}$		x
$\{p \vee q\}$		x

Problem 5 (Belief Revision) 10 %

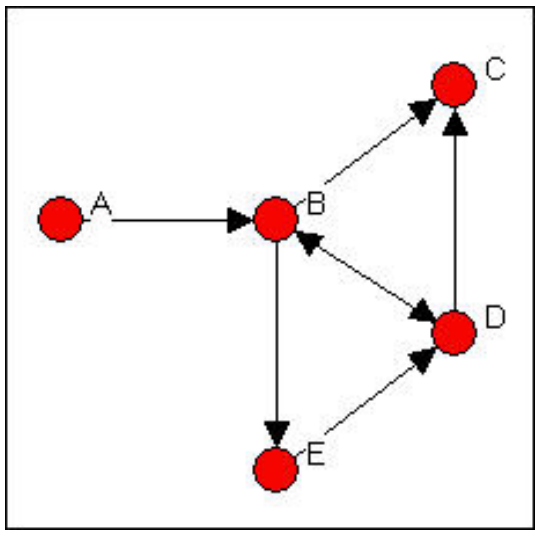
Explain, in your own words, the meaning of Levi Identity:

$$B * \varphi := (B \div \neg\varphi) + \varphi.$$

Write your answer below:
The operation of revising the belief set B with a formula φ can be split into two steps: contraction and expansion... (The more detailed the description of these procedures, the more points will be scored in this question.)

Problem 6 (First-order Logic) 12 %

For each of the formulas, decide if it is true or false in the graph above; Rxy stands for 'an arrow from vertex x to vertex y'. Wrong answers count negatively.



formula	true	false
$\exists x\ (\neg\exists y\ Rxy)$	x	
$\forall x\ \exists y\ (Ryx)$		x
$\exists x\ \exists y\ (Rxy \wedge Ryx)$	x	
$\forall x\ \exists y\ (\neg Rxy \wedge \neg Ryx)$	x	