	INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR Mid-Autumn Semester 2019-20	
mi		Stamp/Signature of the Invigilator

QUESTION PAPER CUM ANSWER BOOKLET

Roll Number										Name	
Subject Number	C	S	6	0	0	4	5		Subject Name	*Artificial Intelligence*	
Department/Centre of the Student											

Instructions and Guidelines to Students appearing in the Examination

1. Ensure that you have occupied the seat as per the examination schedule.
2. Ensure that you do not have a mobile phone or a similar gadget with you even in switched off mode. Note that loose papers, notes, books should not be in your possession, even if those are irrelevant to the paper you are writing.
3. Date book, codes or any other materials are allowed only under the instruction from the paper-setter.
4. Use the instrument box, pencil box and non-programmable calculator is allowed during the examination. However, exchange of these items is not permitted.
5. Additional sheets, graph papers and relevant tables will be provided on request.
6. Write on both sides of the answer script and do not tear off any page. Report to the invigilator if the answer script has torn page(s).
7. Show the admit card / identity card whenever asked for by the invigilator. It is your responsibility to ensure that your attendance is recorded by the invigilator.
8. You may leave the examination hall for wash room or for drinking water. Record your absence from the examination hall in the register provided. Smoking and consumption of any kind of beverages is not allowed inside the examination hall.
9. After the completion of the examination do not leave the seat until invigilator collects the answer script.
10. During the examination, either inside the examination hall or outside the examination hall, gathering information from any kind of sources or any such attempts, exchange or helping in exchange of information with others or any such attempts will be treated as adopting ‘unfair means’. Do not adopt ‘unfair means’ and do not indulge in unseemply behavior as well.

Violation of any of the instructions may lead to disciplinary action.

Signature of the Student

To be filled in by the Examiner

Question Number	1	2	3	4	5	6	7	8	9	10	Total
Marks obtained											

Marks obtained (in words)	Signature of the Examiner	Signature of the Scrutinizer

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
Mid-Autumn Semester 2019-20

Date of examination: ____________________ Session (*FN / AN*): ____________________ Duration: *2 hours*

Subject No.: CS60045 Subject: ARTIFICIAL INTELLIGENCE

Dept: *Computer Science & Engineering.* Full marks: 60 No. of students: 218

Instructions: ***Answer all questions. Write your answers in the space provided.***

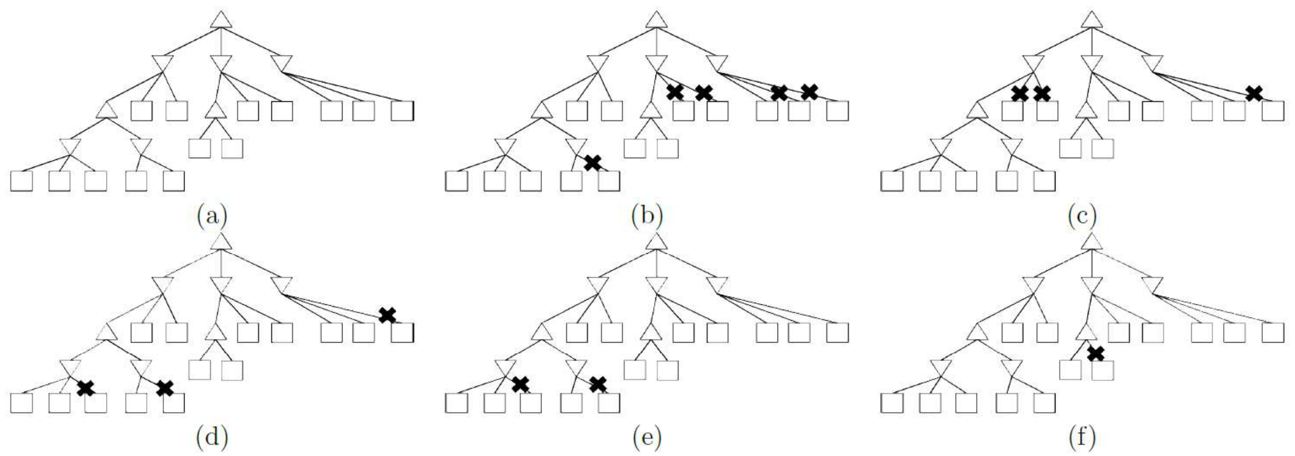
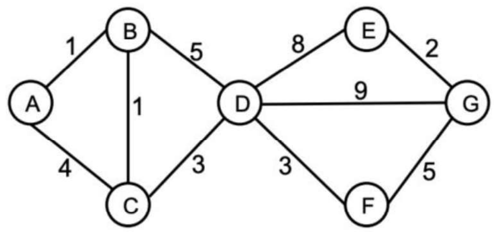


Figure 1.

1. Assume we run αβ-pruning, expanding successors from left to right, on a game tree shown in Figure 1 (a). The *max* nodes are represented by Δ and the *min* nodes are represented by ∇. For each of the following statements, indicate True / False in the box provided. [6 marks]

(a) For some choice of pay-off values, no pruning will be achieved (shown in Figure 1 (a))	True
(b) For some choice of pay-off values, the pruning shown in Figure 1 (b) will be achieved	True
(c) For some choice of pay-off values, the pruning shown in Figure 1 (c) will be achieved	False
(d) For some choice of pay-off values, the pruning shown in Figure 1 (d) will be achieved	False
(e) For some choice of pay-off values, the pruning shown in Figure 1 (e) will be achieved	False
(f) For some choice of pay-off values, the pruning shown in Figure 1 (f) will be achieved	False

2. Consider the state space graph shown below. A is the start state and G is the goal state. The costs for each edge are shown on the graph. Each edge can be traversed in both directions. Note that the heuristic h_1 is monotonic but the heuristic h_2 is not monotonic. [12+6+2 = 20 marks]



Node	h_1	h_2
A	9.5	10
B	9	12
C	8	10
D	7	8
E	1.5	1
F	4	4.5
G	0	0

(a) For each of the following graph search strategies examine which, if any, of the listed paths it could return. Write *Yes / No* in the table accordingly. Note that for some search strategies the specific path returned might depend on tie-breaking behaviour. In any such cases, make sure to write *Yes* in all the boxes corresponding to paths that could be returned under some tie-breaking scheme.

Search Algorithm	A-B-D-G	A-C-D-G	A-B-C-D-F-G
Depth First Search	YES	YES	YES
Breadth First Search	YES	YES	NO
Uniform Cost Search	NO	NO	YES
A* search with heuristic h_1	NO	NO	YES
A* search with heuristic h_2	NO	NO	YES

(b) Consider the new heuristic function h_3 shown below. All the values are known except $h_3(B)$.

Node	A	B	C	D	E	F	G
h_3	10	?	9	7	1.5	4.5	0

Fill in the blanks to answer the following questions:

(i) What values of $h_3(B)$ make h_3 admissible? **Ans:** $0 \le h_3(B) \le 12$

(ii) What values of $h_3(B)$ make h_3 monotonic? **Ans:** $9 \le h_3(B) \le 10$

(iii) What values of $h_3(B)$ will cause A* graph search to expand node A, then node C, then node B, then node D in order? **Ans:** $12 \le h_3(B) \le 13$

(c) When should A* test and declare a node to be a goal node? For the wrong option below, indicate the consequences had A* taken that option. Assume that the heuristic is admissible and monotonic.

(i) At the time it selects a node from OPEN
(ii) At the time it generates the node by expanding its parent

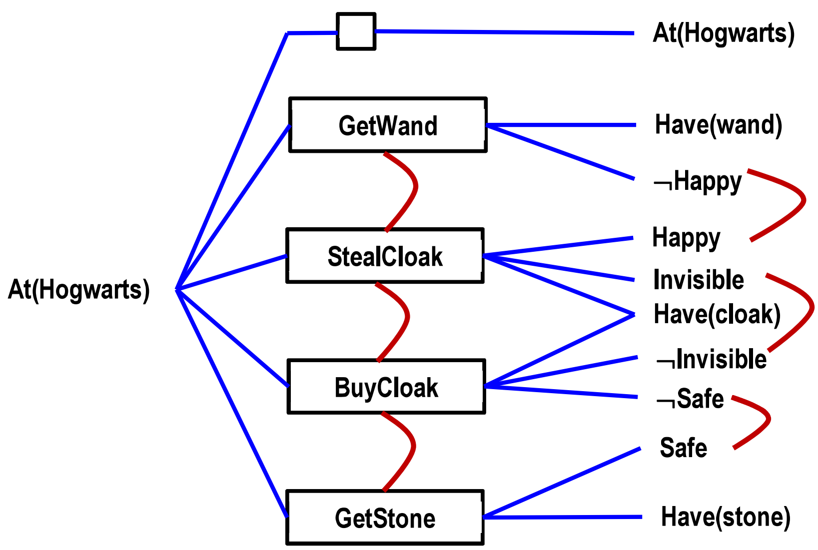
Choice: ___(i)___ **Consequence of the other option:** _It may terminate with a non-optimal solution___

3. Lord Voldemort wishes to acquire the *elder wand*, the *resurrection stone*, and the *invisibility cloak*. There are actions by which he wishes to get these, but the actions also have other side effects. He has written down the actions as follows:

[4+2+4 = 10 marks]

Op(ACTION: GetWand, PRECOND: At(x), EFFECT: Have(wand) ∧ ¬Happy)
Op(ACTION: GetStone, PRECOND: At(x), EFFECT: Have(stone) ∧ Safe)
Op(ACTION: StealCloak, PRECOND: At(x), EFFECT: Have(cloak) ∧ Invisible ∧ Happy)
Op(ACTION: BuyCloak, PRECOND: At(x), EFFECT: Have(cloak) ∧ ¬Invisible ∧ ¬Safe)
Op(ACTION: Start, EFFECT: At(Hogwarts))
Op(ACTION: Finish, PRECOND: Have(wand) ∧ Have(stone) ∧ Have(cloak))

(a) Voldemort has decided to use the GraphPlan algorithm to choose his plan. Draw the planning graph after one iteration clearly indicating all the mutex links.

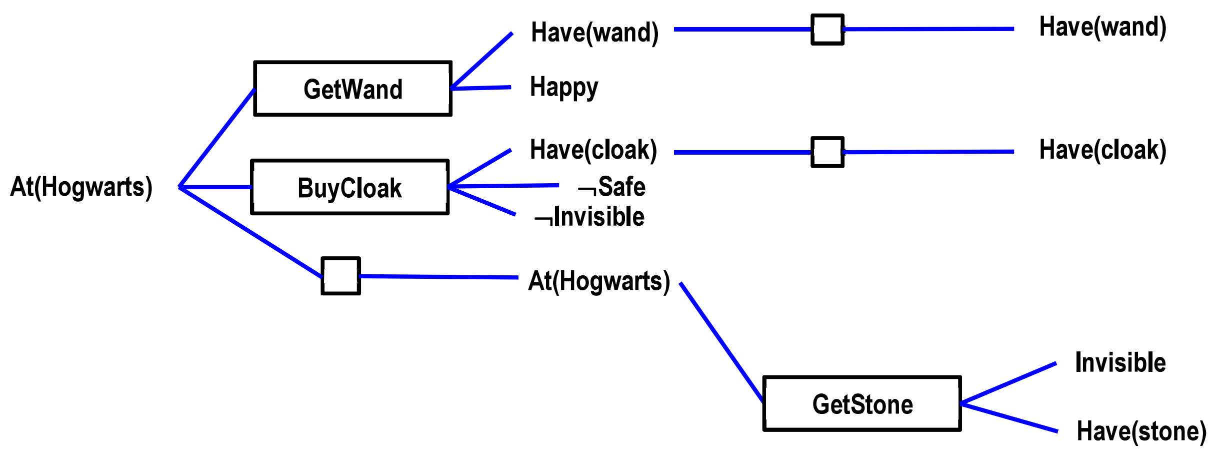


(b) Is any further iteration necessary? Explain.

All though the goal predicates are present after this level without mutexes, a plan does not exist at this level. Therefore more iterations are needed to find a plan if it exists.

(c) Will GraphPlan terminate with a plan in this case? If so, draw the plan. If not, explain why.

GraphPlan will terminate after two iterations with the following plan.



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4. Complete the following definitions for predicate logic: [6 marks]

(a) A formula is said to be valid if ____

____

(b) A formula is said to be satisfiable if ______________________________________

____

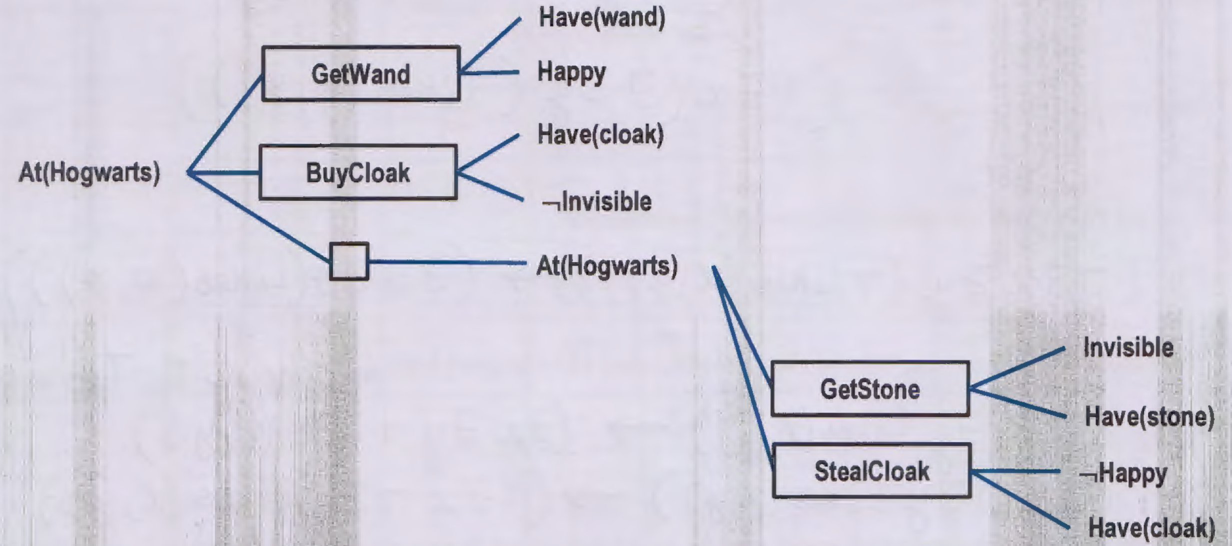
(c) In first order logic formulas ________________________ and ________________________ cannot be quantified by for-all and there-exist operators.

(d) A propositional logic formula of n Boolean variables can have ________________________ number of interpretations.

(e) A predicate logic formula of n variables, k predicate symbols (including propositions), and w function symbols (including constants) can have ________________________________ number of interpretations.

(c) Will GraphPlan terminate with a plan in this case? If so, draw the plan. If not, explain why.

GraphPlan will terminate after two iterations with the following plan.



4. Complete the following definitions for predicate logic: [6 marks]

(a) A formula is said to be valid if it is true under all interpretations

(b) A formula is said to be satisfiable if it is true for at least one interpretation

(c) In first order logic formulas predicates and functions cannot be quantified by for-all and there-exist operators.

(d) A propositional logic formula of n Boolean variables can have 2^n number of interpretations.

(e) A predicate logic formula of n variables, k predicate symbols (including propositions), and w function symbols (including constants) can have infinite number of interpretations.

5. Consider the first order predicate Likes(x, y) meaning x likes y. Write the following sentences in first order calculus without using the $\forall$ (*for-all*) operator, that is, by only using the $\exists$ (*exists*) operator and other Boolean connectors, namely $\wedge$ (*and*), $\vee$ (*or*), $\neg$ (*negation*), and $\Rightarrow$ (*implication*). Make sure you put brackets properly to clearly specify the scope rules:

[2+2+2+2 = 8 marks]

(a) *Someone likes everyone*: $\exists x\,(\neg \exists y\,(\neg \text{Likes}(x,y)))$

(b) *Everyone likes someone*: $(\neg \exists x\,(\neg \exists y\,(\text{Likes}(x,y))))$

(c) *If everyone likes everyone then someone likes someone*:

$(\neg \exists x\, \exists y\,(\neg \text{Likes}(x,y))) \rightarrow (\exists w\, \exists v\,(\text{Likes}(w,v)))$

(d) *If someone does not like anyone then everyone does not like everyone*: Any one of the two is ok:

(1) $(\exists x\, \neg \exists y\, \text{Likes}(x,y)) \rightarrow (\exists x\, \exists y\, \neg \text{Likes}(x,y))$

(2) $(\exists x\, \neg \exists y\, \text{Likes}(x,y)) \rightarrow (\neg \exists x\, \neg \exists y\, \neg \text{Likes}(x,y))$

6. Consider the following deduction problem to be coded and solved in propositional (Boolean) logic. The following propositions are to be used:

PROPOSITION	MEANING
Study	True, if I study. False, otherwise
Do-Well	True, if I do well in exams. False, otherwise
Relax	True, if I relax. False, otherwise
Enjoy	True, if I enjoy. False, otherwise

(a) Write the following sentences in propositional logic *without* using the implication ($\Rightarrow$) operator, that is, using only and ($\wedge$), or ($\vee$), and not ($\neg$) operators. Use the boxes provided.

[1×6 = 6 marks]

Clause	Statement	Propositional Formula
F1	If I study then I do well in the examinations	$\neg$ Study $\vee$ Do-Well
F2	If I relax then I enjoy myself	$\neg$ Relax $\vee$ Enjoy
F3	Either I study or I relax but not both	(Study $\wedge$ $\neg$ Relax) $\vee$ ($\neg$ Study $\wedge$ Relax)
F4	If I study then I do not enjoy myself	$\neg$ Study $\vee$ $\neg$ Enjoy
F5	If I relax then I do not do well in the examinations	$\neg$ Relax $\vee$ $\neg$ Do-Well
Goal G	I enjoy myself if and only if I do not do well in the examinations	($\neg$ Enjoy $\vee$ $\neg$ Do-Well) $\wedge$ (Do-Well $\vee$ Enjoy)

(b) Present a complete Truth Table Method to show that the sequence of sentences in (a) is valid. [4 marks]

Formula F: $F1 \wedge F2 \wedge F3 \wedge F4 \wedge F5 \rightarrow G$

	Study	Do-Well	Relax	Enjoy	F1	F2	F3	F4	F5	G	Formula F
1	T	T	T	T	T	T	F	F	F	F	T
2	T	T	T	F	T	F	F	T	F	T	T
3	T	T	F	T	T	T	T	F	T	F	T
4	T	T	F	F	T	T	T	T	T	T	T
5	T	F	T	T	F	T	F	F	T	T	T
6	T	F	T	F	F	F	F	T	T	F	T
7	T	F	F	T	F	T	T	F	T	T	T
8	T	F	F	F	F	T	T	T	T	F	T
9	F	T	T	T	T	T	T	T	F	F	T
10	F	T	T	F	T	F	T	T	F	T	T
11	F	T	F	T	T	T	F	T	T	F	T
12	F	T	F	F	T	T	F	T	T	T	T
13	F	F	T	T	T	T	T	T	T	T	T
14	F	F	T	F	T	F	T	T	T	F	T
15	F	F	F	T	T	T	F	T	T	T	T
16	F	F	F	F	T	T	F	T	T	F	T