INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR		Stamp / Signature of the Invigilator

EXAMINATION (End Semester)	SEMESTER (Spring)

Roll Number									Section		Name	
Subject Number	A	I	6	1	0	0	5	Subject Name	*Artificial Intelligence Foundations and Applications*			
Department / Centre of the Student									Additional sheets			

Important Instructions and Guidelines for Students

1. You must occupy your seat as per the Examination Schedule/Sitting Plan.
2. Do not keep mobile phones or any similar electronic gadgets with you even in the switched off mode.
3. Loose papers, class notes, books or any such materials must not be in your possession, even if they are irrelevant to the subject you are taking examination.
4. Data book, codes, graph papers, relevant standard tables/charts or any other materials are allowed only when instructed by the paper-setter.
5. Use of instrument box, pencil box and non-programmable calculator is allowed during the examination. However, exchange of these items or any other papers (including question papers) is not permitted.
6. Write on both sides of the answer script and do not tear off any page. **Use last page(s) of the answer script for rough work.** Report to the invigilator if the answer script has torn or distorted page(s).
7. It is your responsibility to ensure that you have signed the Attendance Sheet. Keep your Admit Card/Identity Card on the desk for checking by the invigilator.
8. You may leave the examination hall for wash room or for drinking water for a very short period. Record your absence from the Examination Hall in the register provided. Smoking and the consumption of any kind of beverages are strictly prohibited inside the Examination Hall.
9. Do not leave the Examination Hall without submitting your answer script to the invigilator. **In any case, you are not allowed to take away the answer script with you.** After the completion of the examination, do not leave the seat until the invigilators collect all the answer scripts.
10. During the examination, either inside or outside the Examination Hall, gathering information from any kind of sources or exchanging information with others or any such attempt will be treated as **'unfair means'**. Do not adopt unfair means and do not indulge in unseemly behavior.

Violation of any of the above instructions may lead to severe punishment.

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 Scrutineer

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

End Semester Examination Spring 2022-2023

Date of Examination: 28/4/23 Session:AN Duration: 3 hours Full Marks: 100
Subject No.: AI61005 Artificial Intelligence Foundations and Applications
Department: Centre for Excellence in Artificial Intelligence

Special Instructions: Answer the questions in the boxes provided in the question cum answer booklet only.
Use the last pages for Rough work. If any Supplementary sheets are used, they must be tied to the booklet.

ANSWER ANY FIVE QUESTIONS

Question Number	Full Marks	Marks Obtained
1	20	
2	20	
3	20	
4	20	
5	20	
6	20	
Total:	100	

1. Answer the following questions related to Heuristic Search and Algorithm A*:

   (a) Prove in details the following: For state space minimization problems, if the edge costs are positive, heuristics are non-negative, underestimates and monotonic, then algorithm A* guarantees terminating with minimum cost solutions (assuming that a solution exists at finite depth). (8

(b) For each case below, state True or False with proof sketch or explained counter-examples (using at least a 4-node graph) that A* may not guarantee terminating with optimal cost solutions for minimization problems if

i. The heuristics are non-negative, monotonic but not underestimating and all edge costs are positive. (4)

ii. The heuristics are non-negative and underestimating but not monotonic and all edge costs are positive. (4)

iii. The heuristics are non-negative, underestimating, monotonic but some edge costs may be negative, with no negative cycles. (4)

2. Answer the following questions related to logical deduction

   (a) When is a deduction method said to be Sound and when is it said to be Complete? (4)

   (b) Prove that Resolution Refutation for Propositional Logic is both Sound and Complete. (4)

(c) Encode the following sentences in predicate logic and use resolution refutation to prove its validity or otherwise: (5

Teachers teach all those who do not teach themselves; Therefore, all teachers teach themselves.

[Here *'themselves'* means the same person teaching herself or himself]

(d) Prove its validity or otherwise using resolution refutation if we change the conclusion of the second sentence and try to prove the following: (3)

Teachers teach all those who do not teach themselves; Therefore, teachers do not teach themselves.

(e) What is the relevance of the above two statements from the point of view of logic?

3. (a) Explain why it is a good heuristic to choose the variable that is most constrained, but the value that is least constraining in a CSP search? (4)

(b) Arati is looking for a group of friends for her start-up, which develops and provides web-based solutions to college students. Arati has determined that she needs 2 Developers, 2 Graphic Designers, 1 UX expert, 1 Database Admin, and 1 Systems Engineer. Assume that if a person has two different skillsets from the above, he or she can take on two roles in the company. So, Arati narrowed down her selections to the following people: (8)

Name	Ability
Parama	Developer and Graphic Designer
Binay	Graphic Designer and UX expert
Rokeya	Graphic Designer and Systems Engineer
Janaki	Developer and Database Admin
Charu	Graphic Designer and UX expert
Rizwan	Developer and Systems Engineer

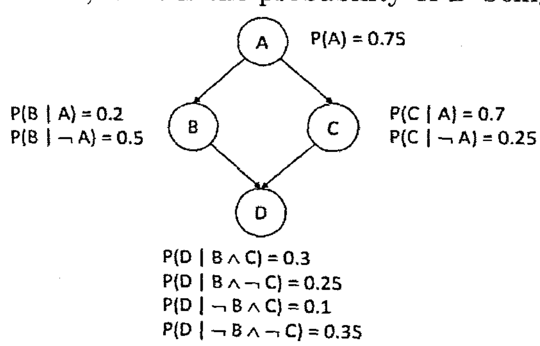
Suppose Arati is a Developer, and only has funds to hire three more people. Model this scenario as a CSP - (using variables, value domains, and constraints).

(c) Given the following two CNF - for each use DPLL algorithm to find an assignment that satisfies the CNF or to show that such assignment does not exist. (8)

i. $(P \vee Q \vee \neg R) \wedge (P \vee \neg Q) \wedge \neg P \wedge R \wedge U$
ii. $(P \vee Q) \wedge (P \vee \neg Q) \wedge (\neg P \vee Q) \wedge (\neg P \vee \neg R)$

4. (a) Consider a test to detect a disease that 0.1 % of the population have. The test is 99 % effective in detecting an infected person. However, the test gives a false positive result in 0.5 % of cases. If a person tests positive for the disease what is the probability that they actually have it? (4)

(b) Consider the following Bayesian network. A, B, C, and D are Boolean random variables. If we know that A is true, what is the probability of D being true?



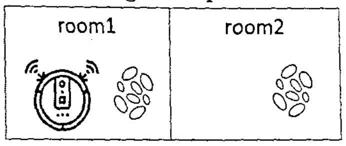
(c) In a nuclear power station, there is an alarm that senses when a temperature gauge exceeds a given threshold. The gauge measures the temperature of the core. Consider the Boolean variables A (alarm sounds), FA (alarm is faulty), and FG (gauge is faulty) and the multivalued, discrete nodes G (gauge reading) and T (actual core temperature). (12)

i. Draw a Bayesian network for this domain, given that the gauge is more likely to fail when the core temperature gets too high.

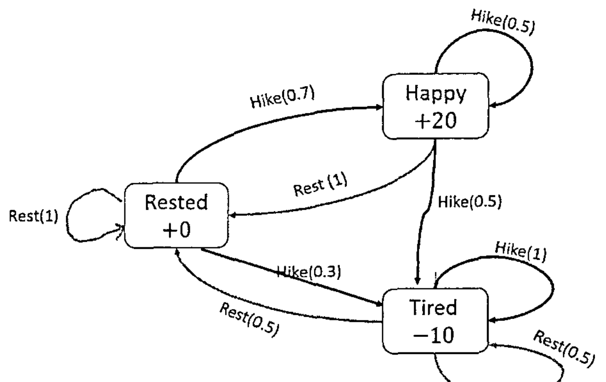
ii. Suppose there are just two possible values for actual and measured temperatures, normal and high; the probability that the gauge gives the correct temperature is x when it is working, but y when it is faulty. Give the conditional probability table associated with G.

iii. Suppose the alarm works correctly unless it is faulty, in which case it never sounds. Give the conditional probability table associated with A.

5. (a) Assume that the initial state is In(room1), the goal state Clean(room1). Give a description of this planning problem in terms of propositional formulas, suitable as an input to the SATPLAN algorithm when searching for a plan consisting of 1 action. (10)



(b) You are on a trail and you have to choose whether to Hike or to Rest. There are three states: Rested, Happy and Tired and the rewards associated with the states are 0, +20 and −10 respectively. You begin from the state Rested. The graph of the MDP is given below.



i. Write the expression to show how you compute $V^{t+1}(s)$ for a given state after you have found the $V^t(s')$ values for every state s'. (3)

ii. Fill out the table with the results of value iteration with a discount factor $\gamma = 0.5$. (3)

t	V^t(Rested)	V^t(Happy)	V^t(Tired)
1	0	20	−10
2			
3			

iii. At $t = 3$ with $\gamma = 0.5$, what policy would you select? Is it necessarily true that this is the optimal policy? (4)

6. (a) i. State two important drawbacks of 1-hot representation of words that are addressed with dense vectors using word2vec. (6)

ii. State two important drawbacks of word2vec models that are addressed in models such as BERT or GPT.

iii. Briefly state the role of self-supervised learning in NLP.

(b) Suppose that you train a classifier which is a deep neural network with training sets of size m. As m increases and $m \to \infty$ we want to understand the typical behavior of the training error and the test error. To answer the question, Draw a graph with m in the horizontal axis and the error in the vertical axis. (4)

(c) Consider the logistic regression model $y = g(w_0 + w_1x_1 + w_2x_2)$, where $g(z) = \frac{1}{1+e^{-z}}$ is the sigmoid function. Use the binary cross entropy loss (negative log loss) function. (10)

i. Write down the expression for the loss function L.

ii. Find out the expressions for the derivatives of w_0, w_1, w_2 with respect to the loss, that is, write down the expressions for $\frac{\partial L}{\partial w_i}$.

iii. Consider that you run one stochastic gradient descent step with a single training example

$$(X, Y) = ((X_1, X_2), Y)$$

How are w_0, w_1, w_2 updated?

iv. Suppose that at some intermediate point, $w_0 = 0, w_1 = 1, w_2 = 0$ the training example is $X = (1, 1), Y = 0$. Assume that the learning rate $\eta = 0.5$. What will be the values of $w_0 = 0, w_1 = 1, w_2 = 0$ after running a stochastic gradient step?