TUFTS UNIVERSITY
Department of Computer Science

CS 131 | **Artificial Intelligence** | **Summer 2022**
Midterm Exam | | **08–10 July 2022**

- **Please sign your name below (or write it to the top of each page of your work, if you are not solving on the exam paper). By doing so, you agree to be bound by Tufts policies on academic integrity.**
- **For this exam, you may use any notes you have taken, the Russell & Norvig text, and any materials distributed by the instructor (including lecture notes/videos and code samples). No other materials are to be used.**
- **This booklet contains 6 pages including the cover page.**
- **You have exactly 105 minutes (one hour, 45 minutes) to complete this exam *and* upload a PDF version to Gradescope. Be sure to leave yourself enough time for the latter steps.**
- **The maximum possible is 50.**

PROBLEM	SCORE
1	
2	
3	
4	
5	
TOTAL	

NAME: ______________________________

1. **(12 pts.)** **TRUE/FALSE & SHORT ANSWER.**

For each of the following, indicate whether the statements is true or false, and explain your answer in the space provided. Answers will not need to be longer than a few sentences.

(a) (3 pts.) (T ___ F ___) You run $A^\star$ search with initial state s and admissible heuristic h. The algorithm returns a solution with total cost C. Let s' be some state of the search problem. If $g(s') + h(s') = C$ then s' *must* be expanded during the search.

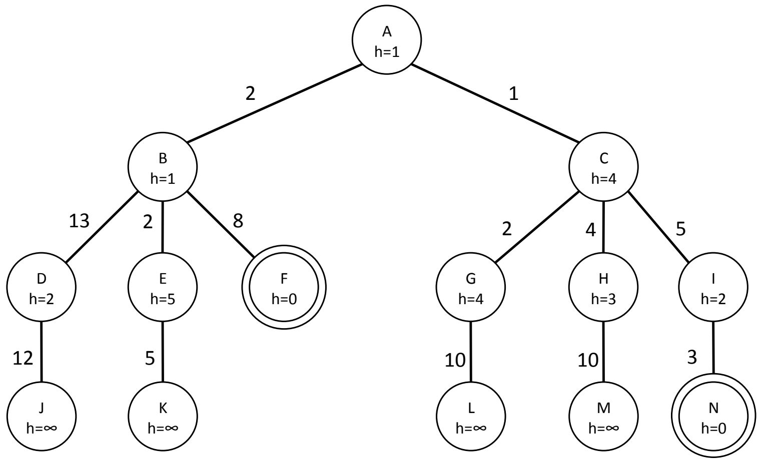
(b) (3 pts.) (T ___ F ___) You run $A^\star$ search with initial state s and admissible heuristic h. The algorithm returns a solution with total cost C. Let s' be some state of the search problem. If $g(s') + h(s') > C$ then s' *must not* be expanded during the search.

(c) (3 pts.) (T ___ F ___) Some CSP solvers use complex *constraint languages* to express the constraints on the variables. Often, this can make the specification of the problem more concise; however, for any CSP, it is also possible to express those constraints by simply listing all permissible pairs of values for any two variables.

(d) (3 pts.) (T ___ F ___) Suppose we use the following logical inference procedure: given any knowledge-base KB, and any query sentence α, we simply return `true` when asked whether KB entails α. This is not a sound inference procedure, but it is complete.

2. **(8 pts.)** **SEARCH ALGORITHMS.**

Consider the following search space. The initial state is A. Goal states are designated by a double circle. Each node has an admissible heuristic value h (shown inside the circle). Nodes from which a goal **cannot** be reached have an h-value of ∞. The actual edge costs for going from each node to its successors are shown.



For each of the following algorithms, list the order in which it expands the nodes of the tree and the solution it returns. Recall that **expanding** a node means generating its successors. Assume that successors are visited in **left-to-right** order when breaking ties. Also assume that a solution is returned when the node is expanded, **not** when it is generated.

(a) (3 pts.) Breadth-first search:

(b) (5 pts.) $A^\star$ search:

3. **(10 pts.)** **SEARCH ALGORITHMS II.**

Iterative Deepening $A^\star$ ($IDA^\star$) search works as follows:

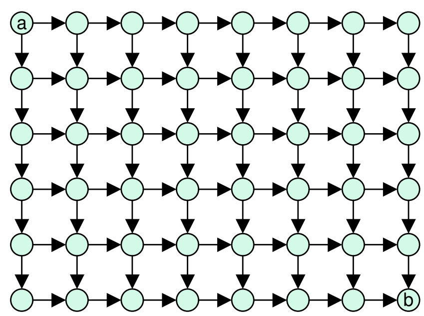
(i) Start with an f-bound F equal to $f(s) = g(s) + h(s)$, where s is the start state, and h is an admissible heuristic.

(ii) Perform **depth-first** search, expanding only nodes x with $f(x) \leq F$, and stopping only if the goal is found, or no more such nodes exist.

(iii) If the goal is not found, set F to the lowest value found in step (ii) that exceeds the prior bound; that is, set it to the minimal value $f(x) > F$, for any x generated in the prior step. Go back to step (ii).

(iv) Terminate and **fail** if all nodes have been expanded and the goal is not found.

Consider the following search space, which forms a two-dimensional grid, with directions of possible movement given by arrows. Suppose each action has a cost of 1 unit.



Assume that the Manhattan distance is used for heuristic h, and that a (top left) is the start state, and b (bottom right) is the goal. What is the total number of nodes that will be expanded by $IDA^\star$ in this space? Explain why, exactly.

4. **(10 pts.)** **CONSTRAINT SATISFACTION.**

Consider the class scheduling problem. We have a set of classes, a set of instructors, a set of classrooms, and a set of time-slots. Each instructor can be given any number of classes, but cannot teach more than one class in a single time-slot. No two classes can be held in the same classroom at the same time.

Explain clearly how to define this problem as a CSP. Clearly define the variables—including their domains—and explain what the constraints are. (You do not need to explicitly list all of the constraints, but you must describe them completely.) Remember that a variable can be anything you wish, and its values need not be restricted to single values.

5. **(10 pts.)** **KNOWLEDGE REPRESENTATION & REASONING.**

Suppose we have a vocabulary to express simple propositions about the animal named Bo:

- Cat stands for "Bo is a cat."
- Dog stands for "Bo is a dog."
- $Mammal$ stands for "Bo is a mammal."
- $Warm$ stands for "Bo is warm-blooded."

(a) (2 pts.) Write the following sentences in propositional logic form:

i. If Bo is a cat, then Bo is a mammal. ____________________

ii. If Bo is a dog, then Bo is a mammal. ____________________

iii. If Bo is a mammal, then Bo is warm-blooded. ____________________

iv. Bo is either a dog or a cat. ____________________

(b) (2 pts.) Convert each of the above sentences into conjunctive normal form.

i. ____________________

ii. ____________________

iii. ____________________

iv. ____________________

(c) (6 pts.) Construct a **resolution proof** to show Bo is warm-blooded (i.e., prove $Warm$).