1. Give a complete problem formulation for each of the following. Choose a formulation that is precise enough to be implemented.

a. Using only four colors, you have to color a planar map so that no two adjacent regions have the same color.
a. Initial state: No regions colored.
Actions (3rd ed.)/Successors (2nd ed.): Assign a color to an uncolored region.
Transition model (3rd ed.): The previously uncolored region has the assigned color.
Goal test: All regions colored, and no two adjacent regions have the same color.
Cost function: Number of assignments.

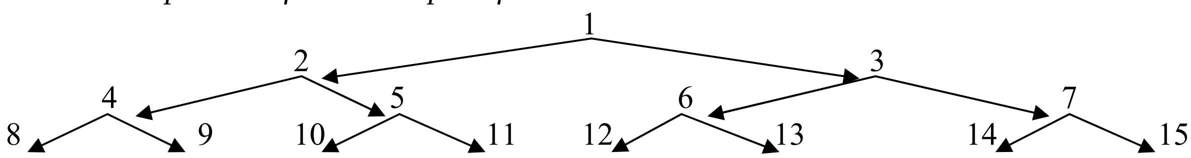
b. A 3-foot tall monkey is in a room where some bananas are suspended from the 8-foot ceiling. He would like to get the bananas. The room contains two stackable, movable, climbable 3-foot-high crates.
b. Initial state: As described in the text.
Actions/Transition model/Successors: Hop on crate; Hop off crate; Push crate from one spot to another; Stack one crate on another; Walk from one spot to another; Grab bananas (if standing on crate).
Goal test: Monkey has bananas.
Cost function: Number of actions.

c. You have a program that outputs the message "illegal input record" when fed a certain file of input records. You know that processing of each record is independent of the other records. You want to discover what record is illegal.
c. Initial state: considering all input records.
Goal test: considering a single record, and it gives "illegal input record" message.
Actions/Transition model/Successors: run again on the first half of the records; run again on the second half of the records.
Cost function: Number of runs.
Note: This is a contingency problem; you need to see whether a run gives an error message or not to decide what to do next.

d. You have three jugs measuring 12 gallons, 8 gallons, and 3 gallons, and a water faucet. You can fill the jugs up or empty them out from one to another or onto the ground. You need to measure out exactly one gallon.

d. Initial state: jugs have values [0, 0, 0].
Actions/Transition model/Successors: given values [x, y, z], generate [12, y, z], [x, 8, z], [x, y, 3] (by filling); [0, y, z], [x, 0, z], [x, y, 0] (by emptying); or for any two jugs with current values x and y, pour y into x; this changes the jug with x to the minimum of x + y and the capacity of the jug, and decrements the jug with y by the amount gained by the first jug.
Cost function: Number of actions.

2. Consider a state space where the start state is the number 1 and each state k has two successors: numbers 2k and 2k+1.
a. Draw the portion of the state space for states 1 to 15.



b. Suppose the goal state is 11. List the order in which nodes will be visited for breadth-first search, depth-limited search with limit 3, and iterative deepening search.
b. Breadth-first: 1 2 3 4 5 6 7 8 9 10 11
Depth-limited: 1 2 4 8 9 5 10 11
Iterative deepening: 1; 1 2 3; 1 2 4 5 3 6 7; 1 2 4 8 9 5 10 11

c. How well would bidirectional search work on this problem? What is the branching factor in each direction of the bidirectional search?
c. Bidirectional search is very useful, because the only successor of n in the reverse direction is $\lfloor(n/2)\rfloor$. This helps focus the search. The branching factor is 2 in the forward direction; 1 in the reverse direction.

d. Does the answer to (c) suggest a reformulation of the problem that would allow you to solve the problem of getting from state 1 to a goal state with almost no search?
d. Yes; start at the goal, and apply the single reverse successor action until you reach 1.

e. Call the action of going from state k to 2k Left, and the action of going to 2k+1 Right. Can you find an algorithm that outputs the solution to this problem without any search at all?
e. f(n) =
{IF (n=1) THEN () ELSEIF (even(n)) THEN f(floor(n/2)).Left ELSE f(floor(n/2)).Right}

3. Prove each of the following statements, or give a counter-example:

a. Breadth-first search is a special case of uniform-cost search.
a. When all step costs are equal, $g(n) \propto depth(n)$, so uniform-cost search reproduces breadth-first search.

b. Depth-first search is a special case of best-first tree search.
b. Depth-first search is best-first search with f(n) = −depth(n); breadth-first search is best-first search with f(n) = depth(n); uniform-cost search is best-first search with f(n) = g(n); greedy-best-first search is best-first search with f(n) = h(n); A* search is best-first search with f(n) = g(n) + h(n).

c. Uniform-cost search is a special case of A search.*
c. Uniform-cost search is A* search with h(n) = 0.

4. Give the name that results from each of the following special cases:
a. Local beam search with k=1.
a. Local beam search with k = 1 is hill-climbing search.

b. Local beam search with one initial state and no limit on the number of states retained.

b. Local beam search with $k = \infty$: strictly speaking, this doesn't make sense. The idea is that if every successor is retained (because k is unbounded), then the search resembles breadth-first search in that it adds one complete layer of nodes before adding the next layer. Starting from one state, the algorithm would be essentially identical to breadth-first search except that each layer is generated all at once.

c. Simulated annealing with T=0 at all times (and omitting the termination test).

c. Simulated annealing with $T = 0$ at all times: ignoring the fact that the termination step would be triggered immediately, the search would be identical to first-choice hill climbing because every downward successor would be rejected with probability 1.

d. Simulated annealing with T=infinity at all times.

d. Simulated annealing with T = infinity at all times: ignoring the fact that the termination step would never be triggered, the search would be identical to a random walk because every successor would be accepted with probability 1. Note that, in this case, a random walk is approximately equivalent to depth-first search.

e. Genetic algorithm with population size N=1.

e. Genetic algorithm with population size $N = 1$: if the population size is 1, then the two selected parents will be the same individual; crossover yields an exact copy of the individual; then there is a small chance of mutation. Thus, the algorithm executes a random walk in the space of individuals.