Q1. Logic

(a) Prove, or find a counterexample to, each of the following assertions:

(i) If $\alpha \models \gamma$ or $\beta \models \gamma$ (or both) then $(\alpha \wedge \beta) \models \gamma$

(ii) If $(\alpha \wedge \beta) \models \gamma$ then $\alpha \models \gamma$ or $\beta \models \gamma$ (or both).

(iii) If $\alpha \models (\beta \vee \gamma)$ then $\alpha \models \beta$ or $\alpha \models \gamma$ (or both).

(b) Decide whether each of the following sentences is valid, unsatisfiable, or neither.

(i) $Smoke \implies Smoke$

(ii) $Smoke \implies Fire$

(iii) $(Smoke \implies Fire) \implies (\neg Smoke \implies \neg Fire)$

(iv) $Smoke \vee Fire \vee \neg Fire$

(v) $((Smoke \wedge Heat) \implies Fire) \iff ((Smoke \implies Fire) \vee (Heat \implies Fire))$

(vi) $(Smoke \implies Fire) \implies ((Smoke \wedge Heat) \implies Fire)$

(vii) $Big \vee Dumb \vee (Big \implies Dumb)$

(c) Suppose an agent inhabits a world with two states, S and $\neg S$, and can do exactly one of two actions, a and b. Action a does nothing and action b flips from one state to the other. Let S^t be the proposition that the agent is in state S at time t, and let a^t be the proposition that the agent does action a at time t (similarly for b^t).

(i) Write a successor-state axiom for S^{t+1}.

(ii) Convert the sentence in the previous part into CNF.

Q2. First Order Logic

Consider a vocabulary with the following symbols:

- $Occuption(p, o)$: Predicate. Person p has occuption o.
- $Customer(p1, p2)$: Predicate. Person $p1$ is a customer of person $p2$.
- $Boss(p1, p2)$: Predicate. Person $p1$ is a boss of person $p2$.
- $Doctor$, $Surgeon$, $Lawyer$, $Actor$: Constants denoting occupations.
- $Emily$, Joe: Constants denoting people.

Use these symbols to write the following assertions in first-order logic:

(iii) Emily is either a surgeon or a lawyer.

(iv) Joe is an actor, but he also holds another job.

(v) All surgeons are doctors.

(vi) Joe does not have a lawyer (i.e., is not a customer of any lawyer).

(vii) Emily has a boss who is a lawyer.

(viii) There exists a lawyer all of whose customers are doctors.

(ix) Every surgeon has a lawyer.

Q3. Local Search

(a) Hill Climbing

(i) Hill-climbing is complete. ☐ True ☐ False

(ii) Hill-climbing is optimal. ☐ True ☐ False

(b) Simulated Annealing

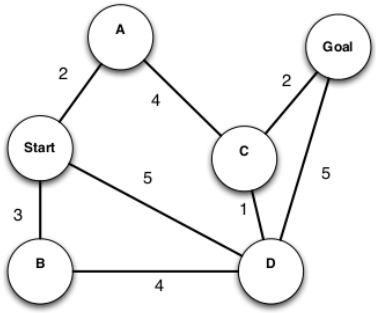
(i) The higher the temperature T is, the more likely the randomly chosen state will be expanded. ☐ True ☐ False

(ii) In one round of simulated annealing, the temperature is 2 and the current state S has energy 1. It has 3 successors: A with energy 2; B with energy 1; C with energy 1-ln 4. If we assume the temperature does not change, What's the probability that these states will be chosen to expand after S eventually?

(iii) On a undirected graph, If T decreases slowly enough, simulated annealing is guaranteed to converge to the optimal state. ☐ True ☐ False

(c) Local Beam Search

The following state graph is being explored with 2-beam graph search. A state's score is its accumulated distance to the start state and lower scores are considered better. Which of the following statements are true?



☐ States A and B will be expanded before C and D.

☐ States A and D will be expanded before B and C.

☐ States B and D will be expanded before A and C.

☐ None of above.

(d) Genetic Algorithm

(i) In genetic algorithm, cross-over combine the genetic information of two parents to generate new offspring.
☐ True ☐ False

(ii) In genetic algorithm, mutation involves a probability that some arbitrary bits in a genetic sequence will be flipped from its original state.
☐ True ☐ False

(e) Gradient Descent

(i) Gradient descent is optimal. ☐ True ☐ False

(ii) For a function $f(x)$ with derivative $f'(x)$, write down the gradient descent update to go from x_t to x_{t+1}. Learning rate is α.