Q1. Local Search

(a) Hill Climbing
(i) Hill-climbing is complete. ■ True □ False
Consider hill-climbing for 8-queen.
(ii) Hill-climbing is optimal. ■ True □ False
No completeness indicates no optimality.

(b) Simulated Annealing
(i) The higher the temperature $T$ is, the more likely the randomly chosen state will be expanded.
■ True □ False
The higher $T$ is, the larger $e^{\Delta E/T}$ is given $\Delta E$ is negative.
(ii) On an undirected graph, if $T$ decreases slowly enough, simulated annealing is guaranteed to converge to
the optimal state exponentially slowly. ■ 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
False. Gradient descent can become trapped in a local minimum.
(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 \( \alpha \).

\[
x_{t+1} = x_t - \alpha f'(x_t), \text{ where } \alpha \text{ is the learning rate.}
\]

2 CSPs: Trapped Pacman

Pacman is trapped! He is surrounded by mysterious corridors, each of which leads to either a pit (P), a ghost (G), or an exit (E). In order to escape, he needs to figure out which corridors, if any, lead to an exit and freedom, rather than the certain doom of a pit or a ghost.

The one sign of what lies behind the corridors is the wind: a pit produces a strong breeze (S) and an exit produces a weak breeze (W), while a ghost doesn’t produce any breeze at all. Unfortunately, Pacman cannot measure the strength of the breeze at a specific corridor. Instead, he can stand between two adjacent corridors and feel the max of the two breezes. For example, if he stands between a pit and an exit he will sense a strong (S) breeze, while if he stands between an exit and a ghost, he will sense a weak (W) breeze. The measurements for all intersections are shown in the figure below.

Also, while the total number of exits might be zero, one, or more, Pacman knows that two neighboring squares will \textit{not} both be exits.

Pacman models this problem using variables \( X_i \) for each corridor \( i \) and domains P, G, and E.

(a) State the binary and/or unary constraints for this CSP (either implicitly or explicitly).

\[
\begin{align*}
\text{Binary:} & \quad X_1 = P \text{ or } X_2 = P, \quad X_2 = E \text{ or } X_3 = E, \\
& \quad X_3 = E \text{ or } X_4 = E, \quad X_4 = P \text{ or } X_5 = P, \\
& \quad X_5 = P \text{ or } X_6 = P, \quad X_1 = P \text{ or } X_6 = P, \\
& \forall i, j \text{ s.t. Adj}(i, j) \quad \neg (X_i = E \text{ and } X_j = E).
\end{align*}
\]

\[
\begin{align*}
\text{Unary:} & \quad X_2 \neq P, \\
& \quad X_3 \neq P, \\
& \quad X_4 \neq P
\end{align*}
\]

Note: This is just one of many solutions. The answers below will be based on this formulation.

(b) Suppose we assign \( X_1 \) to E. Perform forward checking after this assignment. Also, enforce unary constraints.

\[
\begin{array}{|c|c|}
\hline
X_1 & E \\
\hline
X_2 & \\
\hline
X_3 & G \quad E \\
\hline
X_4 & G \quad E \\
\hline
X_5 & P \quad G \quad E \\
\hline
X_6 & P \\
\hline
\end{array}
\]

(c) Suppose forward checking returns the following set of possible assignments:

\[
\begin{array}{|c|c|c|c|}
\hline
X_1 & P & & \\
X_2 & G & E & \\
X_3 & G & E & \\
X_4 & G & E & \\
X_5 & P & & \\
X_6 & P & G & E \\
\hline
\end{array}
\]

According to MRV, which variable or variables could the solver assign first?

\( X_1 \) or \( X_5 \) (tie breaking)

(d) Assume that Pacman knows that \( X_6 = G \). List all the solutions of this CSP or write \textit{none} if no solutions exist.
(P.E.G.E.P,G)
(P.G.E.G.P,G)