1. (25 pts) Search:

(a) For some search algorithms, the solution found might not be the global minimum (with respect to a cost function).
   i. Name and describe one such algorithm.
   ii. Discuss with an example why the algorithm might yield a local minimum.
   iii. Discuss a remedy to reduce the chance for the algorithm to reach a local minimum.

(b) Consider the problem of solving the 8-puzzle:

\[
\begin{array}{ccc}
8 & 7 & 4 \\
6 & 3 & 5 \\
2 & 1 & 6 \\
\end{array}
\quad
\begin{array}{ccc}
1 & 2 & 3 \\
4 & 5 &  \\
6 & 7 & 8 \\
\end{array}
\]

   i. For A* to be optimal, discuss the necessary property for the \( h \) function.
   ii. Describe how to measure cost in this problem.
   iii. Describe an \( h \) function that satisfies the property for A* to be optimal.
2. (25 pts) Given the following state of a Tic-Tac-Toe game (where X moves next):

```
  1 | X
    ----
    0 | X
    ----
    0 | 0
```

Trace the recursive function `int alphaBetaPruning(state, alpha, beta)` that implements the Alpha-beta Pruning Algorithm and list:

- the parameters and
- the return value

of each call.
3. (25 pts) CSP

(a) Describe the elements of a Constraint Satisfaction Problem (CSP).

(b) Describe an algorithm for solving CSPs.

(c) The graph coloring problem is to assign a color to each vertex of a graph such that no adjacent vertices (linked by an edge) have the same color. Trace the solver you proposed in (b) for the problem of coloring using three colors a graph having a vertex in each corner of a square, and an edge for each side and for ONE diagonal.

(d) Can you use A* to solve a CSP? Explain.
4. (25 pts) Resolution inference rule

(a) What does sound and complete (for an inference rule) mean?

(b) What is the resolution inference rule?

(c) Consider:

• \( \forall x, y, z \text{Parent}(x, y) \land \text{Father}(y, z) \Rightarrow \text{Grandfather}(x, z) \)
• \( \forall x, y, z \text{Parent}(x, y) \land \text{Mother}(y, z) \Rightarrow \text{Grandmother}(x, z) \)
• \( \forall x, y \text{Parent}(x, y) \land \text{Male}(y) \Rightarrow \text{Father}(x, y) \)
• \( \forall x, y \text{Parent}(x, y) \land \text{Female}(y) \Rightarrow \text{Mother}(x, y) \)
• \( \text{Male}(\text{Charles}) \)
• \( \text{Female}(\text{Mary}) \)
• \( \text{Female}(\text{Jane}) \)
• \( \text{Parent}(\text{Mary}, \text{Jane}) \)
• \( \text{Parent}(\text{Jane}, \text{Charles}) \)

i. convert each sentence into a conjunctive normal form

ii. apply resolution (and show your steps) to prove: \( \text{Grandfather}(\text{Mary}, \text{Charles}) \)