VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB RECORD

Artificial Intelligence (23CS5PCAIN)

Submitted by

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in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
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B.M.S. College of Engineering,
Bull Temple Road, Bangalore 560019
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Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "**Artificial Intelligence (23CS5PCAIN)**" carried out by **Tanmay Bharadwaj (1BM22CS303),** who is a bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements of the above mentioned subject and the work prescribed for the said degree.

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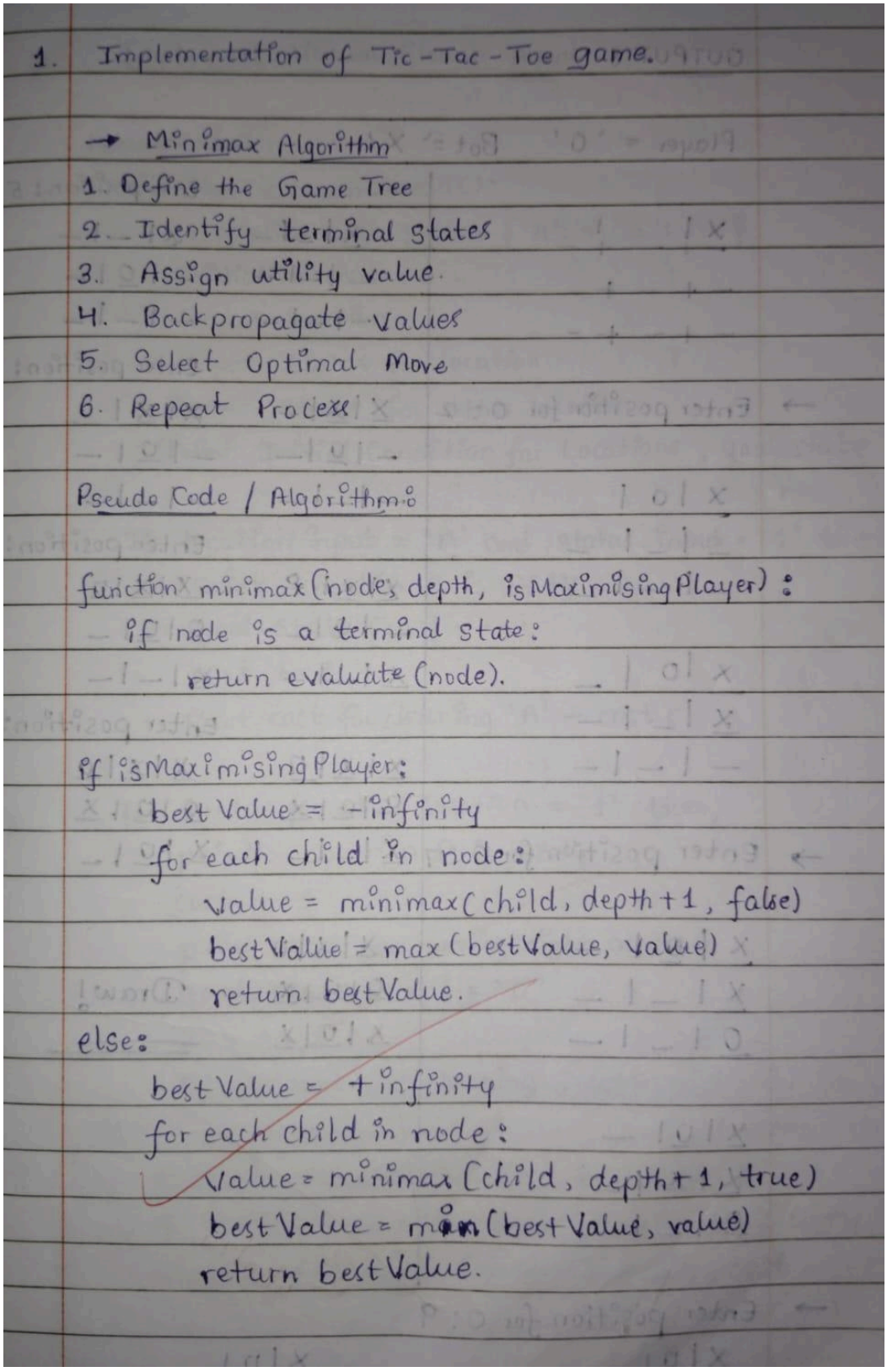
Github Link:
https://github.com/TanmayBj23/AI_LAB

Program 1:

Implement Tic –Tac –Toe Game.

Algorithm/Pseudo Code:



1. Implementation of Tic-Tac-Toe game.

→ Minimax Algorithm

1. Define the Game Tree
2. Identify terminal states
3. Assign utility value.
4. Backpropagate values
5. Select Optimal Move
6. Repeat Process

Pseudo Code / Algorithm:

```
function minimax(node, depth, isMaximisingPlayer):
    if node is a terminal state:
        return evaluate(node).

if isMaximisingPlayer:
    bestValue = -infinity
    for each child in node:
        value = minimax(child, depth+1, false)
        bestValue = max(bestValue, value)
    return bestValue.
else:
    bestValue = +infinity
    for each child in node:
        value = minimax(child, depth+1, true)
        bestValue = min(bestValue, value)
    return bestValue.
```

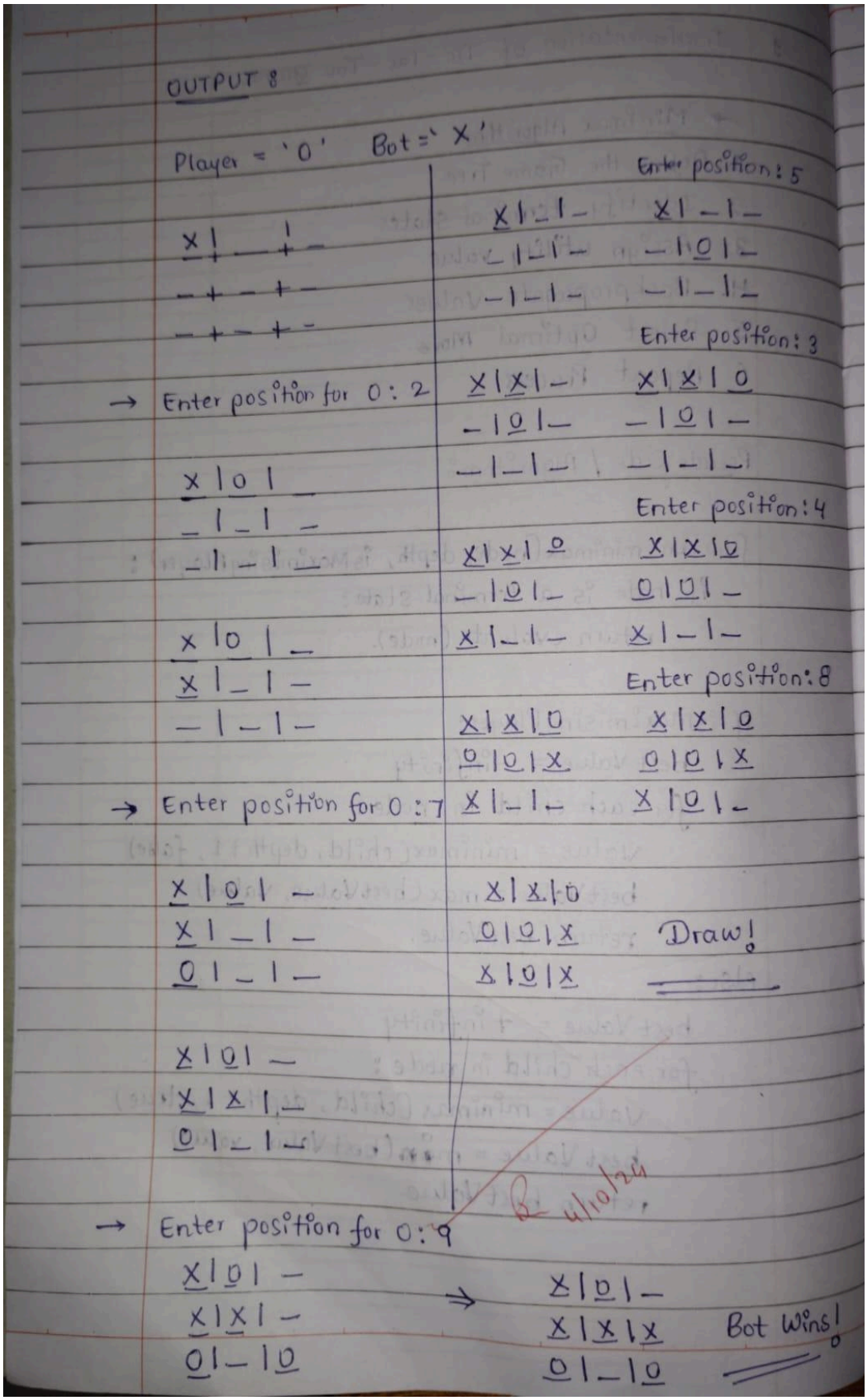
Code:

```
board={1:' ',2:' ',3:' ',
      4:' ',5:' ',6:' ',
      7:' ',8:' ',9:' '
}

def printBoard(board):
   print(board[1]+'|'+board[2]+'|'+board[3])
   print('-+-+-')
   print(board[4] + '|' + board[5] + '|' + board[6])
   print('-+-+-')
   print(board[7] + '|' + board[8] + '|' + board[9])
   print('\n')

def spaceFree(pos):
   if(board[pos]==' '):
      return True
   else:
      return False

def checkWin():
   if(board[1]==board[2] and board[1]==board[3] and board[1]!=' '):
      return True
   elif(board[4]==board[5] and board[4]==board[6] and board[4]!=' '):
      return True
   elif(board[7]==board[8] and board[7]==board[9] and board[7]!=' '):
      return True
   elif (board[1] == board[5] and board[1] == board[9] and board[1] != ' '):
      return True
   elif (board[3] == board[5] and board[3] == board[7] and board[3] != ' '):
      return True
   elif (board[1] == board[4] and board[1] == board[7] and board[1] != ' '):
      return True
   elif (board[2] == board[5] and board[2] == board[8] and board[2] != ' '):
      return True
   elif (board[3] == board[6] and board[3] == board[9] and board[3] != ' '):
      return True
   else:
      return False

def checkMoveForWin(move):
   if (board[1]==board[2] and board[1]==board[3] and board[1] ==move):
      return True
   elif (board[4]==board[5] and board[4]==board[6] and board[4] ==move):
      return True
   elif (board[7]==board[8] and board[7]==board[9] and board[7] ==move):
      return True
   elif (board[1]==board[5] and board[1]==board[9] and board[1] ==move):
      return True
```

```
    elif (board[3]==board[5] and board[3]==board[7] and board[3] ==move):
        return True
    elif (board[1]==board[4] and board[1]==board[7] and board[1] ==move):
        return True
    elif (board[2]==board[5] and board[2]==board[8] and board[2] ==move):
        return True
    elif (board[3]==board[6] and board[3]==board[9] and board[3] ==move):
        return True
    else:
        return False

def checkDraw():
    for key in board.keys():
        if (board[key]==' '):
            return False
    return True


def insertLetter(letter, position):
    if (spaceFree(position)):
        board[position] = letter
        printBoard(board)

        if (checkDraw()):
            print('Draw!')
        elif (checkWin()):
            if (letter == 'X'):
                print('Bot wins!')
            else:
                print('You win!')
        return

    else:
        print('Position taken, please pick a different position.')
        position = int(input('Enter new position: '))
        insertLetter(letter, position)
        return

player = 'O'
bot ='X'

def playerMove():
    position=int(input('Enter position for O:'))
    insertLetter(player, position)
    return

def compMove():
    bestScore=-1000
    bestMove=0
    for key in board.keys():
```

```
        if (board[key]==' '):
            board[key]=bot
            score = minimax(board, False)
            board[key] = ' '
            if (score > bestScore):
                bestScore = score
                bestMove = key

    insertLetter(bot, bestMove)
    return


def minimax(board, isMaximizing):
    if (checkMoveForWin(bot)):
        return 1
    elif (checkMoveForWin(player)):
        return -1
    elif (checkDraw()):
        return 0

    if isMaximizing:
        bestScore = -1000

        for key in board.keys():
            if board[key] == ' ':
                board[key] = bot
                score = minimax(board, False)
                board[key] = ' '
                if (score > bestScore):
                    bestScore = score
        return bestScore
    else:
        bestScore = 1000

        for key in board.keys():
            if board[key] == ' ':
                board[key] = player
                score = minimax(board, True)
                board[key] = ' '
                if (score < bestScore):
                    bestScore = score
        return bestScore

while not checkWin():
    compMove()
    playerMove()
```

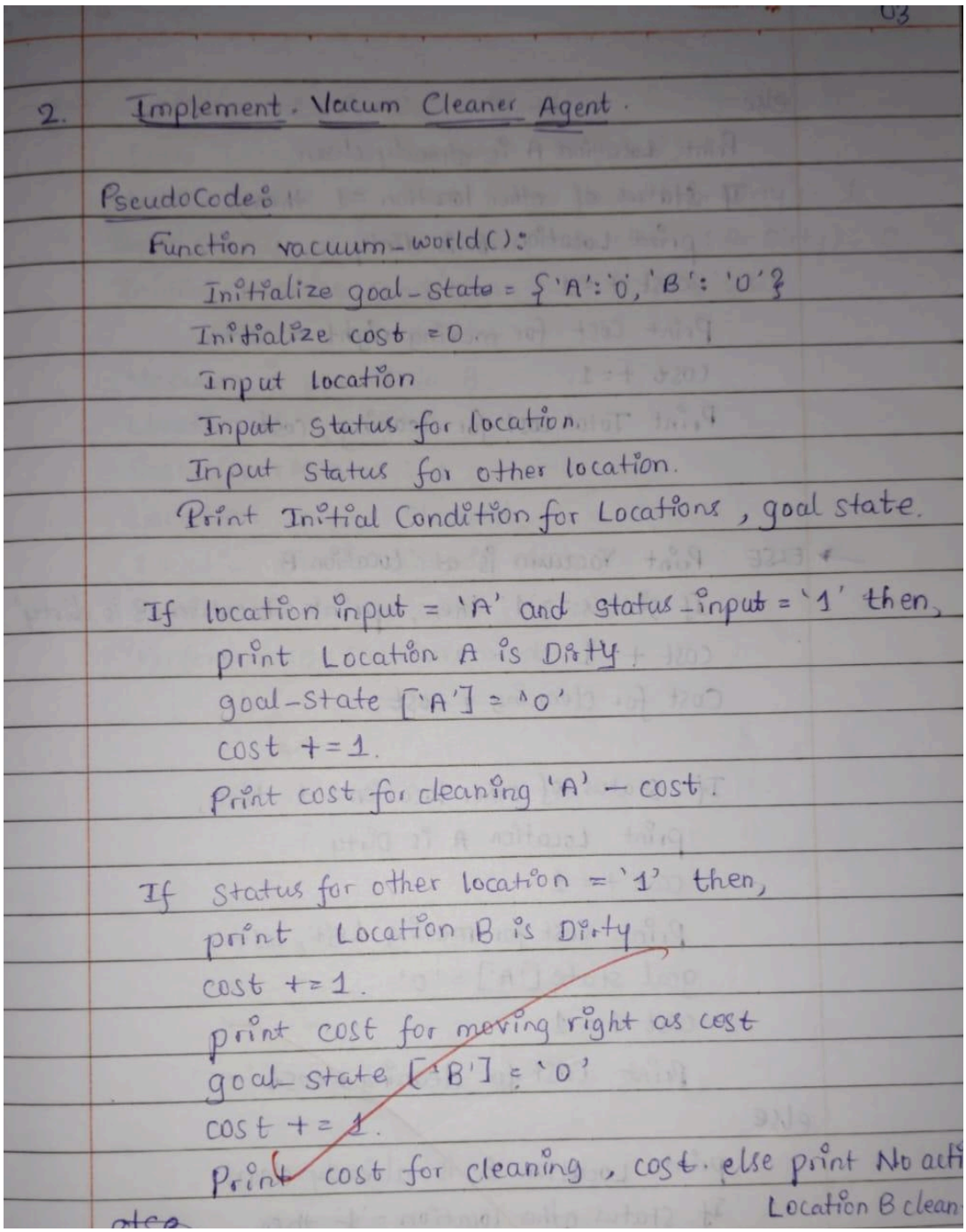
Output:


OUTPUT :
Player = '0' Bot = 'X'
Enter position: 5
Enter position: 3
Enter position for 0: 2
Enter position: 4
Enter position: 8
Enter position for 0: 7
Draw!
Enter position for 0: 9
Bot wins!

Program 2:

Implement a vacuum cleaner agent.

Algorithm/Pseudo Code:



2. Implement. Vacum Cleaner Agent.

PseudoCode:

```
Function vacuum_world():
    Initialize goal_state = {'A': '0', 'B': '0'}
    Initialize cost = 0.
    Input location
    Input status for location.
    Input status for other location.
    Print Initial Condition for Locations, goal state.

If location input = 'A' and status_input = '1' then,
    print Location A is Dirty
    goal_state ['A'] = '0'
    cost += 1.
    Print cost for cleaning 'A' — cost.

If status for other location = '1' then,
    print Location B is Dirty
    cost += 1.
    print cost for moving right as cost
    goal_state ['B'] = '0'
    cost += 1.
    Print cost for cleaning, cost. else print No acti
ates                                    Location B clean
```

else
Print Location A is already clean.
If status of other location =1 then,
print Location B is dirty
cost + = 1
Print Cost for moving right = cost.
cost += 1
Print Total cost for cleaning, cost.

→ ELSE Print Vacuum is at Location B.
If status = = '1' then, print 'Location B is dirty'
cost += 1
Cost for cleaning, cost.

If status of other location = 1 then,
print Location A is Dirty.
cost + = 1
Print Cost for moving Left, cost
goal state ['A'] = '0'
cost + = 1
Print Cost for cleaning, cost
else
print Location B is already clean.
If status other location = '1' then
Print Location A is dirty
cost + = 1.
print Cost for moving Left, cost.
goal_state ['A'] = '0'.
cost + = 1
Print Cost for clean, cost.
Print Performance Measurement, cost

Code:

```
def vacuum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    location_input = input("Enter Location of Vacuum: ")
    status_input = input("Enter status of " + location_input + " (0 for Clean, 1 for Dirty): ")
    status_input_complement = input("Enter status of other room (0 for Clean, 1 for Dirty): ")
    print("Initial Location Condition: " + str(goal_state))
    if location_input == 'A':
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            goal_state['A'] = '0'
            cost += 1
            print("Cost for CLEANING A: " + str(cost))
            print("Location A has been Cleaned.")
            if status_input_complement == '1':
                print("Location B is Dirty.")
                print("Moving right to Location B.")
                cost += 1
                print("COST for moving RIGHT: " + str(cost))
                goal_state['B'] = '0'
                cost += 1
                print("COST for SUCK: " + str(cost))
                print("Location B has been Cleaned.")
            else:
                print("No action: " + str(cost))
                print("Location B is already clean.")
        if status_input == '0':
            print("Location A is already clean.")
            if status_input_complement == '1':
                print("Location B is Dirty.")
                print("Moving RIGHT to Location B.")
                cost += 1
                print("COST for moving RIGHT: " + str(cost))
                goal_state['B'] = '0'
                cost += 1
                print("Cost for SUCK: " + str(cost))
                print("Location B has been Cleaned.")
            else:
                print("No action: " + str(cost))
                print("Location B is already clean.")
    else:
        print("Vacuum is placed in Location B")
        if status_input == '1':
            print("Location B is Dirty.")
            goal_state['B'] = '0'
            cost += 1
            print("COST for CLEANING: " + str(cost))
```

```
            print("Location B has been Cleaned.")
            if status_input_complement == '1':
                print("Location A is Dirty.")
                print("Moving LEFT to Location A.")
                cost += 1
                print("COST for moving LEFT: " + str(cost))
                goal_state['A'] = '0'
                cost += 1
                print("COST for SUCK: " + str(cost))
                print("Location A has been Cleaned.")
            else:
                print("Location A is already clean.")
        if status_input == '0':
            print("Location B is already clean.")
            if status_input_complement == '1':
                print("Location A is Dirty.")
                print("Moving LEFT to Location A.")
                cost += 1
                print("COST for moving LEFT: " + str(cost))
                goal_state['A'] = '0'
                cost += 1
                print("Cost for SUCK: " + str(cost))
                print("Location A has been Cleaned.")
            else:
                print("No action: " + str(cost))
                print("Location A is already clean.")
    print("GOAL STATE: ")
    print(goal_state)
    print("Performance Measurement: " + str(cost))

vacuum_world()
```

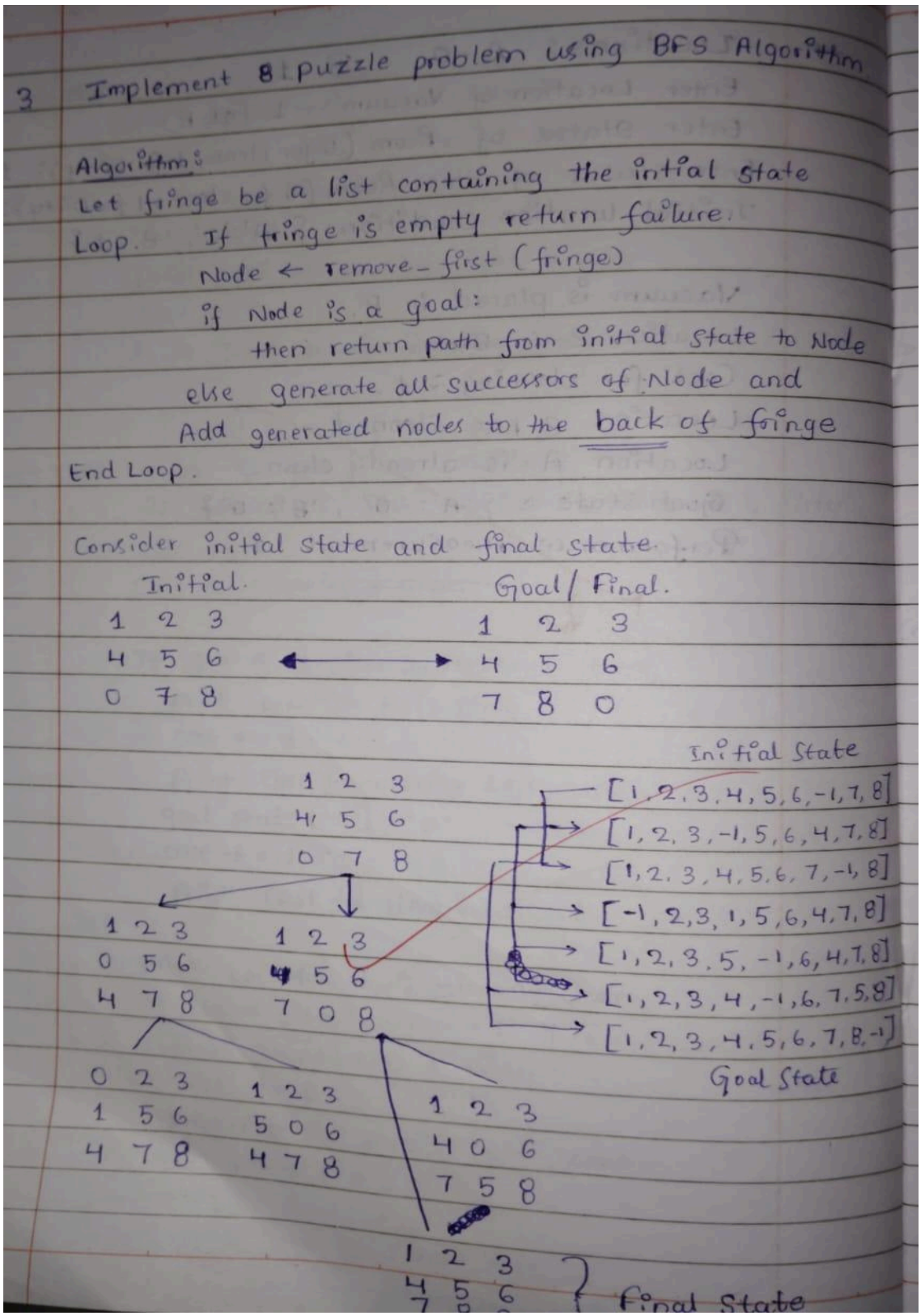
Output:

```
Enter Location of Vacuum: A
Enter status of A (0 for Clean, 1 for Dirty): 0
Enter status of other room (0 for Clean, 1 for Dirty): 1
Initial Location Condition: {'A': '0', 'B': '0'}
Vacuum is placed in Location A
Location A is already clean.
Location B is Dirty.
Moving RIGHT to Location B.
COST for moving RIGHT: 1
Cost for SUCK: 2
Location B has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 2
```

Program 3:

Solve 8 puzzle problems using BFS and DFS techniques.

Algorithm / PseudoCode:



11. Implement 8 puzzle problem using DFS algorithm.

Algorithm:

Let fringe be a list containing the initial state.
Loop If fringe is empty return failure
Node ← remove-first (fringe)
if Node is a goal:
then return path from initial state to Node.
else generate all successors of Node and
Add generated nodes to the front of fringe.
End Loop.

Initial State

1 2 3
4 5 6
0 7 8.

1 2 3
0 5 6
4 7 8

0 2 3
1 5 6
4 7 8

2 0 3
1 5 6
4 7 8

⋮

1 2 3
4 5 6
7 8 0

} Final State Success.

18/10/2024

Code:

```
#BFS Algorithm

from collections import deque
def solve_8puzzle_dfs(initial_state):
  def find_blank(state):
    for row in range(3):
      for col in range(3):
        if state[row][col] == 0:
          return row, col
  def get_neighbors(state):
    row, col = find_blank(state)
    neighbors = []
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)] # Up, Down, Left, Right
    for dr, dc in directions:
      new_row, new_col = row + dr, col + dc
      if 0 <= new_row < 3 and 0 <= new_col < 3:
        new_state = [r[:] for r in state]
        new_state[row][col], new_state[new_row][new_col] = new_state[new_row][new_col],
new_state[row][col]
        neighbors.append(new_state)
    return neighbors


  goal_state = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]
  stack = [(initial_state, [])]
  visited = set()
  while stack:
    current_state, path = stack.pop()
    state_tuple = tuple(map(tuple, current_state))
    if state_tuple in visited:
      continue
    visited.add(state_tuple)
    if current_state == goal_state:
      return path + [current_state]
    for neighbor in get_neighbors(current_state):
      stack.append((neighbor, path + [current_state]))
  return None

initial_state = [[1, 2, 3], [4, 5, 6], [0, 7, 8]]
solution = solve_8puzzle_dfs(initial_state)
if solution:
  print("Solution found:")
  for state in solution:
    for row in state:
      print(row)
    print()
else:
  print("No solution found.")
```

#DFS Algorithm

```
from collections import deque
def solve_8puzzle_dfs(initial_state):
  def find_blank(state):
    for row in range(3):
      for col in range(3):
        if state[row][col] == 0:
          return row, col
  def get_neighbors(state):
    row, col = find_blank(state)
    neighbors = []
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)] # Up, Down, Left, Right
    for dr, dc in directions:
      new_row, new_col = row + dr, col + dc
      if 0 <= new_row < 3 and 0 <= new_col < 3:
          new_state = [r[:] for r in state]
          new_state[row][col], new_state[new_row][new_col] = new_state[new_row][new_col],
new_state[row][col]
          neighbors.append(new_state)
    return neighbors

  goal_state = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]
  stack = [(initial_state, [])]
  visited = set()
  while stack:
    current_state, path = stack.pop()
    state_tuple = tuple(map(tuple, current_state))
    if state_tuple in visited:
      continue
    visited.add(state_tuple)
    if current_state == goal_state:
      return path + [current_state]
    for neighbor in get_neighbors(current_state):
        stack.append((neighbor, path + [current_state]))
  return None

initial_state = [[1, 2, 3], [4, 5, 6], [0, 7, 8]]
solution = solve_8puzzle_dfs(initial_state)
if solution:
  print("Solution found:")
  for state in solution:
    for row in state:
      print(row)
    print()
else:
  print("No solution found.")
```

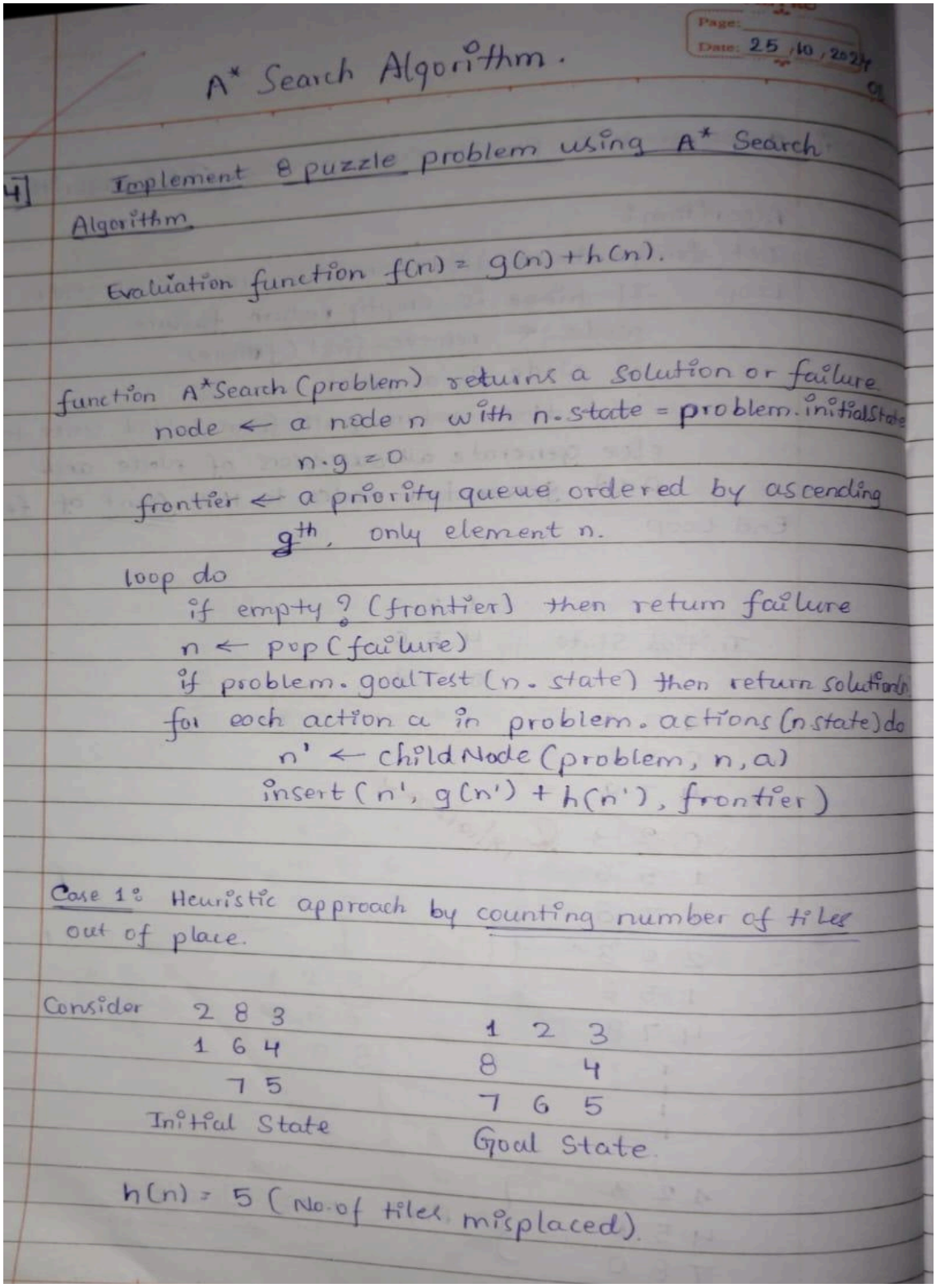
Output:

```
Solution found:
[1, 2, 3]
[4, 5, 6]
[0, 7, 8]

[1, 2, 3]
[4, 5, 6]
[7, 0, 8]

[1, 2, 3]
[4, 5, 6]
[7, 8, 0]
```

Program 4:

Implement A* search algorithm for 8 Puzzle Problem using heuristic approach: Misplaced tiles and Manhattan distance.

Algorithm/Pseudo Code:



A* Search Algorithm.

Page:
Date: 25/10/2024

4] Implement 8 puzzle problem using A* Search Algorithm

Evaluation function f(n) = g(n) + h(n).

function A*Search (problem) returns a solution or failure
node ← a node n with n.state = problem.initialState
n.g = 0
frontier ← a priority queue ordered by ascending g^th, only element n.
loop do
if empty? (frontier) then return failure
n ← pop (failure)
if problem.goalTest (n.state) then return solution(n)
for each action a in problem.actions (n.state) do
n' ← childNode (problem, n, a)
insert (n', g(n') + h(n'), frontier)

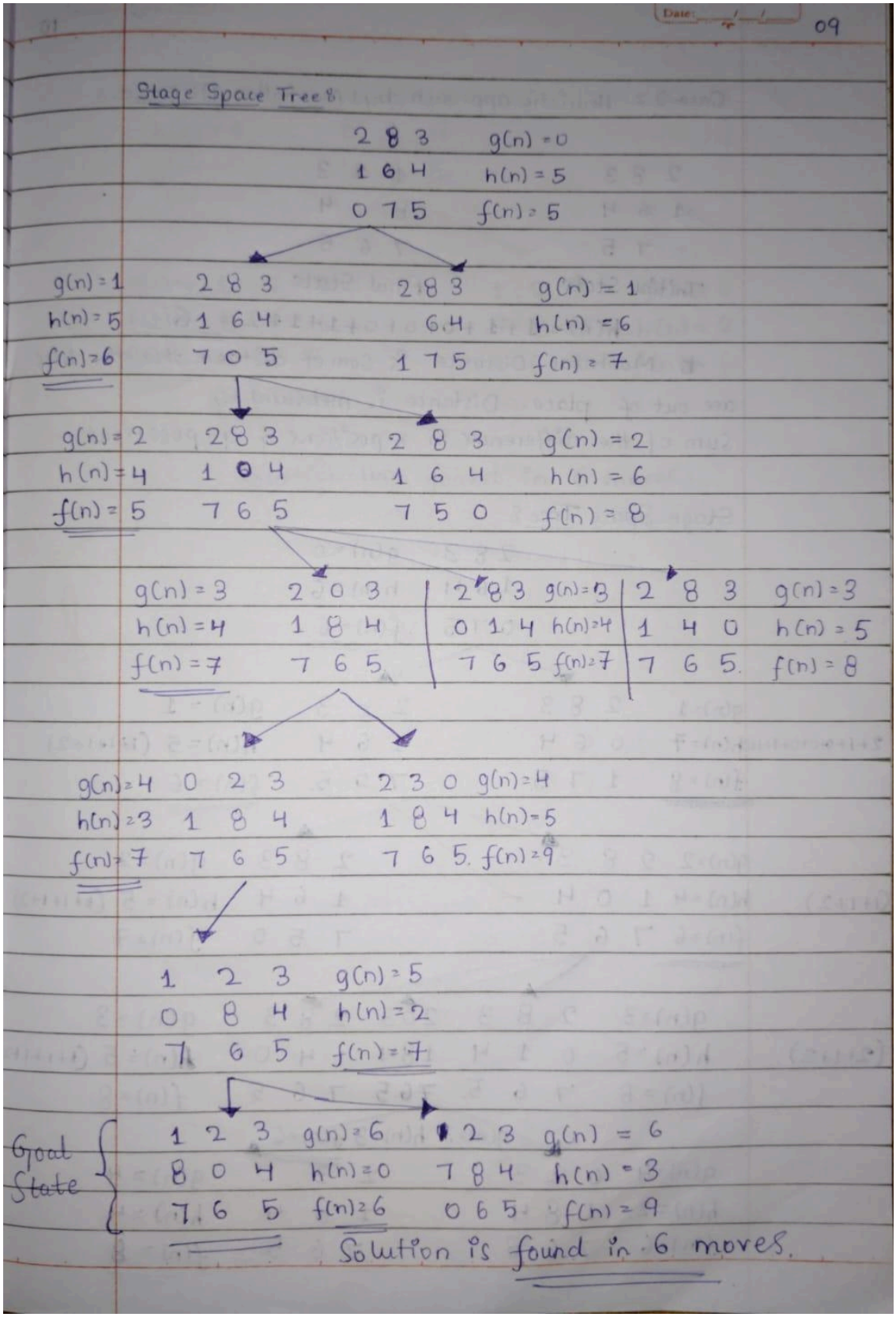
Case 1: Heuristic approach by counting number of tiles out of place.

Consider

2 8 3	1 2 3
1 6 4	8 4
7 5	7 6 5
Initial State	Goal State

h(n) = 5 (No. of tiles misplaced).

Stage Space Tree:



Solution is found in 6 moves.

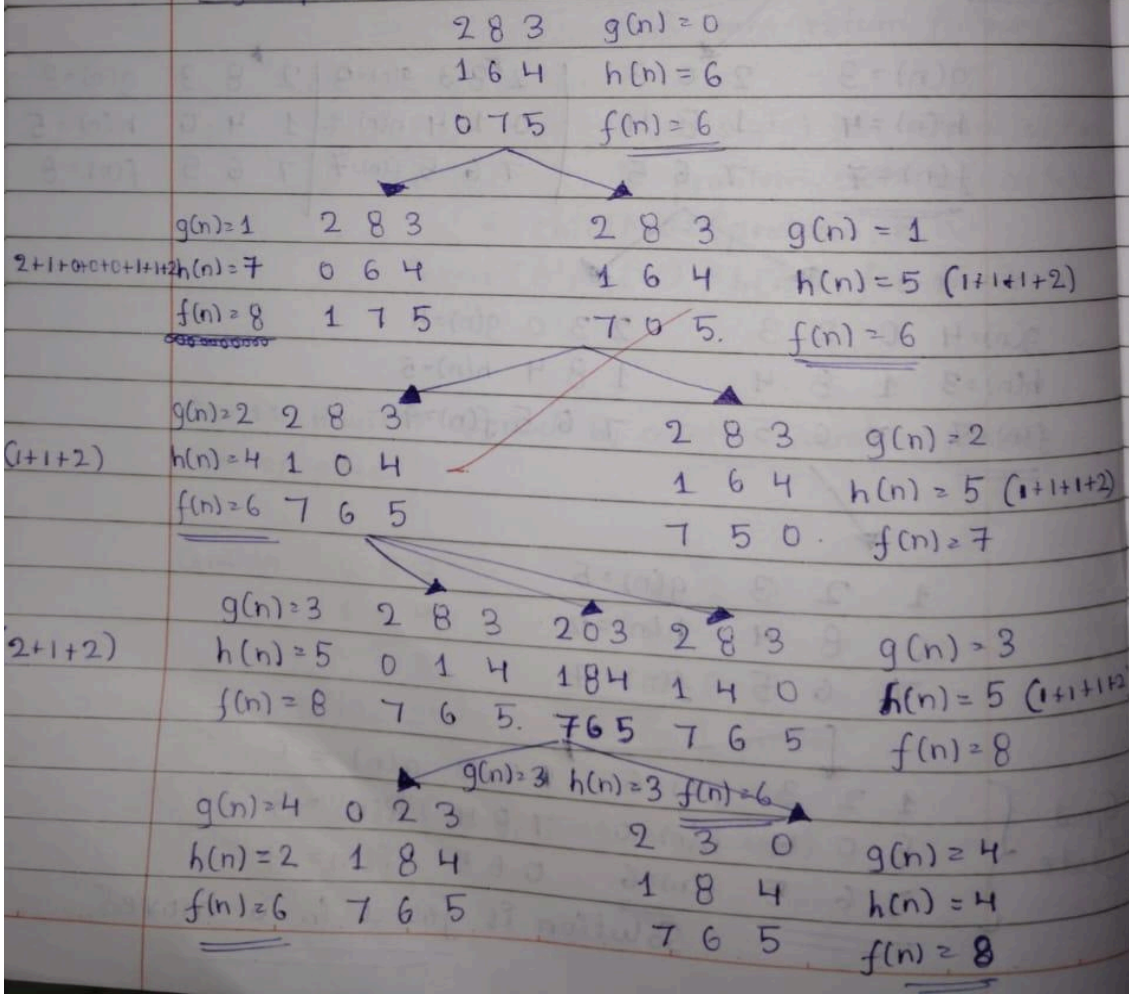
Case 2 : Heuristic approach by Manhatten Distance.

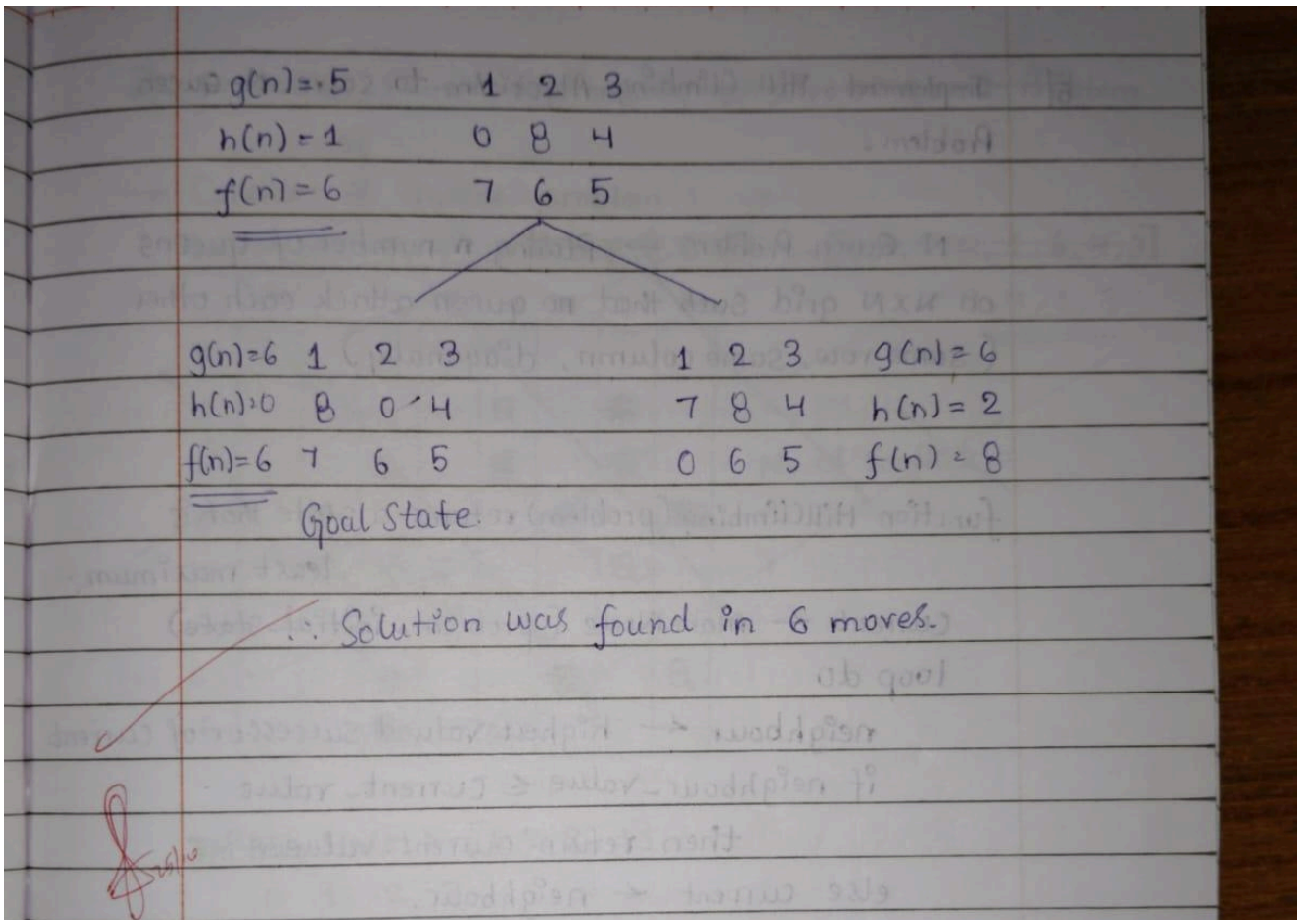
2 8 3	1 2 3
1 6 4	8 4
7 5	7 6 5
Initial State	Final State

$h(n) = 1+1+0+0+0+1+1+2 = 6$

Manhattan Distance is sum of distance that the tiles are out of place. Distance is measured by sum of the differences in x-positions & y-positions.

Stage Space Tree :





Code:

```
# Heuristic function: number of misplaced tiles
import heapq
# Define the goal state
GOAL_STATE = [[1, 2, 3],
              [8, 0, 4],
              [7, 6, 5]]

# Utility function to find the position of the blank tile
def find_blank_position(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j

def h(state):
    misplaced = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != 0 and state[i][j] != GOAL_STATE[i][j]:
                misplaced += 1
    return misplaced
```

```
# Generate possible moves (Up, Down, Left, Right)
def get_neighbors(state):
    neighbors = []
    x, y = find_blank_position(state)
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]  # Up, Down, Left, Right
    for dx, dy in directions:
        new_x, new_y = x + dx, y + dy
        if 0 <= new_x < 3 and 0 <= new_y < 3:
            new_state = [row[:] for row in state]
            new_state[x][y], new_state[new_x][new_y] = new_state[new_x][new_y], new_state[x][y]
            neighbors.append(new_state)
    return neighbors

# A* search algorithm
def a_star_search(initial_state):
    open_list = []
    heapq.heappush(open_list, (h(initial_state), 0, initial_state, []))  # (f(n), g(n), state, path)
    closed_set = set()
    while open_list:
        f, g, current_state, path = heapq.heappop(open_list)
        if current_state == GOAL_STATE:
            return path + [current_state]  # Return the path to the goal
        closed_set.add(tuple(tuple(row) for row in current_state))  # Add to closed set
        for neighbor in get_neighbors(current_state):
            neighbor_tuple = tuple(tuple(row) for row in neighbor)
            if neighbor_tuple in closed_set:
                continue
            heapq.heappush(open_list, (g + 1 + h(neighbor), g + 1, neighbor, path + [current_state]))
    return None  # No solution

# Print the puzzle state
def print_state(state):
    for row in state:
        print(row)
    print()

# Define the initial state
initial_state = [[2, 8, 3],
                 [1, 6, 4],
                 [0, 7, 5]]

# Run the A* search
solution_path = a_star_search(initial_state)
# Print the solution path
if solution_path:
    print("Solution found in", len(solution_path)-1, "moves:")
    for step in solution_path:
        print_state(step)
else:
    print("No solution found.")
```

```
# Heuristic function: Manhattan distance
import heapq
# Define the goal state
GOAL_STATE = [[1, 2, 3],
              [8, 0, 4],
              [7, 6, 5]]
# Utility function to find the position of the blank tile
def find_blank_position(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
def h(state):
    distance = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != 0:
                goal_x, goal_y = divmod(state[i][j] - 1, 3)
                distance += abs(goal_x - i) + abs(goal_y - j)
    return distance
# Generate possible moves (Up, Down, Left, Right)
def get_neighbors(state):
    neighbors = []
    x, y = find_blank_position(state)
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]  # Up, Down, Left, Right
    for dx, dy in directions:
        new_x, new_y = x + dx, y + dy
        if 0 <= new_x < 3 and 0 <= new_y < 3:
            new_state = [row[:] for row in state]
            new_state[x][y], new_state[new_x][new_y] = new_state[new_x][new_y], new_state[x][y]
            neighbors.append(new_state)
    return neighbors
# A* search algorithm
def a_star_search(initial_state):
    open_list = []
    heapq.heappush(open_list, (h(initial_state), 0, initial_state, []))  # (f(n), g(n), state, path)
    closed_set = set()
    while open_list:
        f, g, current_state, path = heapq.heappop(open_list)
        if current_state == GOAL_STATE:
            return path + [current_state]  # Return the path to the goal
        closed_set.add(tuple(tuple(row) for row in current_state))  # Add to closed set
        for neighbor in get_neighbors(current_state):
            neighbor_tuple = tuple(tuple(row) for row in neighbor)
            if neighbor_tuple in closed_set:
                continue
            heapq.heappush(open_list, (g + 1 + h(neighbor), g + 1, neighbor, path + [current_state]))
    return None  # No solution
```

```
# Print the puzzle state
def print_state(state):
    for row in state:
        print(row)
    print()
# Define the initial state
initial_state = [[2, 8, 3],
                 [1, 6, 4],
                 [0, 7, 5]]
# Run the A* search
solution_path = a_star_search(initial_state)
# Print the solution path
if solution_path:
    print("Solution found in", len(solution_path)-1, "moves:")
    for step in solution_path:
        print_state(step)
else:
    print("No solution found.")
```

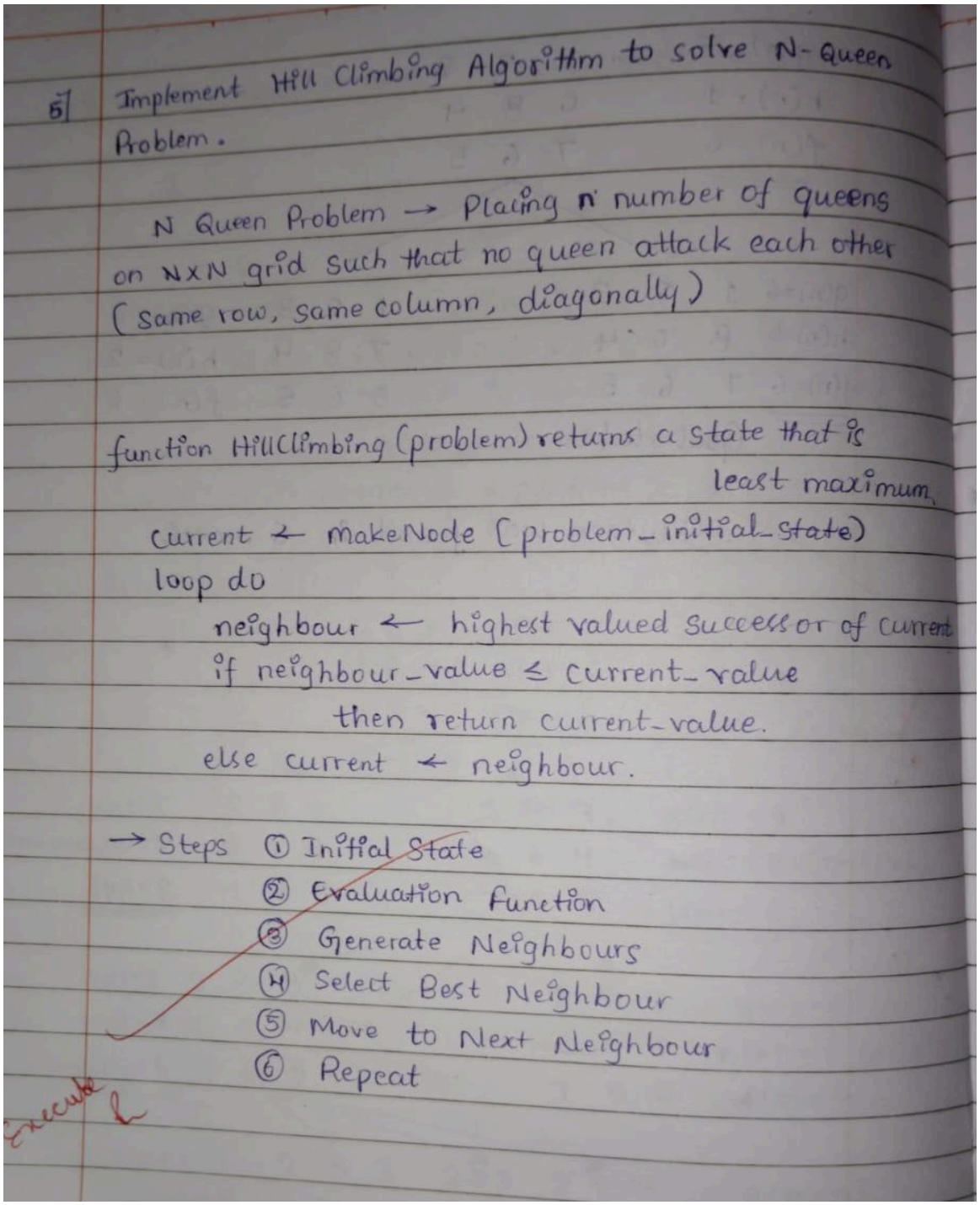
Output:

```
Solution found in 6 moves:
[2, 8, 3]
[1, 6, 4]
[0, 7, 5]

[2, 8, 3]
[1, 6, 4]
[7, 0, 5]

[2, 8, 3]
[1, 0, 4]
[7, 6, 5]

[2, 0, 3]
[1, 8, 4]
[7, 6, 5]

[0, 2, 3]
[1, 8, 4]
[7, 6, 5]

[1, 2, 3]
[0, 8, 4]
[7, 6, 5]

[1, 2, 3]
[8, 0, 4]
[7, 6, 5]
```

Program 5:

Implement Hill Climbing Algorithm to solve N Queens Problem.

Algorithm/Pseudo Code:

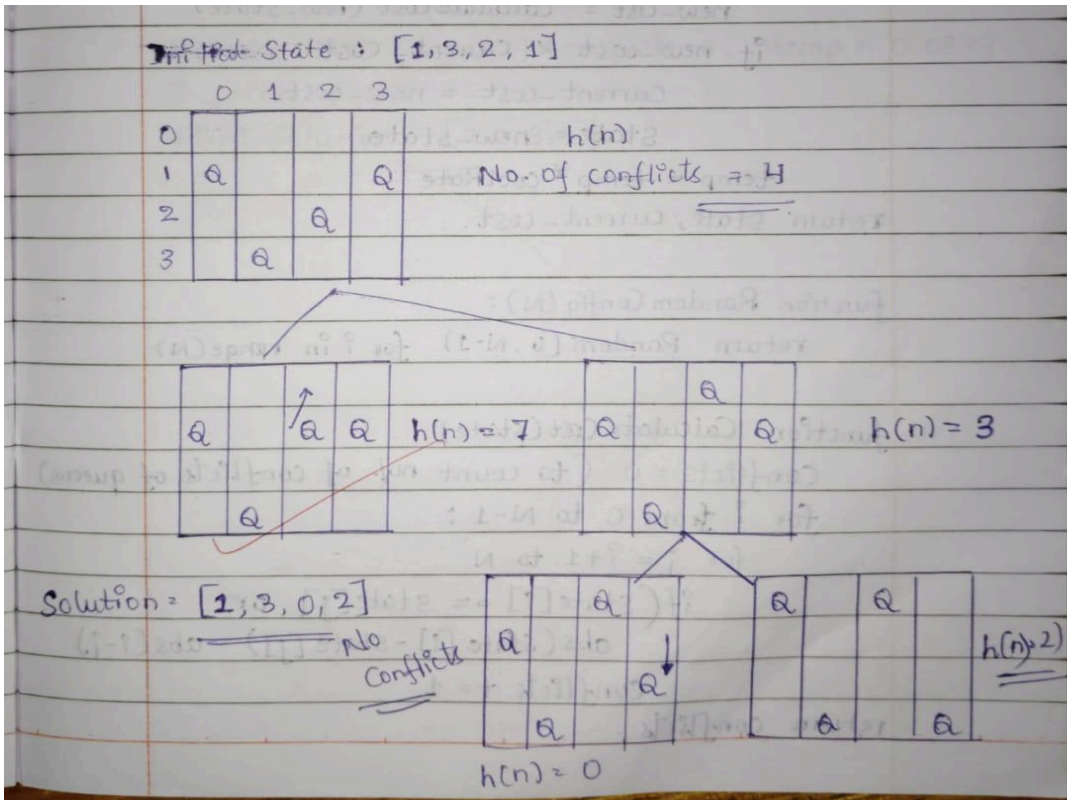


Code:

```
import random
def calculate_cost(state):
    conflicts = 0
    N = len(state)
    for i in range(N):
        for j in range(i + 1, N):
            # Check if queens i and j are attacking each other
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts
def generate_neighbors(state):
    neighbors = []
    N = len(state)
    for col in range(N):
        # Try moving the queen in column `col` to all other rows
        for row in range(N):
            if state[col] != row:  # Avoid moving to the same position
                new_state = state[:]
                new_state[col] = row
                neighbors.append(new_state)
    return neighbors
def hill_climbing(N):
     # Step 1: Initialize a random state
    state = [random.randint(0, N - 1) for _ in range(N)]
    print(f"Initial State: {state}")
    current_cost = calculate_cost(state)
    print(f"Initial Conflicts: {current_cost}"
    # Step 2: Loop until a solution is found or no improvement is possible
    while current_cost > 0:
        # Generate neighbors
        neighbors = generate_neighbors(state)
        # Step 3: Select the best neighbor (with the least conflicts)
        best_neighbor = None
        best_cost = float('inf')
        for neighbor in neighbors:
            cost = calculate_cost(neighbor)
            if cost < best_cost:
                best_cost = cost
                best_neighbor = neighbor
        # If no better neighbor is found, we've reached a local minimum
        if best_cost >= current_cost:
            print("No better neighbor found. Stopping.")
            return None  # Return None indicating failure (local minimum reached)

        # Step 4: Move to the best neighbor
        state = best_neighbor
        current_cost = best_cost
        print(f"New State: {state}")
```

```
        print(f"New Conflicts: {current_cost}")
    # If the loop terminates with zero conflicts, we have found a solution
    print(f"Solution found: {state}")
    return state
# Example usage
N = 4
 # Number of queens (8-Queens problem)
solution = hill_climbing(N)
if solution:
    print(f"Final Solution: {solution}")
else:
    print("No solution found.")
```

Output:

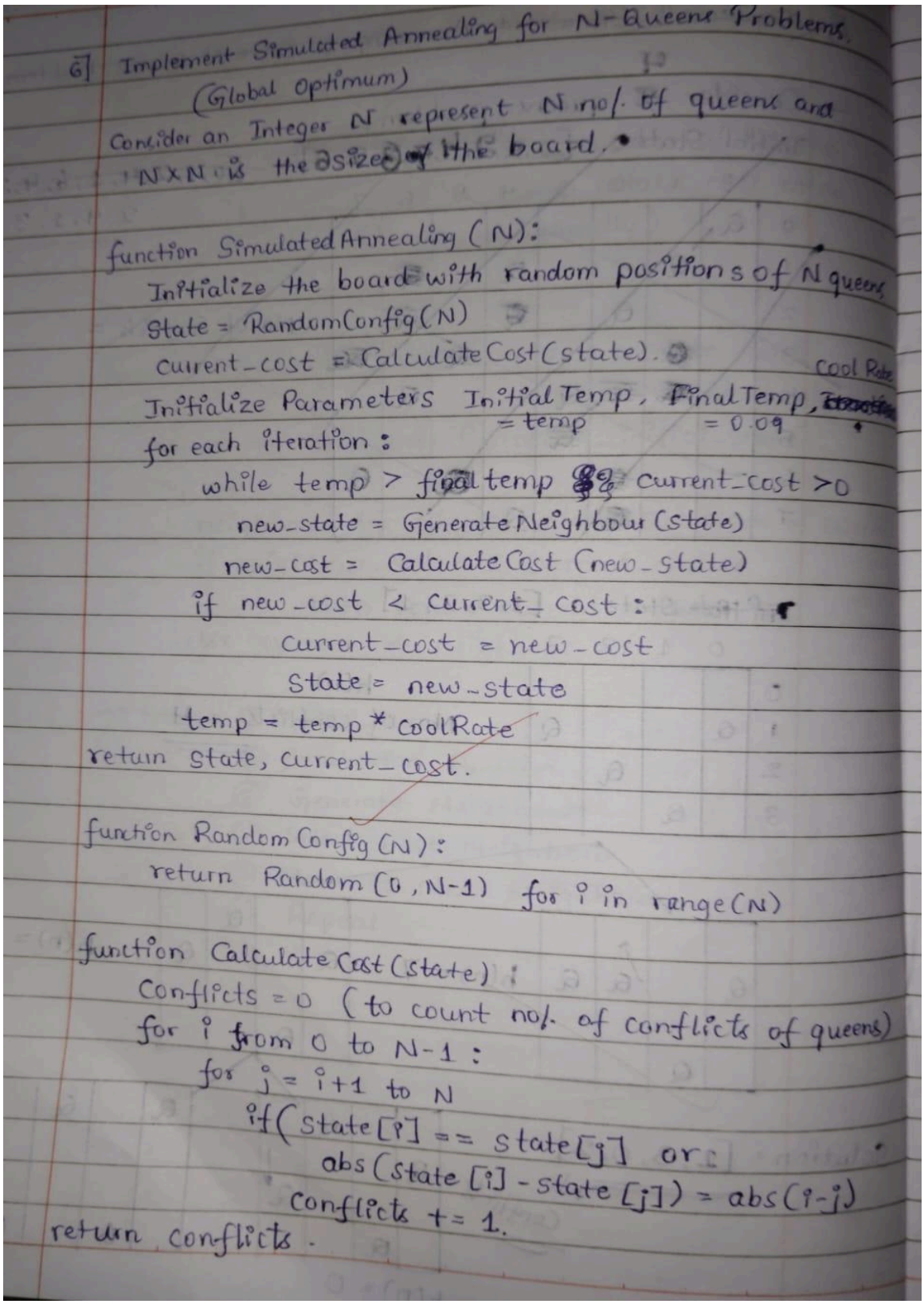



```
Initial State: [2, 2, 2, 1]
Initial Conflicts: 4
New State: [2, 0, 2, 1]
New Conflicts: 2
New State: [2, 0, 3, 1]
New Conflicts: 0
Solution found: [2, 0, 3, 1]
Final Solution: [2, 0, 3, 1]
```

Program 6:

Write a program to implement a Simulated Annealing Algorithm.

Algorithm/Pseudo Code:

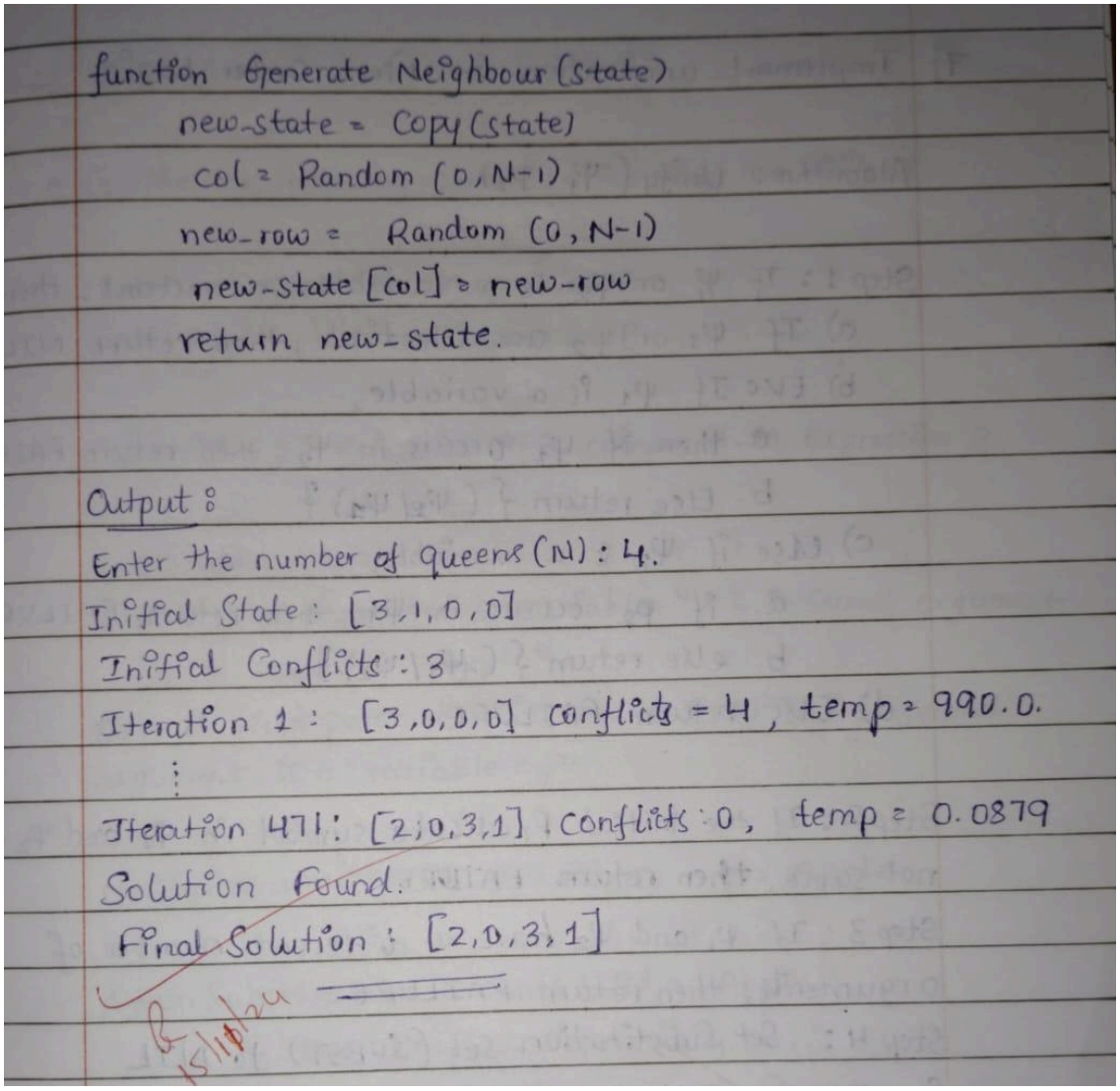


6] Implement Simulated Annealing for N-Queens Problems.
(Global Optimum)
Consider an Integer N represent N no/. of queens and
N X N is the size of the board.

function SimulatedAnnealing (N):
Initialize the board with random positions of N queens
State = RandomConfig(N)
current_cost = CalculateCost(state).
Initialize Parameters InitialTemp = temp, FinalTemp = 0.09, CoolRate
for each iteration:
while temp > final temp & current_cost > 0
new_state = GenerateNeighbour(state)
new_cost = CalculateCost(new_state)
if new_cost < current_cost:
current_cost = new_cost
State = new_state
temp = temp * coolRate
return state, current_cost.

function RandomConfig(N):
return Random(0, N-1) for i in range(N)

function CalculateCost(state):
Conflicts = 0 (to count no/. of conflicts of queens)
for i from 0 to N-1:
for j = i+1 to N
if(State[i] == state[j] or
abs(state[i] - state[j]) = abs(i-j)
Conflicts += 1.
return conflicts.



Code:

```
import random
import math

def calculate_cost(state):
    conflicts = 0
    N = len(state)

    for i in range(N):
        for j in range(i + 1, N):
            # Check if queens i and j are attacking each other
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts
```

```
def generate_neighbor(state):
    N = len(state)
    new_state = state[:]

    # Randomly select a column to move a queen
    col = random.randint(0, N - 1)

    # Randomly select a new row for the queen in that column (avoid current row)
    new_row = random.randint(0, N - 1)
    while new_row == new_state[col]:
        new_row = random.randint(0, N - 1)

    # Move the queen to the new row
    new_state[col] = new_row

    return new_state

def simulated_annealing(N, initial_temp, cooling_rate, max_iterations):
    """
    Simulated Annealing algorithm to solve the N-Queens problem.
    N: Number of queens (board size)
    initial_temp: Initial temperature
    cooling_rate: Rate at which temperature decreases
    max_iterations: Maximum number of iterations to run
    """
    # Step 1: Initialize the state with a random configuration of queens
    state = [random.randint(0, N - 1) for _ in range(N)]
    current_cost = calculate_cost(state)

    # Step 2: Start with an initial temperature
    temp = initial_temp
    best_state = state[:]
    best_cost = current_cost
    print(f"Initial State: {state}")
    print(f"Initial Conflicts: {current_cost}")

    # Step 3: Main loop
    for iteration in range(max_iterations):
        # Generate a neighboring state
        neighbor = generate_neighbor(state)
        neighbor_cost = calculate_cost(neighbor)
        # If the neighbor is better, accept it
        if neighbor_cost < current_cost:
            state = neighbor
            current_cost = neighbor_cost
        else:
            # If the neighbor is worse, accept it with a certain probability
            delta_cost = neighbor_cost - current_cost
            acceptance_prob = math.exp(-delta_cost / temp)
```

```
            if random.random() < acceptance_prob:
                state = neighbor
                current_cost = neighbor_cost
        # Keep track of the best solution found
        if current_cost < best_cost:
            best_state = state[:]
            best_cost = current_cost
        # Cool down the temperature
        temp *= cooling_rate
        # Print the current state and its conflicts
        if iteration % (max_iterations // 10) == 0 or current_cost == 0:
            print(f"Iteration {iteration + 1}: {state}, Conflicts: {current_cost}, Temperature: {temp}")
        # Stop if the solution is found (zero conflicts)
        if current_cost == 0:
            print(f"Solution found: {state}")
            return state
    print("Reached maximum iterations without finding a solution.")
    return best_state

# Example usage
N = int(input("Enter the number of queens (N): "))  # Number of queens (board size)
initial_temp = 1000  # Initial temperature
cooling_rate = 0.99  # Cooling rate
max_iterations = 10000  # Maximum iterations
# Run the Simulated Annealing algorithm
solution = simulated_annealing(N, initial_temp, cooling_rate, max_iterations)
if solution:
    print(f"Final Solution: {solution}")
else:
    print("No solution found.")
```

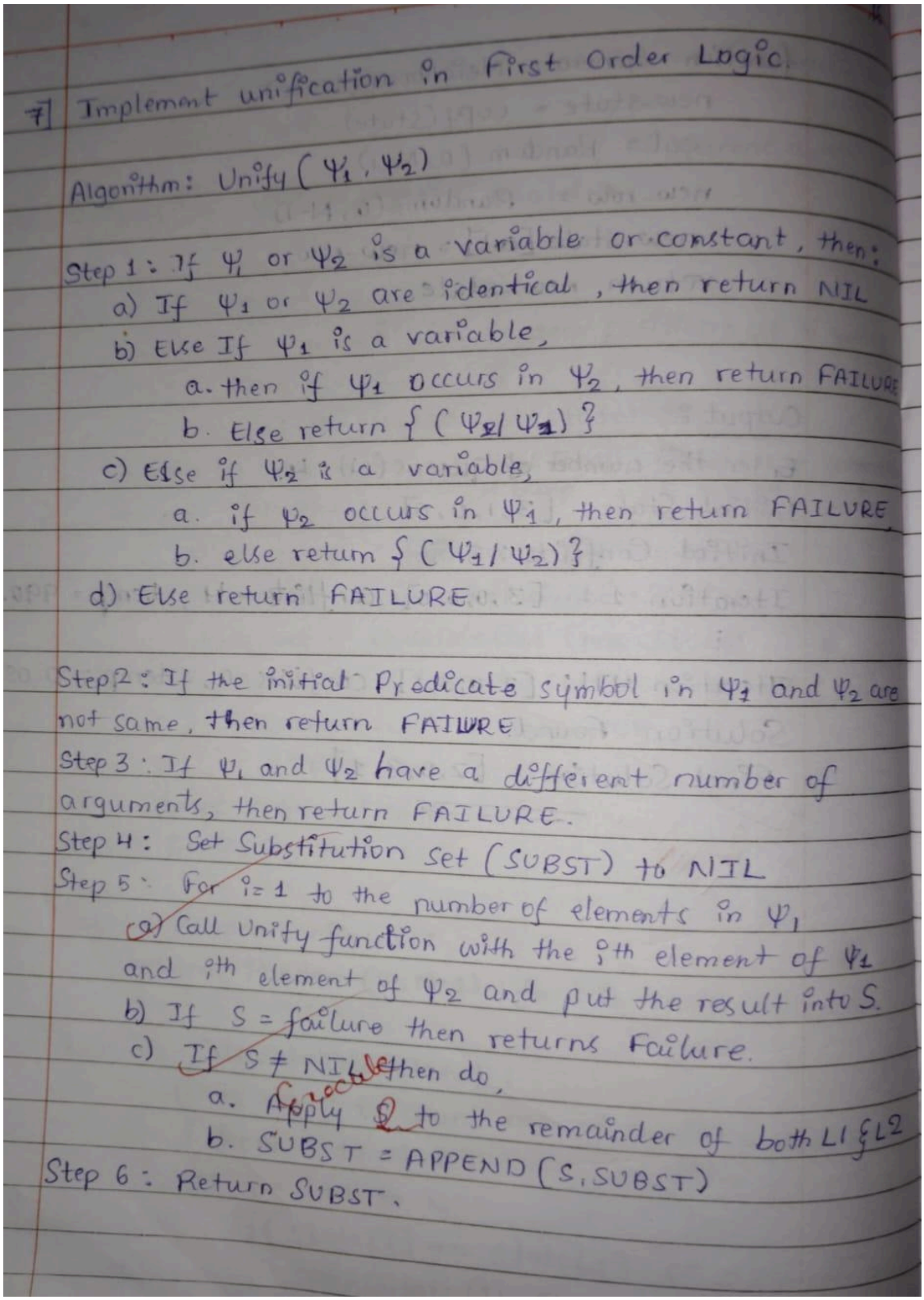
Output:

```
Enter the number of queens (N): 4
Initial State: [3, 1, 0, 0]
Initial Conflicts: 3
Iteration 1: [3, 0, 0, 0], Conflicts: 4, Temperature: 990.0
Iteration 471: [2, 0, 3, 1], Conflicts: 0, Temperature: 8.793801444488377
Solution found: [2, 0, 3, 1]
Final Solution: [2, 0, 3, 1]
```

Program 7:

Implement unification in first order logic.

Algorithm/Pseudo Code:



7] Implement unification in First Order Logic.

Algorithm: Unify (Ψ_1, Ψ_2)

Step 1: If Ψ_1 or Ψ_2 is a variable or constant, then:
a) If Ψ_1 or Ψ_2 are identical, then return NIL
b) Else If Ψ_1 is a variable,
a. then if Ψ_1 occurs in Ψ_2, then return FAILURE
b. Else return { (Ψ_2/ Ψ_1) }
c) Else if Ψ_2 is a variable,
a. if Ψ_2 occurs in Ψ_1, then return FAILURE.
b. else return { (Ψ_1/ Ψ_2) }
d) Else return FAILURE

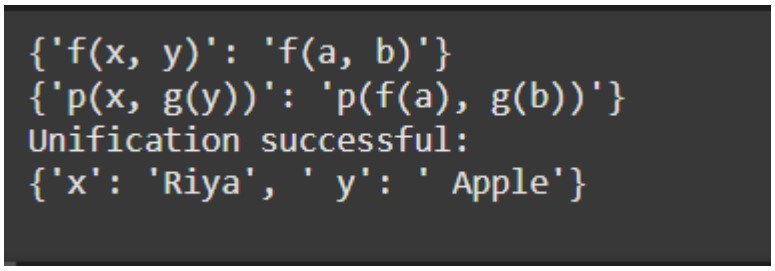
Step 2: If the initial Predicate symbol in Ψ_1 and Ψ_2 are not same, then return FAILURE
Step 3: If Ψ_1 and Ψ_2 have a different number of arguments, then return FAILURE.
Step 4: Set Substitution set (SUBST) to NIL
Step 5: For i= 1 to the number of elements in Ψ_1
a) Call Unify function with the ith element of Ψ_1 and ith element of Ψ_2 and put the result into S.
b) If S = failure then returns Failure.
c) If S ≠ NIL then do,
a. Apply S to the remainder of both L1 & L2
b. SUBST = APPEND (S, SUBST)
Step 6: Return SUBST.

Code:

```
def unify(x, y, subst=None):
    if subst is None:
        subst = {}
    # Step 1: If x and y are the same, return the current substitutions
    if x == y:
        return subst
    # If x is a variable
    if is_variable(x):
        return unify_var(x, y, subst)
    # If y is a variable
    if is_variable(y):
        return unify_var(y, x, subst)
    # If x and y are compound expressions
    if is_compound(x) and is_compound(y):
        if get_predicate(x) != get_predicate(y):
            return "FAILURE"
        return unify(get_args(x), get_args(y), subst)

    # If x and y are lists
    if isinstance(x, list) and isinstance(y, list):
        if len(x) != len(y):
            return "FAILURE"
        if not x and not y:
            return subst
        return unify(x[1:], y[1:], unify(x[0], y[0], subst))

    # If x and y are constants or cannot be unified
    return "FAILURE"

def unify_var(var, x, subst):
    if var in subst:
        return unify(subst[var], x, subst)
    if x in subst:
        return unify(var, subst[x], subst)
    if occurs_check(var, x):
        return "FAILURE"
    subst[var] = x
    return subst

def occurs_check(var, x):
    if var == x:
        return True
    if isinstance(x, list):
        return any(occurs_check(var, arg) for arg in x)
    return False

def is_variable(x):
    return isinstance(x, str) and x.islower()  # Variables are lowercase strings
```

```
def is_compound(x):
    return isinstance(x, str) and '(' in x and ')' in x

def get_predicate(x):
    return x.split('(')[0]

def get_args(x):
    return x[x.index('(') + 1:x.index(')')].split(',')

# Test cases
x1 = "f(x, y)"
x2 = "f(a, b)"
print(unify(x1, x2))  # Expected: {'x': 'a', 'y': 'b'}

x3 = "p(x, g(y))"
x4 = "p(f(a), g(b))"
print(unify(x3, x4))  # Expected: {'x': 'f(a)', 'y': 'b'}

expression_a = "Eats(x, Apple)"
expression_b = "Eats(Riya, y)"

substitution = unify(expression_a, expression_b)

# Print the result
if substitution == "FAILURE":
    print("Unification failed.")
else:
    print("Unification successful:")
    print(substitution)
```

Output:



Output:

Consider the following phrases, which must be unified.

Eats(x, Apple) is an expression A
Eats(Riya, y) is an expression B

Comparision : Expression A is compared to Expression B.

Substitution Variable :
Exp A first parameter is variable "x" & Second argument is a constant "Apple"
Exp B first parameter is constant "Riya" & Second argument is a variable "y".

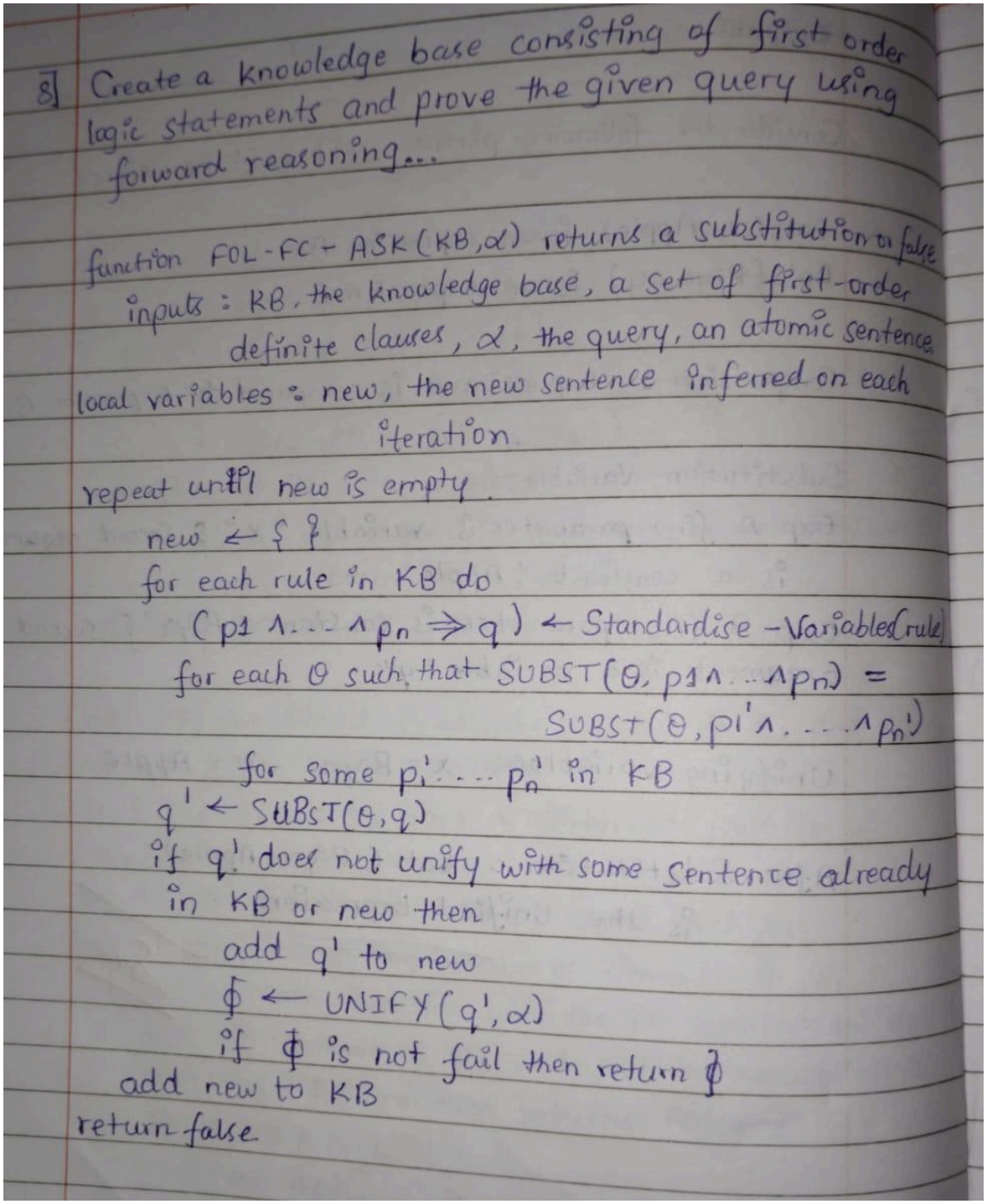
Unifying variables : x = Riya y = Apple.

After Substitution : Eats (Riya , Apple)
is the Unified Expression.

Program 8:

Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.

Algorithm/Pseudo Code:



8] Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning...

function FOL-FC-ASK(KB, α) returns a substitution or false
  inputs : KB, the knowledge base, a set of first-order definite clauses, α, the query, an atomic sentence
local variables : new, the new sentence inferred on each iteration
repeat until new is empty
  new $\leftarrow$ { }
  for each rule in KB do
    $(p_1 \wedge \ldots \wedge p_n \Rightarrow q) \leftarrow$ Standardise-Variables(rule)
    for each θ such that SUBST($\theta, p_1 \wedge \ldots \wedge p_n$) = SUBST($\theta, p_1' \wedge \ldots \wedge p_n'$)
      for some $p_1' \ldots p_n'$ in KB
    $q' \leftarrow$ SUBST(θ, q)
    if q' does not unify with some sentence already in KB or new then
      add q' to new
      $\phi \leftarrow$ UNIFY(q', α)
      if ϕ is not fail then return ϕ
  add new to KB
return false

→ KB = [
"American (Robert)"
"Enemy (A, America)",
"Missile (T1),
"Owns (A, T1)",
"Missile(x) ⇒ Weapon(x)"
"Weapon(x) ∧ Sells (Robert, x, A) ∧ Hostile(A) ⇒ Criminal (Robert)"
"Enemy (x, America) ⇒ Hostile(x)",
"Sells (Robert, T1, A)",
]

query = "Criminal (Robert)"

⇒ The query 'Criminal (Robert)' can be proved.

- Missile(x) ⇒ Weapon(x).
  Substitute x = T1 Inference: Weapon(T1)

- Enemy (x, America) ⇒ Hostile(x).
  Fact in KB: Enemy (A, America).
  Substitute x = A. Inference: Hostile(A)

- Weapon(x) ∧ Sells(p, x, r) ∧ Hostile(r) ⇒ Criminal(p).
  Substitute x = T1, p = Robert, r = A
  Weapon (T1), Sells (Robert, T1, A), Hostile(A)
  Inference: Criminal (Robert).

9) Every Surgeon has a lawyer.
∀p (Occupation(p, Surgeon) → ∃l (Occupation(l, lawyer) ∧ Customer(p, l))

Code:

```
def unify(x, y, subst=None):
    if subst is None:
        subst = {}
    # Step 1: If x and y are the same, return the current substitutions
    if x == y:
        return subst
    # If x is a variable
    if is_variable(x):
        return unify_var(x, y, subst)
    # If y is a variable
    if is_variable(y):
        return unify_var(y, x, subst)
    # If x and y are compound expressions
    if is_compound(x) and is_compound(y):
        if get_predicate(x) != get_predicate(y):
            return "FAILURE"
        return unify(get_args(x), get_args(y), subst)

    # If x and y are lists
    if isinstance(x, list) and isinstance(y, list):
        if len(x) != len(y):
            return "FAILURE"
        if not x and not y:
            return subst
        return unify(x[1:], y[1:], unify(x[0], y[0], subst))

    # If x and y are constants or cannot be unified
    return "FAILURE"

def unify_var(var, x, subst):
    if var in subst:
        return unify(subst[var], x, subst)
    if x in subst:
        return unify(var, subst[x], subst)
    if occurs_check(var, x):
        return "FAILURE"
    subst[var] = x
    return subst

def occurs_check(var, x):
    if var == x:
        return True
    if isinstance(x, list):
        return any(occurs_check(var, arg) for arg in x)
    return False

def is_variable(x):
    return isinstance(x, str) and x.islower()  # Variables are lowercase strings
```

```
def is_compound(x):
    return isinstance(x, str) and '(' in x and ')' in x

def get_predicate(x):
    return x.split('(')[0]

def get_args(x):
    return x[x.index('(') + 1:x.index(')')].split(',')

# Test cases
x1 = "f(x, y)"
x2 = "f(a, b)"
print(unify(x1, x2))  # Expected: {'x': 'a', 'y': 'b'}

x3 = "p(x, g(y))"
x4 = "p(f(a), g(b))"
print(unify(x3, x4))  # Expected: {'x': 'f(a)', 'y': 'b'}

expression_a = "Eats(x, Apple)"
expression_b = "Eats(Riya, y)"

substitution = unify(expression_a, expression_b)

# Print the result
if substitution == "FAILURE":
    print("Unification failed.")
else:
    print("Unification successful:")
    print(substitution)
# Define the Knowledge Base (KB)
kb = []
# Facts
kb.append(("fact", "American", ["Robert"]))
kb.append(("fact", "Enemy", ["A", "America"]))
kb.append(("fact", "Missile", ["T1"]))
# Rules
kb.append(("rule", ["Missile(x)"], "Weapon(x)"))  # All missiles are weapons
kb.append(("rule", ["Weapon(x)", "Sells(Robert, x, A)", "Hostile(A)"], "Criminal(Robert)"))  #
Selling weapons to hostiles implies criminality
kb.append(("rule", ["Enemy(x, America)"], "Hostile(x)"))  # Enemies of America are hostile
kb.append(("fact", "Sells", ["Robert", "T1", "A"]))  # Robert sells T1 to A

# Forward Reasoning Function
def forward_reasoning(kb, query):
    inferred = set()  # Already inferred facts
    while True:
        new_inferred = set()
        for entry in kb:
            if entry[0] == "fact":
```

```
            # Add atomic facts to inferred
            fact_name = entry[1]
            fact_args = tuple(entry[2])
            new_inferred.add((fact_name, fact_args))

        elif entry[0] == "rule":
            # Check if the rule's premise is satisfied
            premises = entry[1]
            conclusion = entry[2]

            # Evaluate premises
            premises_satisfied = True
            substitutions = {}
            for premise in premises:
                satisfied = False
                for fact in inferred:
                    fact_name, fact_args = fact
                    if match(premise, fact_name, fact_args, substitutions):
                        satisfied = True
                        break
                if not satisfied:
                    premises_satisfied = False
                    break

            # If all premises are satisfied, infer the conclusion
            if premises_satisfied:
                conclusion_name, conclusion_args = parse_predicate(conclusion)
                conclusion_args = [
                    substitutions.get(arg, arg) for arg in conclusion_args
                ]
                new_inferred.add((conclusion_name, tuple(conclusion_args)))

        # If no new facts are inferred, stop
        if not new_inferred.difference(inferred):
            break
        inferred.update(new_inferred)

        # Check if the query is inferred
        query_name, query_args = parse_predicate(query)
        if (query_name, tuple(query_args)) in inferred:
            return True

    return False

# Helper functions for matching and parsing
def match(premise, fact_name, fact_args, substitutions):
    premise_name, premise_args = parse_predicate(premise)
    if premise_name != fact_name or len(premise_args) != len(fact_args):
        return False
    for p_arg, f_arg in zip(premise_args, fact_args):
```

```
        if p_arg.islower():  # Variable
            substitutions[p_arg] = f_arg
        elif p_arg != f_arg:  # Constant mismatch
            return False
    return True

def parse_predicate(predicate):
    name, args = predicate.split("(")
    args = args[:-1].split(",")  # Remove closing ")"
    return name, args

# Query
query = "Criminal(Robert)"

# Check if the query can be proved
if forward_reasoning(kb, query):
    print(f"The query {query} can be proved.")
else:
    print(f"The query {query} cannot be proved.")
```

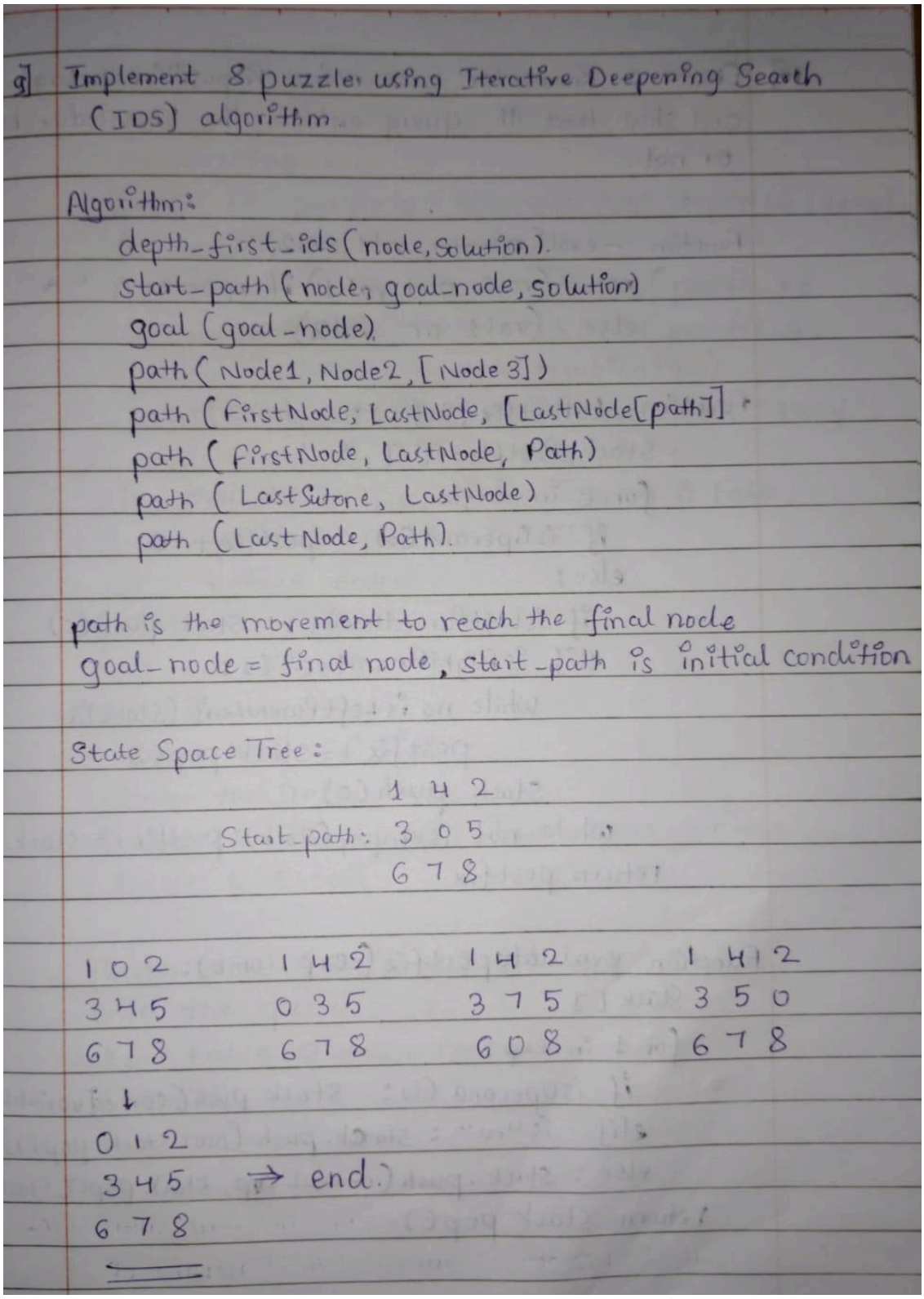
Output:

```
The query Criminal(Robert) cannot be proved.
```

Program 9:

Implement Iterative deepening search algorithm.

Algorithm/Pseudo Code:



9] Implement 8 puzzle using Iterative Deepening Search (IDS) algorithm

Algorithm:

depth_first_ids(node, Solution).
start_path (node, goal_node, solution)
goal (goal_node).
path (Node1, Node2, [Node 3])
path (FirstNode, LastNode, [LastNode[path]]
path (FirstNode, LastNode, Path)
path (LastSutone, LastNode)
path (LastNode, Path).

path is the movement to reach the final node
goal_node = final node, start_path is initial condition

State Space Tree:

1 4 2
Start_path: 3 0 5
6 7 8

1 0 2	1 4 2	1 4 2	1 4 2
3 4 5	0 3 5	3 7 5	3 5 0
6 7 8	6 7 8	6 0 8	6 7 8
↓			
0 1 2			
3 4 5 ⇒ end.			
6 7 8			

Code:

```
from collections import deque
def is_valid_position(x, y):
    return 0 <= x < 3 and 0 <= y < 3
def iterative_deepening_search(initial_state, goal_state):
    def dfs_limited(state, depth):
        if state == goal_state:
            return []
        if depth == 0:
            return None
        empty_x, empty_y = [(x, y) for x in range(3) for y in range(3) if state[x][y] == 0][0]
        moves = [(-1, 0), (1, 0), (0, -1), (0, 1)]
        for dx, dy in moves:
            new_x, new_y = empty_x + dx, empty_y + dy

            if is_valid_position(new_x, new_y):
                new_state = [list(row) for row in state]
                new_state[empty_x][empty_y], new_state[new_x][new_y] = new_state[new_x][new_y],
new_state[empty_x][empty_y]
                new_state = tuple(tuple(row) for row in new_state)
                result = dfs_limited(new_state, depth - 1)
                if result is not None:
                    return [(new_state, (new_x, new_y))] + result
        return None

    depth = 0
    initial_state = tuple(tuple(row) for row in initial_state)
    goal_state = tuple(tuple(row) for row in goal_state)
    while True:
        result = dfs_limited(initial_state, depth)
        if result is not None:
            return result
        depth += 1
# Example usage
def print_state(state):
    for row in state:
        print(" ".join(map(str, row)))
    print()

initial_state = [
    [1, 2, 3],
    [4, 0, 5],
    [6, 7, 8]
]
goal_state = [
    [1, 2, 3],
    [4, 5, 6],
    [7, 8, 0]
]
```

```
solution = iterative_deepening_search(initial_state, goal_state)
if solution:
    print("Solution found!")
    current_state = tuple(tuple(row) for row in initial_state)
    print("Initial State:")
    print_state(current_state)

    for new_state, move in solution:
        print(f"Move empty tile to position {move}:")
        print_state(new_state)
else:
    print("No solution exists.")
```

Output:

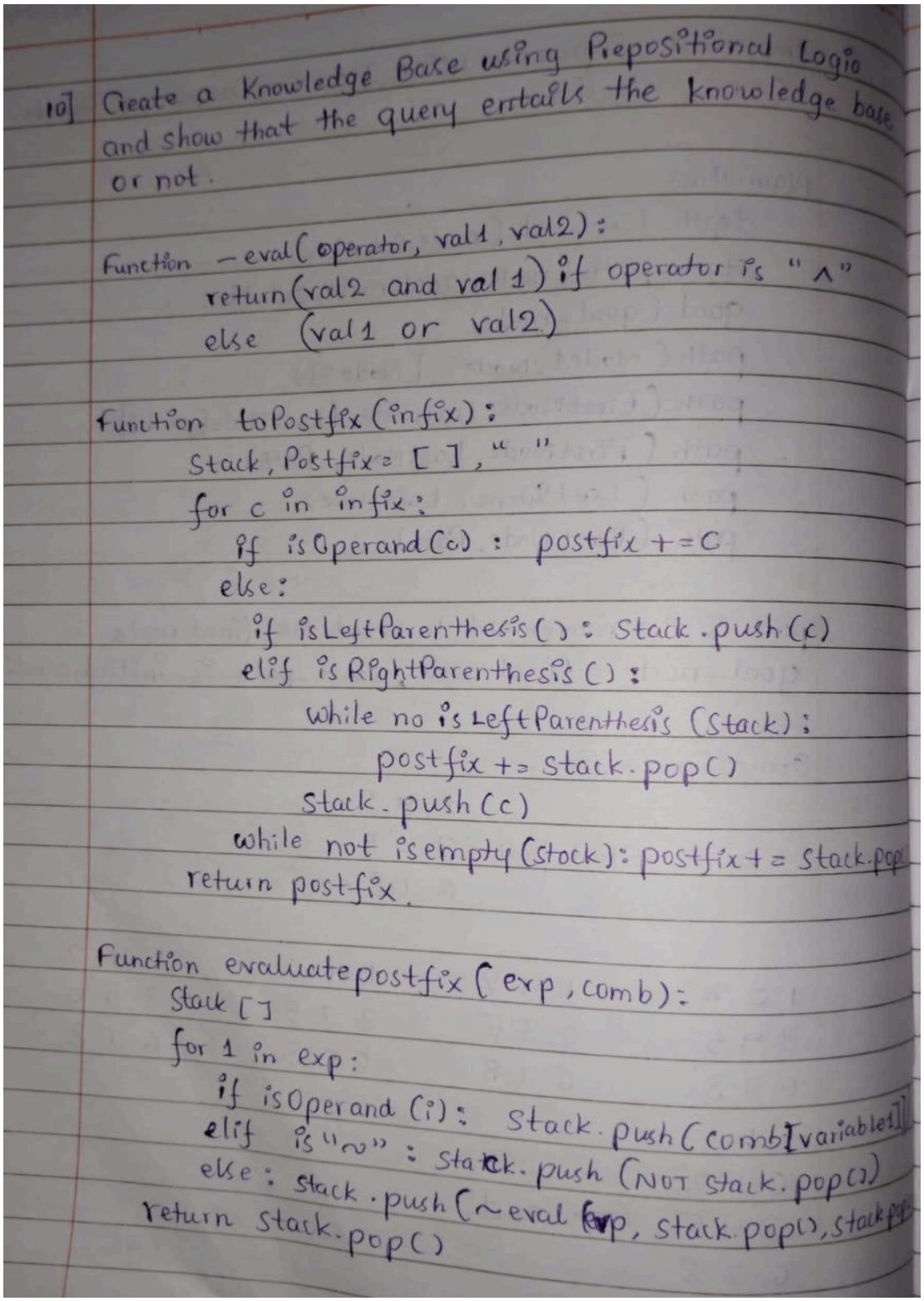
```
Solution found!
Initial State:
1 2 3
4 0 5
6 7 8

Move empty tile to position (1, 2):
1 2 3
4 5 0
6 7 8

Move empty tile to position (2, 2):
1 2 3
4 5 8
6 7 0

Move empty tile to position (2, 1):
1 2 3
4 5 8
6 0 7

Move empty tile to position (2, 0):
1 2 3
4 5 8
0 6 7

Move empty tile to position (1, 0):
1 2 3
0 5 8
4 6 7
```

```
Move empty tile to position (2, 2):
1 2 3
5 6 8
4 7 0

Move empty tile to position (1, 2):
1 2 3
5 6 0
4 7 8

Move empty tile to position (1, 1):
1 2 3
5 0 6
4 7 8

Move empty tile to position (1, 0):
1 2 3
0 5 6
4 7 8

Move empty tile to position (2, 0):
1 2 3
4 5 6
0 7 8

Move empty tile to position (2, 1):
1 2 3
4 5 6
7 0 8

Move empty tile to position (2, 2):
1 2 3
4 5 6
7 8 0
```

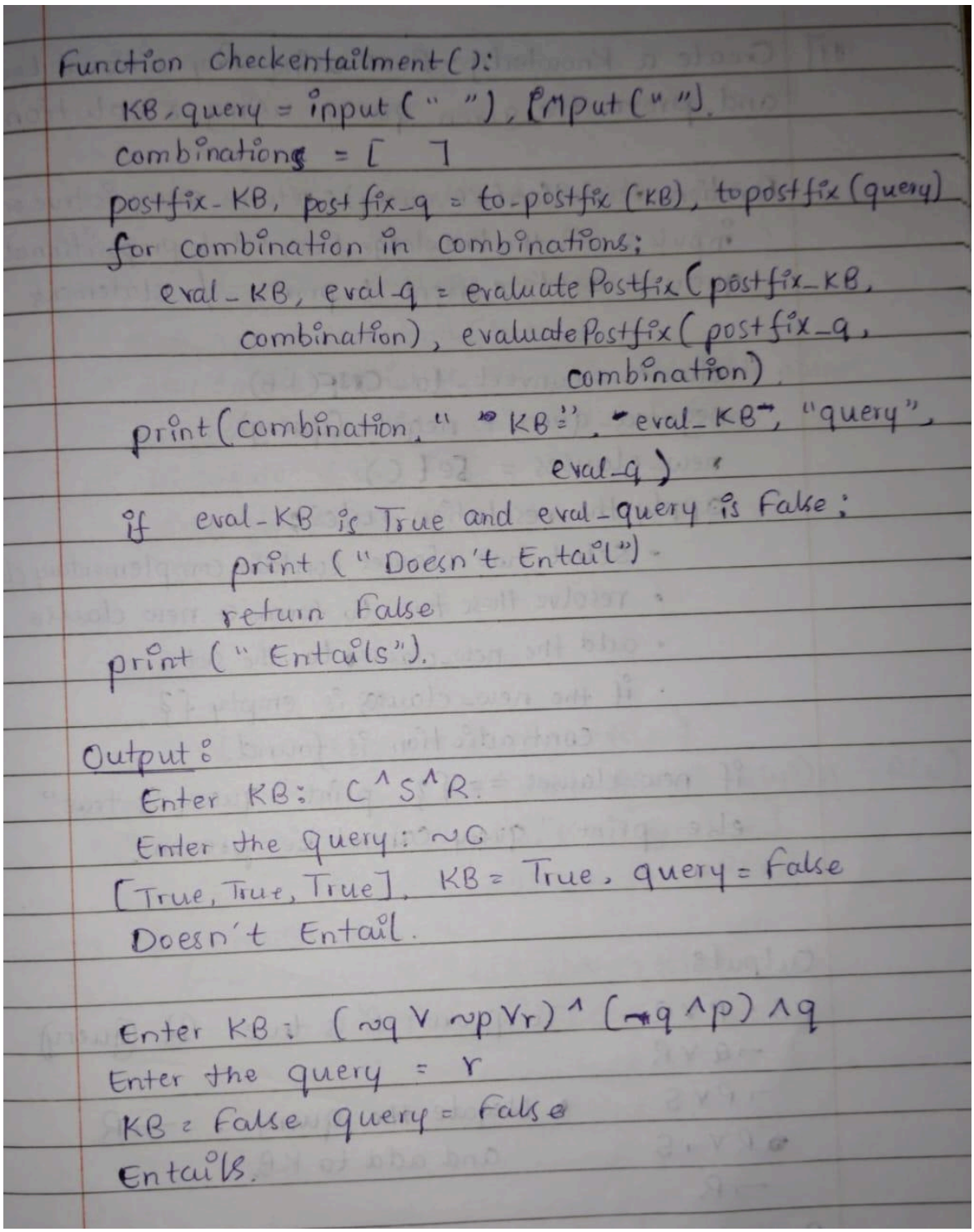
Program 10:

Create a knowledge base using propositional logic and show that the given query entails the knowledge base or not.

Algorithm/Pseudo Code:



```
10] Create a Knowledge Base using Propositional Logic
and show that the query entails the knowledge base
or not.

Function - eval(operator, val1, val2):
    return(val2 and val1) if operator is "^"
    else (val1 or val2)

Function toPostfix(infix):
    Stack, Postfix = [ ], " "
    for c in infix:
      if isOperand(c) : postfix += c
      else:
        if isLeftParenthesis() : Stack.push(c)
        elif isRightParenthesis():
            while no isLeftParenthesis(Stack):
                postfix += stack.pop()
            Stack.push(c)
      while not isempty(stock): postfix += stack.pop
    return postfix.

Function evaluatepostfix(exp, comb):
    Stack [ ]
    for i in exp:
      if isOperand(i): Stack.push(comb[variable1]
      elif is "~" : stack.push(NOT stack.pop())
      else: stack.push(~eval(exp, stack.pop(), stack.pop
    return stack.pop()
```



Code:

```
class KnowledgeBase:
    def __init__(self):
        self.facts = set()
        self.rules = []
```

```
 def add_fact(self, fact):
        self.facts.add(fact)

    def add_rule(self, rule):
        self.rules.append(rule)
    def entails(self, query):
        inferred = set()
        new_facts = True
        while new_facts:
            new_facts = False
            for rule in self.rules:
                for fact in self.facts:
                    inferred_fact = rule(fact, self.facts)
                    if inferred_fact and inferred_fact not in self.facts and inferred_fact not in inferred:
                        inferred.add(inferred_fact)
                        new_facts = True
        return query in inferred

# Define propositional logic rules
def rule_crime_law(fact, facts):
    if fact == "American(Robert)" and "Sells(Robert, Weapons, CountryA)" in facts and
"Hostile(CountryA)" in facts:
        return "Criminal(Robert)"
    return None
# Initialize the knowledge base
kb = KnowledgeBase()
# Add facts to the knowledge base
kb.add_fact("American(Robert)")
kb.add_fact("Sells(Robert, Weapons, CountryA)")
kb.add_fact("Hostile(CountryA)")
# Add rules to the knowledge base
kb.add_rule(rule_crime_law)
# Define the query
query = "Criminal(Robert)"
# Check if the query is entailed
if kb.entails(query):
    print(f"The query '{query}' is entailed by the knowledge base.")
else:
    print(f"The query '{query}' is NOT entailed by the knowledge base.")
```

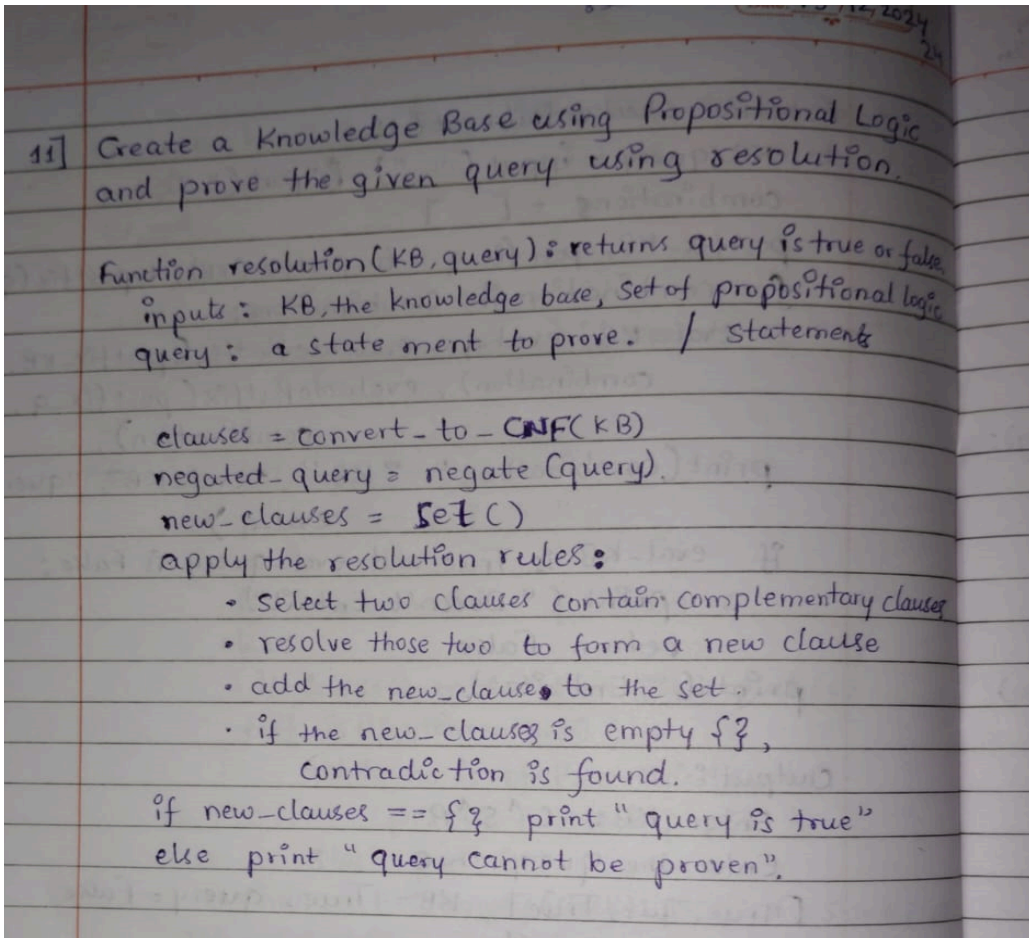
Output:

```
The query 'Criminal(Robert)' is entailed by the knowledge base.
```

Program 11:

Create a knowledge base using propositional logic and prove the given query using resolution.

Algorithm/Pseudo Code:



Code:

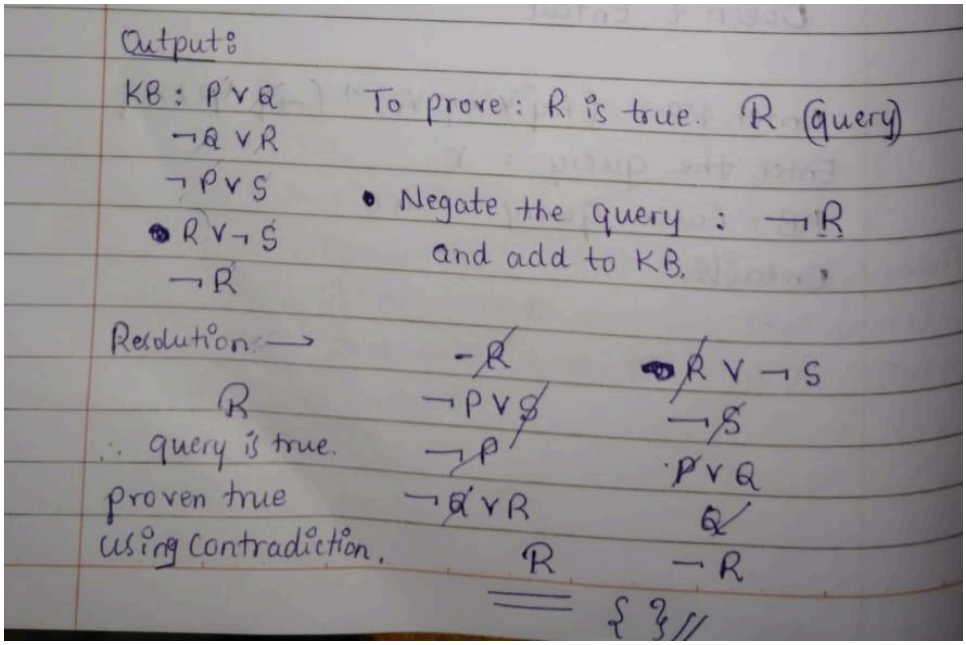
```
class KnowledgeBase:
    def __init__(self):
        self.facts = set()
        self.rules = []

    def add_fact(self, fact):
        self.facts.add(fact)

    def add_rule(self, rule):
        self.rules.append(rule)

    def entails(self, query):
        inferred = set()
```

```
        new_facts = True

        while new_facts:
            new_facts = False
            for rule in self.rules:
                for fact in self.facts:
                    inferred_fact = rule(fact, self.facts)
                    if inferred_fact and inferred_fact not in self.facts and inferred_fact not in inferred:
                        inferred.add(inferred_fact)
                        new_facts = True

        return query in inferred

# Define propositional logic rules
def rule_crime_law(fact, facts):
    if fact == "American(Robert)" and "Sells(Robert, Weapons, CountryA)" in facts and
"Hostile(CountryA)" in facts:
        return "Criminal(Robert)"
    return None
# Initialize the knowledge base
kb = KnowledgeBase()
# Add facts to the knowledge base
kb.add_fact("American(Robert)")
kb.add_fact("Sells(Robert, Weapons, CountryA)")
kb.add_fact("Hostile(CountryA)")

# Add rules to the knowledge base
kb.add_rule(rule_crime_law)

# Define the query
query = "Criminal(Robert)"

# Check if the query is entailed
if kb.entails(query):
    print(f"The query '{query}' is entailed by the knowledge base.")
else:
    print(f"The query '{query}' is NOT entailed by the knowledge base.")def parse_clause(clause):
    """
    Parse a clause string into a set of literals.
    """
    return set(clause.split(" ∨ "))

def resolve(clause1, clause2):
    """
    Resolve two clauses if they contain complementary literals.
    Returns a new clause or None if they cannot be resolved.
    """
    for literal in clause1:
        if literal.startswith("¬") and literal[1:] in clause2:
            new_clause = (clause1 - {literal}) | (clause2 - {literal[1:]})
```

```
            return new_clause
        elif not literal.startswith("¬") and f"¬{literal}" in clause2:
            new_clause = (clause1 - {literal}) | (clause2 - {f"¬{literal}"})
            return new_clause
    return None


def resolution(kb, query):
    """
    Perform resolution to prove if the query is true or not.
    :param kb: List of clauses in the knowledge base (each clause is a set of literals).
    :param query: The query to prove (string).
    :return: True if the query is proven, False otherwise.
    """
    # Step 1: Convert KB and query to CNF
    clauses = [parse_clause(clause) for clause in kb]
    negated_query = {f"¬{query}"}
    clauses.append(negated_query)

    # Step 2: Apply resolution rules
    new_clauses = set()
    while True:
        n = len(clauses)
        for i in range(n):
            for j in range(i + 1, n):
                resolvent = resolve(clauses[i], clauses[j])
                if resolvent is not None:
                    if not resolvent:  # Empty clause found
                        return True
                    new_clauses.add(frozenset(resolvent))

        # Check if new clauses are added
        if not new_clauses.difference(set(map(frozenset, clauses))):
            break
        clauses.extend(map(set, new_clauses))

    return False


if __name__ == "__main__":
    # Example Knowledge Base (KB)
    kb = [
        "P ∨ Q",
        "¬Q ∨ R",
        "¬P ∨ S",
        "R ∨ ¬S"
    ]
    query = "R"
```

```
# Prove the query
    if resolution(kb, query):
        print("Query is true.")
    else:
        print("Query cannot be proven.")
```

Output:

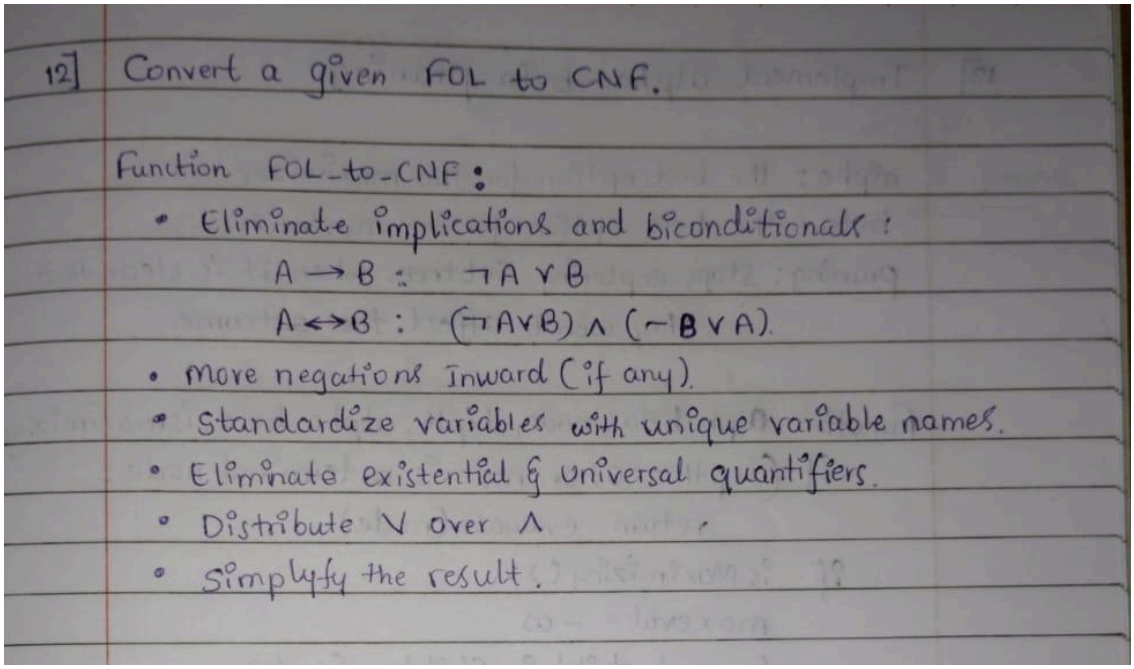



```
Query is true.
```

Program 12:

Convert a given first order logic statement into Conjunctive Normal Form (CNF).

Algorithm/Pseudo Code:

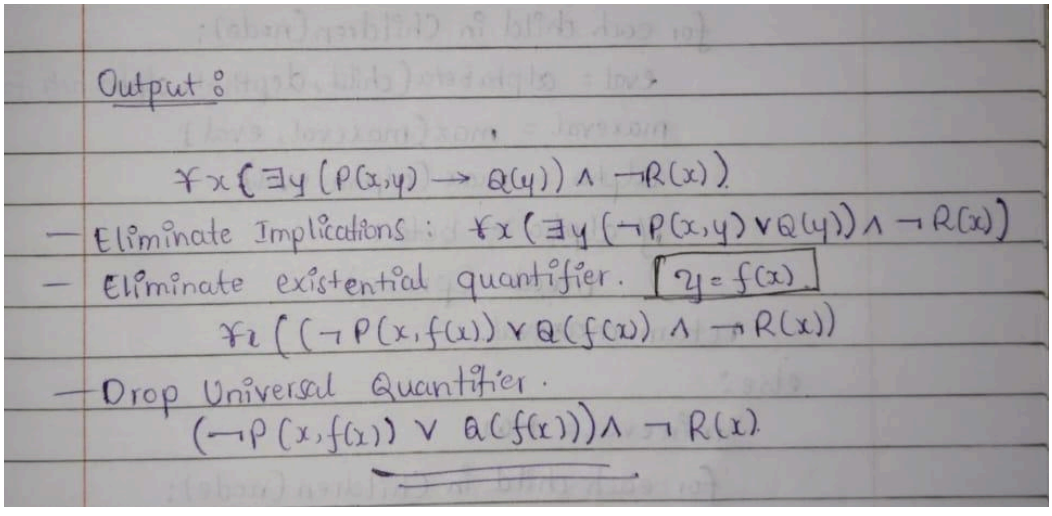


Code:

```
from sympy.logic.boolalg import Or, And, Not, Implies
from sympy import symbols, Function, Predicate, AppliedPredicate

# Define symbols and Skolem functions
x, y = symbols("x y")  # Variables
f = Function("f")      # Skolem function
# Define predicates
P = Predicate("P", x)
Q = Predicate("Q", x)
A = Predicate("A", x)
R = Predicate("R", x)
# Helper function to eliminate implications
def eliminate_implications(formula):
    """Eliminate implications (A → B ≡ ¬A ∨ B)."""
    return formula.replace(
        lambda x: isinstance(x, Implies),
        lambda x: Or(Not(x.args[0]), x.args[1])
    )
# Helper function to replace existential quantifiers with Skolem functions
def eliminate_existential_quantifier(formula):
    """Replace existential quantifier ∃ with Skolem functions."""
    # Assume y is existentially quantified and replace it with f(x) (Skolemization)
    return formula.subs(y, f(x))
```

```
# Helper function to drop universal quantifiers
def drop_universal_quantifiers(formula):
    """Drop universal quantifiers, as they are implied in CNF."""
    # Universal quantifiers are implicit in CNF
    return formula
# Main function to convert FOL to CNF
def fol_to_cnf(formula):
    """Convert a First-Order Logic formula to Conjunctive Normal Form (CNF)."""
    # Step 1: Eliminate implications
    formula = eliminate_implications(formula)
    # Step 2: Eliminate existential quantifier (Skolemization)
    formula = eliminate_existential_quantifier(formula)
    # Step 3: Drop universal quantifiers
    formula = drop_universal_quantifiers(formula)
    # Step 4: Distribute OR over AND manually for this example
    cnf = And(
        Or(Not(AppliedPredicate(P, x, f(x))), AppliedPredicate(Q, f(x))),  # First clause
        Or(Not(AppliedPredicate(A, x)), Not(AppliedPredicate(R, x)))      # Second clause
    )
    return cnf

# Original FOL formula
# ∀x (∃y (P(x, y) → Q(y)) ∧ (A(x) → ¬R(x)))
fol_formula = And(
    Implies(AppliedPredicate(P, x, y), AppliedPredicate(Q, y)),  # First implication
    Implies(AppliedPredicate(A, x), Not(AppliedPredicate(R, x)))  # Second implication
)
# Convert to CNF
cnf_formula = fol_to_cnf(fol_formula)
# Output the CNF formula
print("CNF Formula:", cnf_formula)
```

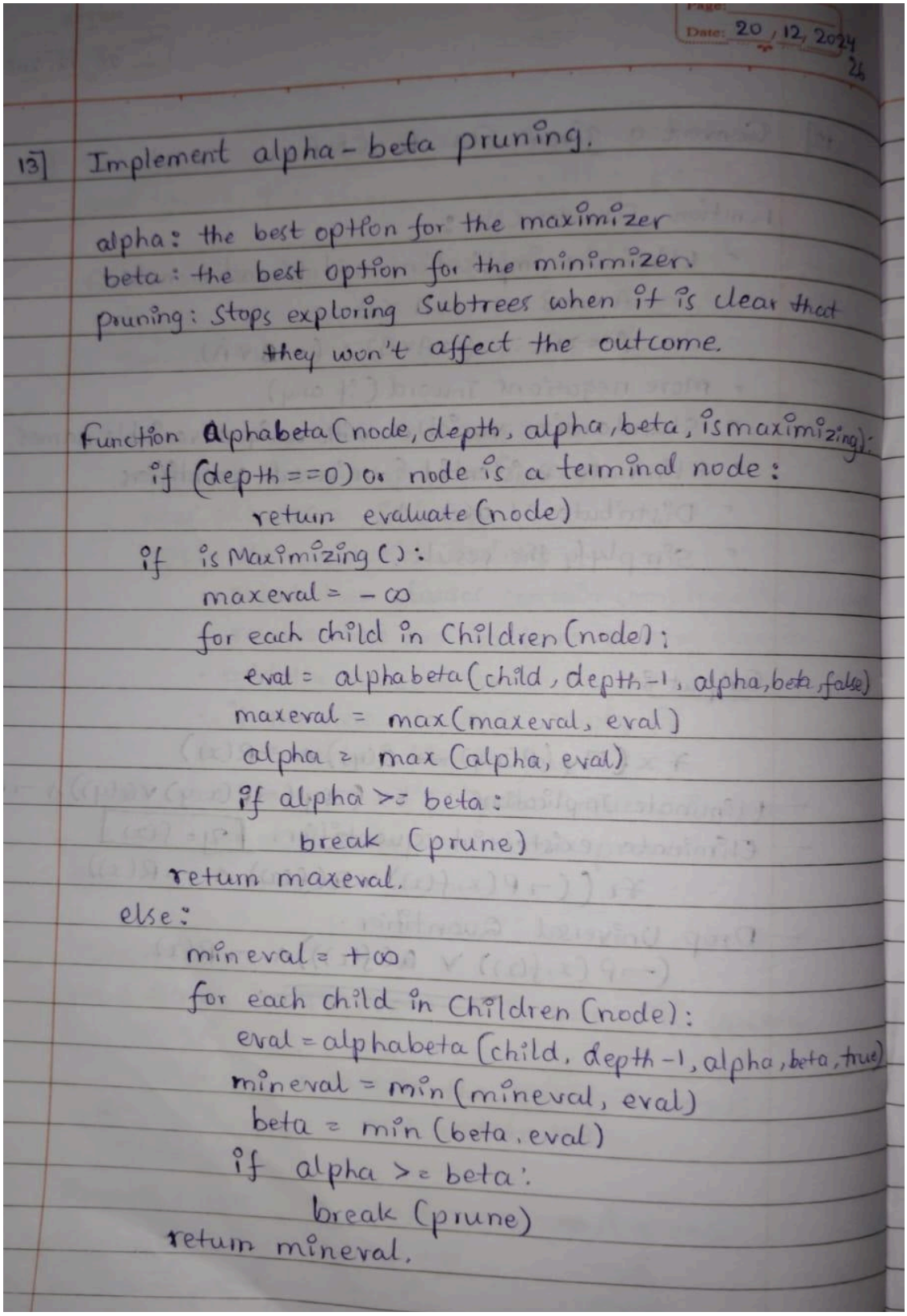
Output:



Program 13:

Implement Alpha-Beta Pruning.

Algorithm/Pseudo Code:



13] Implement alpha-beta pruning.

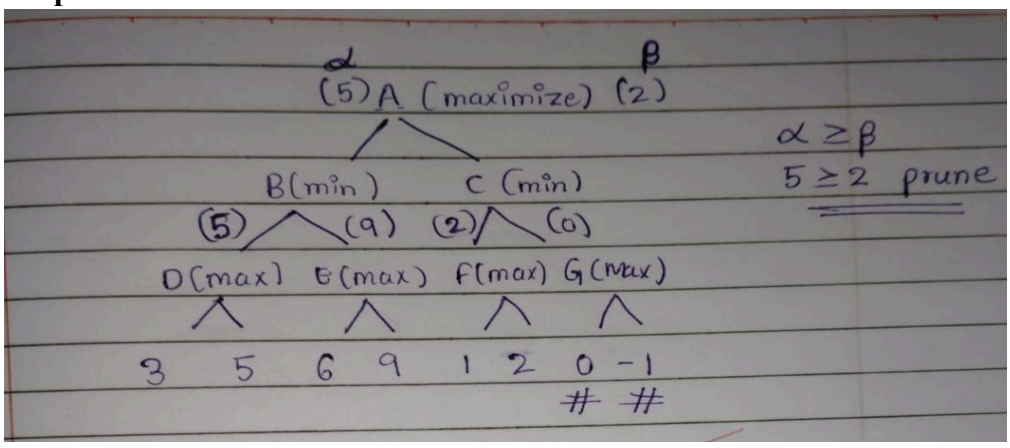
alpha: the best option for the maximizer
beta: the best option for the minimizer.
pruning: Stops exploring subtrees when it is clear that they won't affect the outcome.

```
Function alphabeta(node, depth, alpha, beta, ismaximizing):
    if (depth==0) or node is a terminal node:
        return evaluate(node)
    if isMaximizing():
        maxeval = -∞
        for each child in Children(node):
            eval = alphabeta(child, depth-1, alpha, beta, false)
            maxeval = max(maxeval, eval)
            alpha = max(alpha, eval)
            if alpha >= beta:
                break (prune)
        return maxeval.
    else:
        mineval = +∞
        for each child in Children(node):
            eval = alphabeta(child, depth-1, alpha, beta, true)
            mineval = min(mineval, eval)
            beta = min(beta, eval)
            if alpha >= beta:
                break (prune)
        return mineval.
```

Code:

```
# Alpha-Beta Pruning Implementation
def alpha_beta_pruning(depth, node_index, maximizing_player, values, alpha, beta):
    # Base case: Leaf node
    if depth == 3:  # Assuming depth of 3 for the provided tree
        return values[node_index]
    if maximizing_player:
        max_eval = float('-inf')
        for i in range(2):  # Each node has 2 children
            eval_value = alpha_beta_pruning(depth + 1, node_index * 2 + i, False, values, alpha, beta)
            max_eval = max(max_eval, eval_value)
            alpha = max(alpha, eval_value)
            # Prune the branch
            if beta <= alpha:
                break
        return max_eval
    else:
        min_eval = float('inf')
        for i in range(2):  # Each node has 2 children
            eval_value = alpha_beta_pruning(depth + 1, node_index * 2 + i, True, values, alpha, beta)
            min_eval = min(min_eval, eval_value)
            beta = min(beta, eval_value)
            # Prune the branch
            if beta <= alpha:
                break
        return min_eval
# Example Usage
if __name__ == "__main__":
    # Values at the leaf nodes of the game tree
    values = [3, 5, 6, 9, 1, 2, 0, -1]
    alpha = float('-inf')
    beta = float('inf')
    result = alpha_beta_pruning(0, 0, True, values, alpha, beta)
    print("The optimal value is:", result)
```

Output:




```
The optimal value is: 5
```