# VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

**LAB REPORT**
**on**

# Artificial Intelligence (23CS5PCAIN)

***Submitted by***

**Sanketh M Hanasi (1BM22CS242)**

***in partial fulfillment for the award of the degree of***
**BACHELOR OF ENGINEERING**
***in***
**COMPUTER SCIENCE AND ENGINEERING**

**B.M.S. COLLEGE OF ENGINEERING**
**(Autonomous Institution under VTU)**
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**B.M.S. College of Engineering,**
**Bull Temple Road, Bangalore 560019**
(Affiliated To Visvesvaraya Technological University, Belgaum)
**Department of Computer Science and Engineering**

## CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Sanketh M Hanasi (1BM22CS242),** who is 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 in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

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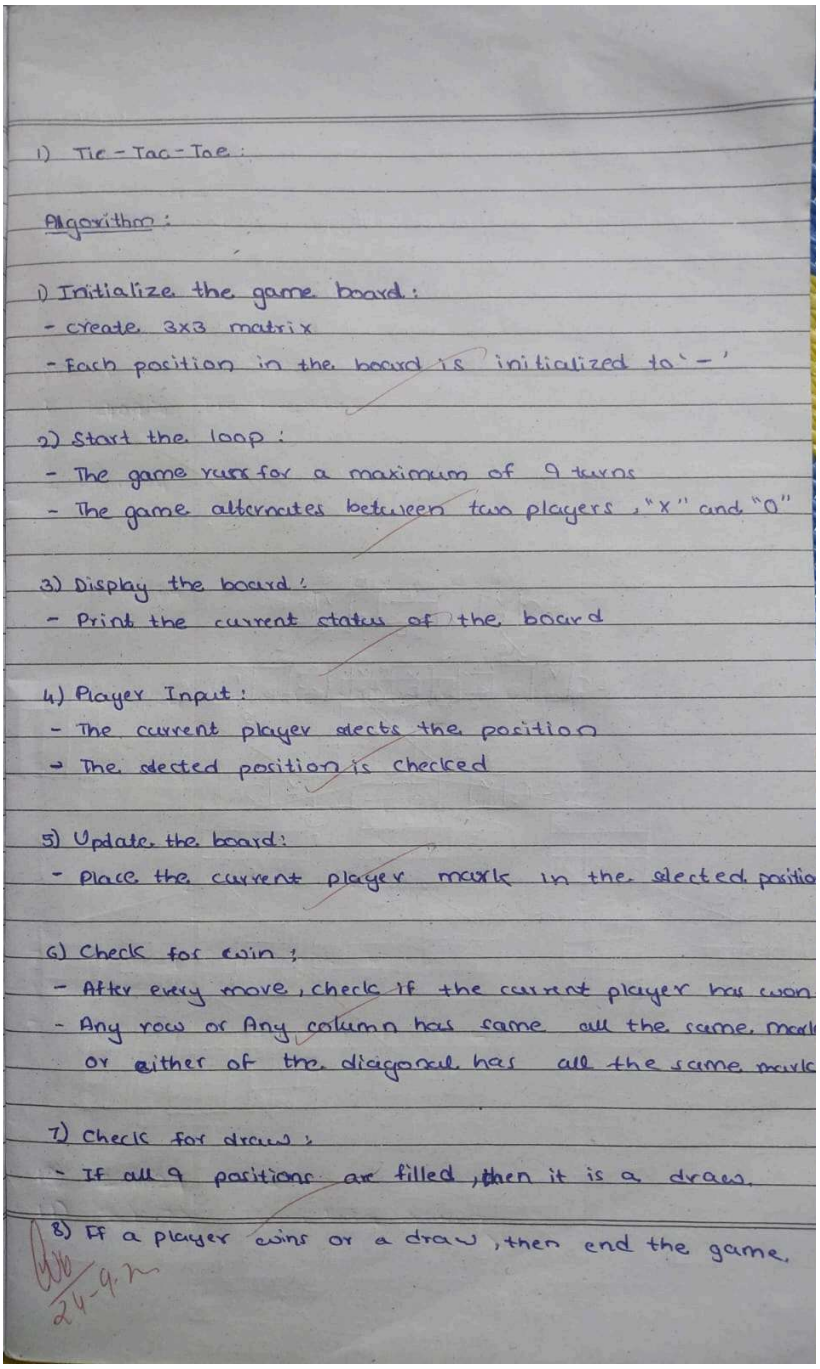
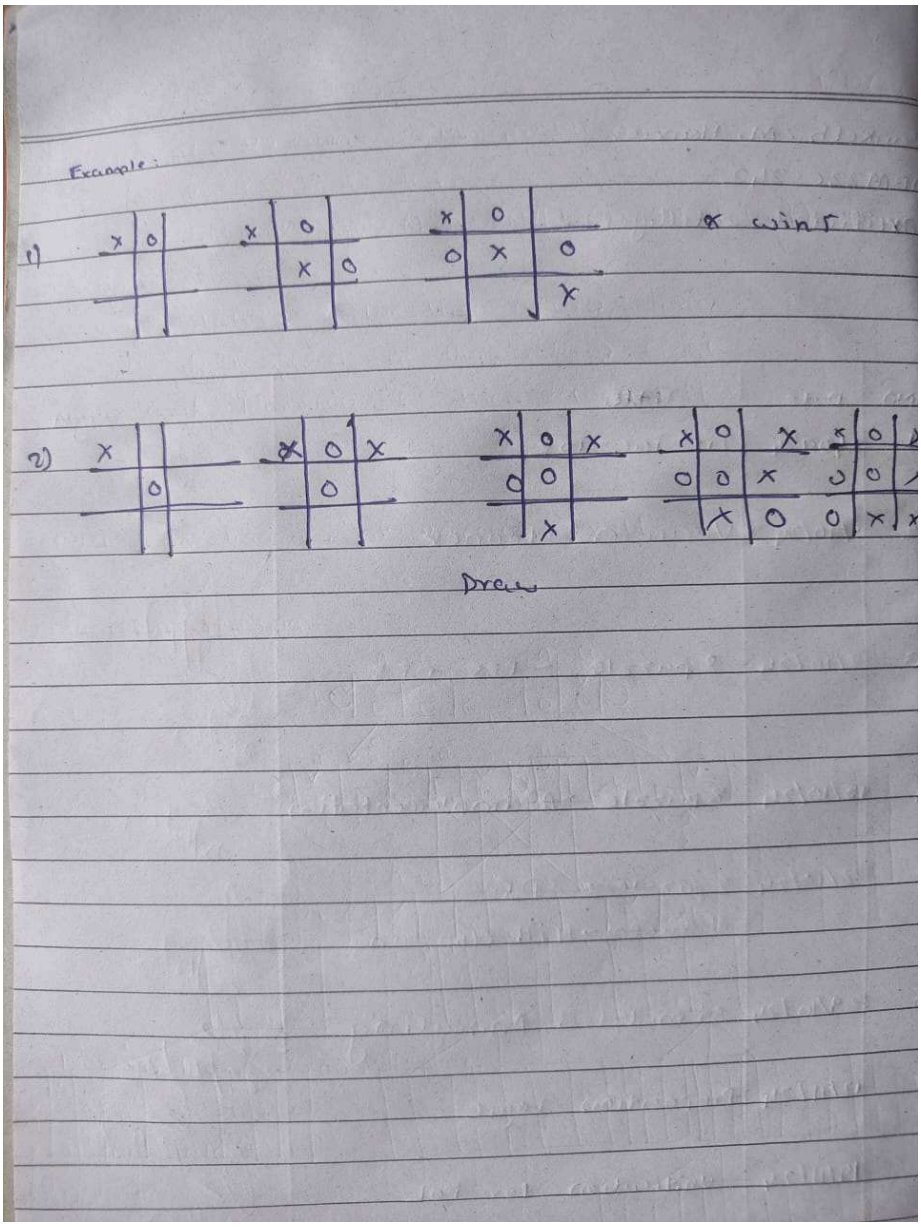
Github Link:
https://github.com/SankethHanasi/AI/tree/main

**Program 1**
Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

Algorithm:




Example:
1)
X win
2)
Draw

1/10/24

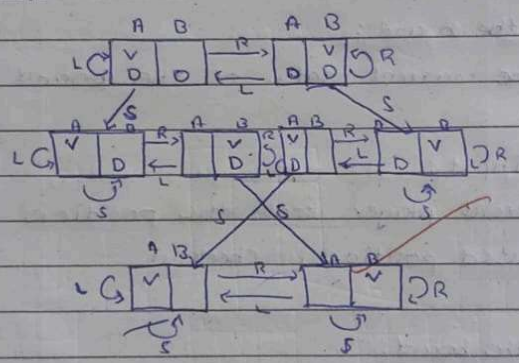
2) Implement vaccum world problem

function REFLEX-VACCUM-AGENT([LOCATION, status]) returns an action

if status = Dirty then return Suck
else if location = A then return Right
else if location = B then return Left

state space diagram of vaccum world

function simple




Problem formulation steps :

States

Initial state

Actions

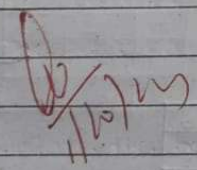
Transition model

Goal test

Path cost

Algorithm:

1) Initialize room and cost
2) Check the room are clean or not
   If room is dirty clean the room and move to the next location.
3) Next checks whether previously cleaned is room is dirty if dirty clean.
4) If both the rooms are clean then return the total cost and off the vacuum cleaner.



Code: 1: Tic - Tac - Toe

```
import numpy as np
board=np.array([['-','-','-'],['-','-','-'],['-','-','-']])
current_player='X'
flag=0

def check_win():
    for i in range(3):
        if board[i][0] == board[i][1] == board[i][2] != '-':
            return True
    for i in range(3):
        if board[0][i] == board[1][i] == board[2][i] != '-':
            return True
    if board[0][0] == board[1][1] == board[2][2] != '-':
        return True
    if board[0][2] == board[1][1] == board[2][0] != '-':
        return True
    return False

def tic_tac_toe():
    n=0
    print(board)
    while n<9:
        if n%2==0:
            current_player='X'
        else :
            current_player='O'
        row = int(input("Enter row: "))
        col = int(input("Enter column: "))

        if(board[row][col]=='-'):
            board[row][col]=current_player
            print(board)
            flag=check_win();
            if flag==1:
                print(current_player+' wins')
                break
            else:
                n=n+1
        else :
            print("Invalid Position")

    if n==9:
        print("Draw")

tic_tac_toe()
```

Output:

```
[['-' '-' '-']
 ['-' '-' '-']
 ['-' '-' '-']]
Enter row: 1
Enter column: 1
[['-' '-' '-']
 ['-' 'X' '-']
 ['-' '-' '-']]
Enter row: 0
Enter column: 1
[['-' 'O' '-']
 ['-' 'X' '-']
 ['-' '-' '-']]
Enter row: 2
Enter column: 1
[['-' 'O' '-']
 ['-' 'X' '-']
 ['-' 'X' '-']]
Enter row: 0
Enter column: 0
[['O' 'O' '-']
 ['-' 'X' '-']
 ['-' 'X' '-']]
Enter row: 0
Enter column: 2
[['O' 'O' 'X']
 ['-' 'X' '-']
 ['-' 'X' '-']]
Enter row: 2
Enter column: 0
[['O' 'O' 'X']
 ['-' 'X' '-']
 ['O' 'X' '-']]
Enter row: 1
Enter column: 0
[['O' 'O' 'X']
 ['X' 'X' '-']
 ['O' 'X' '-']]
Enter row: 1
Enter column: 2
[['O' 'O' 'X']
 ['X' 'X' 'O']
 ['O' 'X' '-']]
Enter row: 2
Enter column: 2
[['O' 'O' 'X']
 ['X' 'X' 'O']
 ['O' 'X' 'X']]
Draw
```

```
[['-' '-' '-']
 ['-' '-' '-']
 ['-' '-' '-']]
Enter row: 0
Enter column: 1
[['-' 'X' '-']
 ['-' '-' '-']
 ['-' '-' '-']]
Enter row: 0
Enter column: 0
[['O' 'X' '-']
 ['-' '-' '-']
 ['-' '-' '-']]
Enter row: 1
Enter column: 0
[['O' 'X' '-']
 ['X' '-' '-']
 ['-' '-' '-']]
Enter row: 1
Enter column: 1
[['O' 'X' '-']
 ['X' 'O' '-']
 ['-' '-' '-']]
Enter row: 1
Enter column: 2
[['O' 'X' '-']
 ['X' 'O' 'X']
 ['-' '-' '-']]
Enter row: 2
Enter column: 2
[['O' 'X' '-']
 ['X' 'O' 'X']
 ['-' '-' 'O']]
O wins
```

2. Vacuum Cleaner :

```
cost =0
def vacuum_world(state, location):
  global cost
  if(state['A']==0 and state['B']==0):
    print('All rooms are clean')
    return

  if state[location]==1:
    state[location]=0
    cost+=1
    state[location]=(int(input('Is room '+ str(location) +' still dirty : ')))

    if state[location]==1:
      return vacuum_world(state, location)
    else:
      print('Room ' + str(location) + ' cleaned')

  next_location='B' if location=='A' else 'A'
  if state[next_location]==0:
    state[next_location]=(int(input('Is room '+ str(next_location) +' dirty : ')))
  print('Moving to room '+str(next_location))
  return vacuum_world(state, next_location)

state={}
state['A']=int(input('Enter status of room A : '))
state['B']=int(input('Enter status of room B : '))
location=input('Enter initial location of vacuum (A/B) : ')
vacuum_world(state,location)
print("Status = "+str(state))
print('Total cost: ' + str(cost))
```

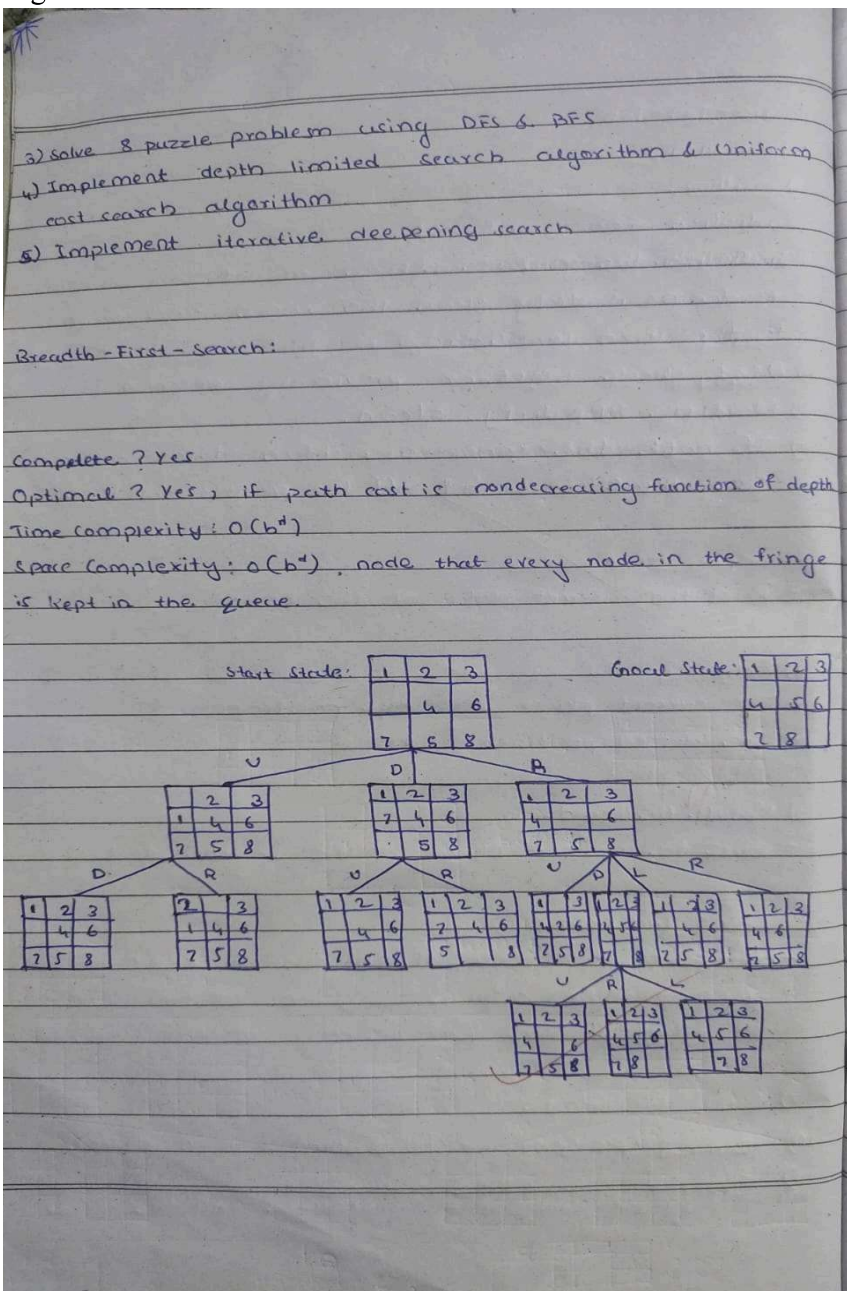
Output :

```
Enter status of room A : 1
Enter status of room B : 1
Enter initial location of vacuum (A/B) : A
Is room A still dirty : 0
Room A cleaned
Moving to room B
Is room B still dirty : 0
Room B cleaned
Is room A dirty : 0
Moving to room A
All rooms are clean
Status = {'A': 0, 'B': 0}
Total cost: 2
```

**Program 2**

Implement 8 puzzle problems using Depth First Search (DFS)
Implement Iterative deepening search algorithm

Algorithm:



3) Solve 8 puzzle problem using DFS & BFS.

BFS:

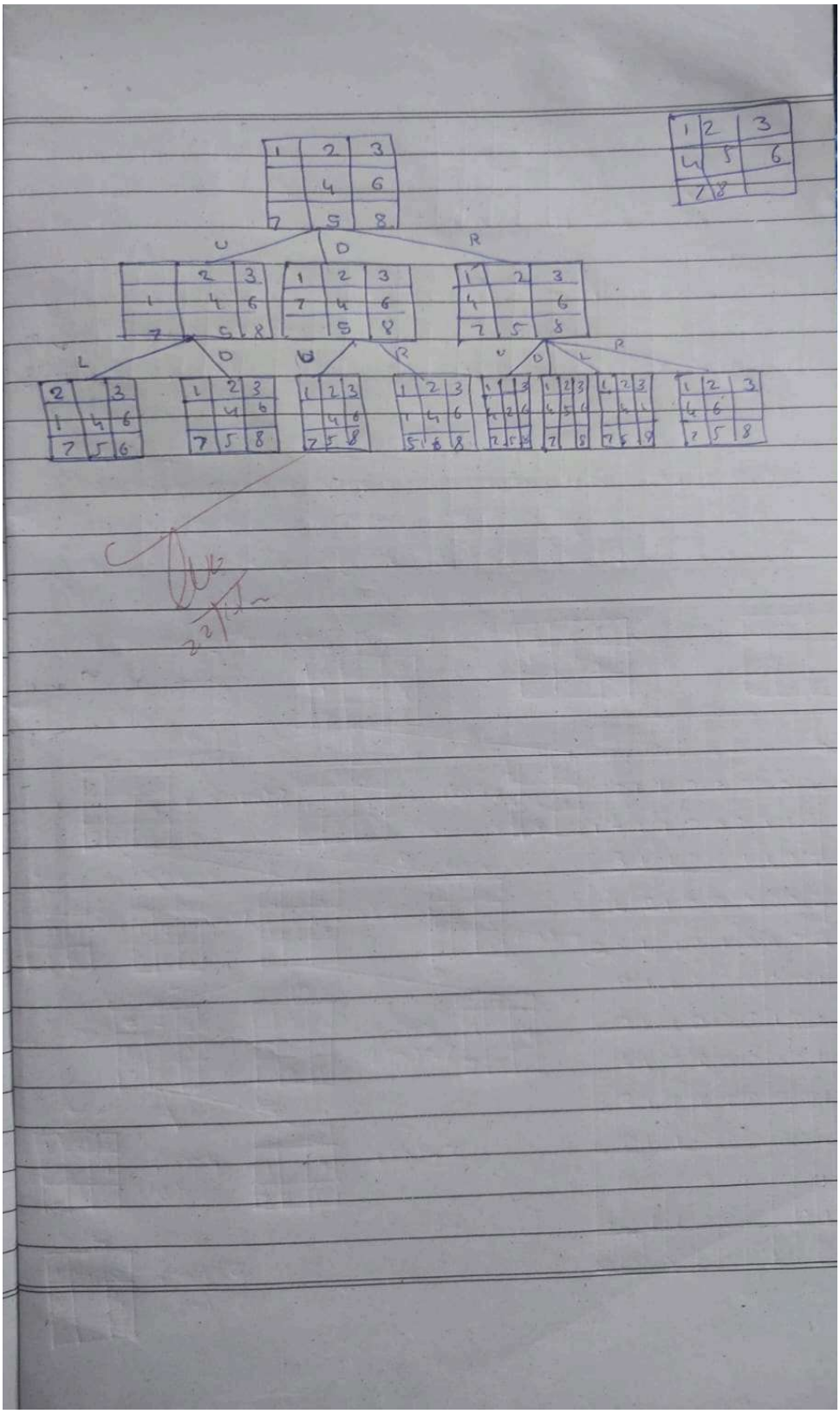
- The initial state & goal state will be given.
- We need to achieve goal state of 8 puzzle using BFS algorithm.
- Initially the parent node will be the initial state, the possible movements of blank space will be recorded i.e, up, down, right, left.
- These possible movements will be the child nodes of initial state.
- Define helper function find_blank_title(state) to locate the position of blank tile
- Define another function get_possible_moves(state) that generates all valid moves for the current state:
  - Determine the position of the blank tile
  - For each possible direction (up, down, left, right), record direction & move the tile.
- Run the BFS loop until we reach the goal state.

Lab 5: Implement Iterative Deepening Search Algorithm.

1) For each child of the current node
2) If it is the target node, return
3) If the curr max depth is reached return
4) Set the current node to this node & go back to 1
5) After having gone through all children go to the next child of the parent (the next sibling)
6) After having gone through all children of the start node increase the maximum depth & go back to 1
7) If we have reached all leaf (bottom) nodes, the goal node doesn't exist.

function Iterative-Deepening-Search(problem) returns a solution or failure

for depth = 0 to ∞ do
result ← Depth-Limited-Search(problem, depth)
if result ≠ cutoff then return result


U
D
R
L

Code:
1: DFS

```
cnt = 0;
def print_state(in_array):
 global cnt
 cnt += 1
 for row in in_array:
  print(' '.join(str(num) for num in row))
 print()

def helper(goal, in_array, row, col, vis):

 vis[row][col] = 1
 drow = [-1, 0, 1, 0]
 dcol = [0, 1, 0, -1]
 dchange = ['U', 'R', 'D', 'L']

 print("Current state:")
 print_state(in_array)

 if in_array == goal:
  print_state(in_array)
  print(f"Number of states : {cnt}")
  return True


 for i in range(4):
  nrow = row + drow[i]
  ncol = col + dcol[i]

  if 0 <= nrow < len(in_array) and 0 <= ncol < len(in_array[0]) and not vis[nrow][ncol]:

    print(f"Took a {dchange[i]} move")
    in_array[row][col], in_array[nrow][ncol] = in_array[nrow][ncol], in_array[row][col]

    if helper(goal, in_array, nrow, ncol, vis):
      return True

    in_array[row][col], in_array[nrow][ncol] = in_array[nrow][ncol], in_array[row][col]


 vis[row][col] = 0
 return False


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

```
goal_state = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]
visited = [[0] * 3 for _ in range(3)]
empty_row, empty_col = 1, 0
found_soluΘon = helper(goal_state, iniΘal_state, empty_row, empty_col, visited)
print("SoluΘon found:", found_soluΘon)
```

Output :

```
Current state:
1 2 3
0 4 6
7 5 8

Took a U move
Current state:
0 2 3
1 4 6
7 5 8

Took a R move
Current state:
2 0 3
1 4 6
7 5 8

Took a R move
Current state:
2 3 0
1 4 6
7 5 8

Took a D move
Current state:
2 3 6
1 4 0
7 5 8

Took a D move
Current state:
2 3 6
1 4 8
7 5 0

Took a L move
Current state:
2 3 6
1 4 8
7 0 5

Took a U move
Current state:
2 3 6
1 0 8
7 4 5

Took a L move
Current state:
2 3 6
1 4 8
0 7 5

Took a L move
Current state:
2 3 6
1 0 4
7 5 8

Took a D move
Current state:
2 3 6
1 5 4
7 0 8

Took a R move
Current state:
2 3 6
1 5 4
7 8 0

Took a L move
Current state:
2 3 6
1 5 4
0 7 8

Took a D move
Current state:
2 4 3
1 0 6
7 5 8

Took a R move
Current state:
2 4 3
1 6 0
7 5 8

Took a U move
Current state:
2 4 0
1 6 3
7 5 8

Took a L move
Current state:
1 0 2
4 6 3
7 5 8

Took a L move
Current state:
0 1 2
4 6 3
7 5 8

Took a D move
Current state:
1 2 3
4 6 8
7 5 0

Took a L move
Current state:
1 2 3
4 6 8
7 0 5

Took a L move
Current state:
1 2 3
4 6 8
0 7 5

Took a D move
Current state:
1 2 3
4 5 6
7 0 8

Took a R move
Current state:
1 2 3
4 5 6
7 8 0

1 2 3
4 5 6
7 8 0

Number of states : 42
SoluΘon found: True
```

2 : Iterative deepening search

```
class PuzzleState:
    def __init__(self, board, empty_tile_pos, depth=0, path=[]):
        self.board = board
        self.empty_tile_pos = empty_tile_pos  # (row, col)
        self.depth = depth
        self.path = path  # Keep track of the path taken to reach this state

    def is_goal(self, goal):
        return self.board == goal

    def generate_moves(self):
        row, col = self.empty_tile_pos
        moves = []
        directions = [(-1, 0, 'Up'), (1, 0, 'Down'), (0, -1, 'Left'), (0, 1, 'Right')]  # up, down, left, right
        for dr, dc, move_name in directions:
            new_row, new_col = row + dr, col + dc
            if 0 <= new_row < 3 and 0 <= new_col < 3:
                new_board = self.board[:]
                new_board[row * 3 + col], new_board[new_row * 3 + new_col] = new_board[new_row *
3 + new_col], new_board[row * 3 + col]
                new_path = self.path + [move_name]  # Update the path with the new move
                moves.append(PuzzleState(new_board, (new_row, new_col), self.depth + 1, new_path))
        return moves

    def display(self):
        # Display the board in a matrix form
        for i in range(0, 9, 3):
            print(self.board[i:i + 3])
        print(f"Moves: {self.path}")  # Display the moves taken to reach this state
        print()  # Newline for better readability

def iddfs(initial_state, goal, max_depth):
    for depth in range(max_depth + 1):
        print(f"Searching at depth: {depth}")
        found = dls(initial_state, goal, depth)
        if found:
            print(f"Goal found at depth: {found.depth}")
            found.display()
            return found
    print("Goal not found within max depth.")
    return None

def dls(state, goal, depth):
    if state.is_goal(goal):
        return state
```

```
    if depth <= 0:
        return None

    for move in state.generate_moves():
        print("Current state:")
        move.display()  # Display the current state
        result = dls(move, goal, depth - 1)
        if result is not None:
            return result
    return None

def main():
    # User input for initial state, goal state, and maximum depth
    initial_state_input = input("Enter initial state (0 for empty tile, space-separated, e.g. '1 2 3 4 5 6 7 8
0'): ")
    goal_state_input = input("Enter goal state (0 for empty tile, space-separated, e.g. '1 2 3 4 5 6 7 8
0'): ")
    max_depth = int(input("Enter maximum depth: "))

    initial_board = list(map(int, initial_state_input.split()))
    goal_board = list(map(int, goal_state_input.split()))
    empty_tile_pos = initial_board.index(0) // 3, initial_board.index(0) % 3  # Calculate the position of
the empty tile

    initial_state = PuzzleState(initial_board, empty_tile_pos)

    solution = iddfs(initial_state, goal_board, max_depth)

if __name__ == "__main__":
    main()
```

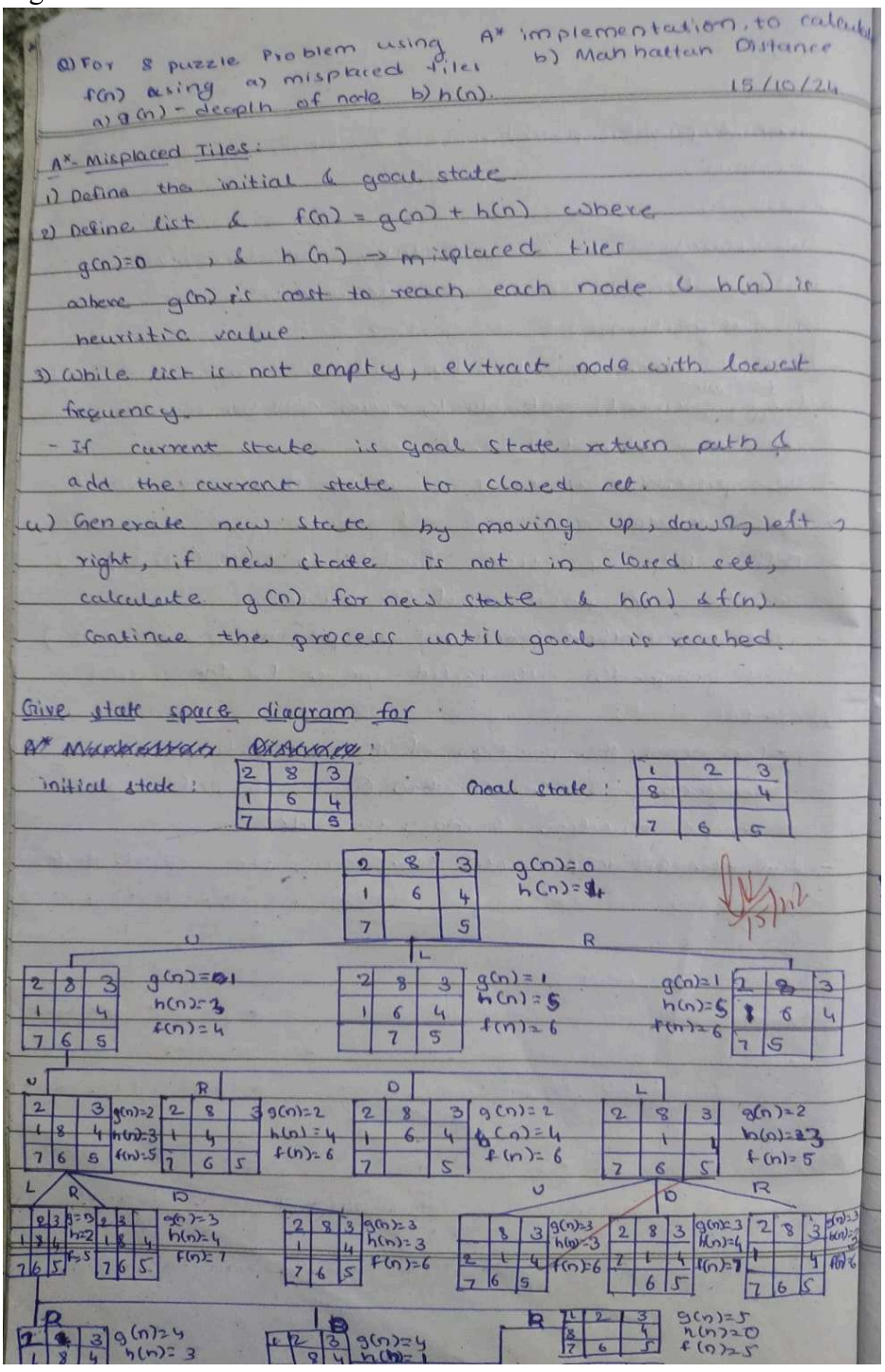
Output :

```
Enter initial state (0 for empty tile, space-separated, e.g. '1 2 3 4 5 6 7 8 0'): 1 2 3 0 4 6 7 5 8
Enter goal state (0 for empty tile, space-separated, e.g. '1 2 3 4 5 6 7 8 0'): 1 2 3 4 5 6 7 8 0
Enter maximum depth: 2
Searching at depth: 0
Searching at depth: 1

Current state:
[0, 2, 3]
[1, 4, 6]
[7, 5, 8]
Moves: ['Up']

Current state:
[1, 2, 3]
[7, 4, 6]
[0, 5, 8]
Moves: ['Down']

Current state:
[1, 2, 3]
[4, 0, 6]
[7, 5, 8]
Moves: ['Right']

Searching at depth: 2
Current state:
[0, 2, 3]
[1, 4, 6]
[7, 5, 8]
Moves: ['Up']

Current state:
[1, 2, 3]
[0, 4, 6]
[7, 5, 8]
Moves: ['Up', 'Down']

Current state:
[2, 0, 3]
[1, 4, 6]
[7, 5, 8]
Moves: ['Up', 'Right']

Current state:
[1, 2, 3]
[7, 4, 6]
[0, 5, 8]
Moves: ['Down']

Current state:
[1, 2, 3]
[7, 4, 6]
[0, 5, 8]
Moves: ['Down']

Current state:
[1, 2, 3]
[0, 4, 6]
[7, 5, 8]
Moves: ['Down', 'Up']

Current state:
[1, 2, 3]
[7, 4, 6]
[5, 0, 8]
Moves: ['Down', 'Right']

Current state:
[1, 2, 3]
[4, 0, 6]
[7, 5, 8]
Moves: ['Right']

Current state:
[1, 0, 3]
[4, 2, 6]
[7, 5, 8]
Moves: ['Right', 'Up']

Current state:
[1, 2, 3]
[4, 5, 6]
[7, 0, 8]
Moves: ['Right', 'Down']

Current state:
[1, 2, 3]
[0, 4, 6]
[7, 5, 8]
Moves: ['Right', 'Left']

Current state:
[1, 2, 3]
[4, 6, 0]
[7, 5, 8]
Moves: ['Right', 'Right']

Goal not found within max depth.
```

**Program 3**

Implement A* search algorithm

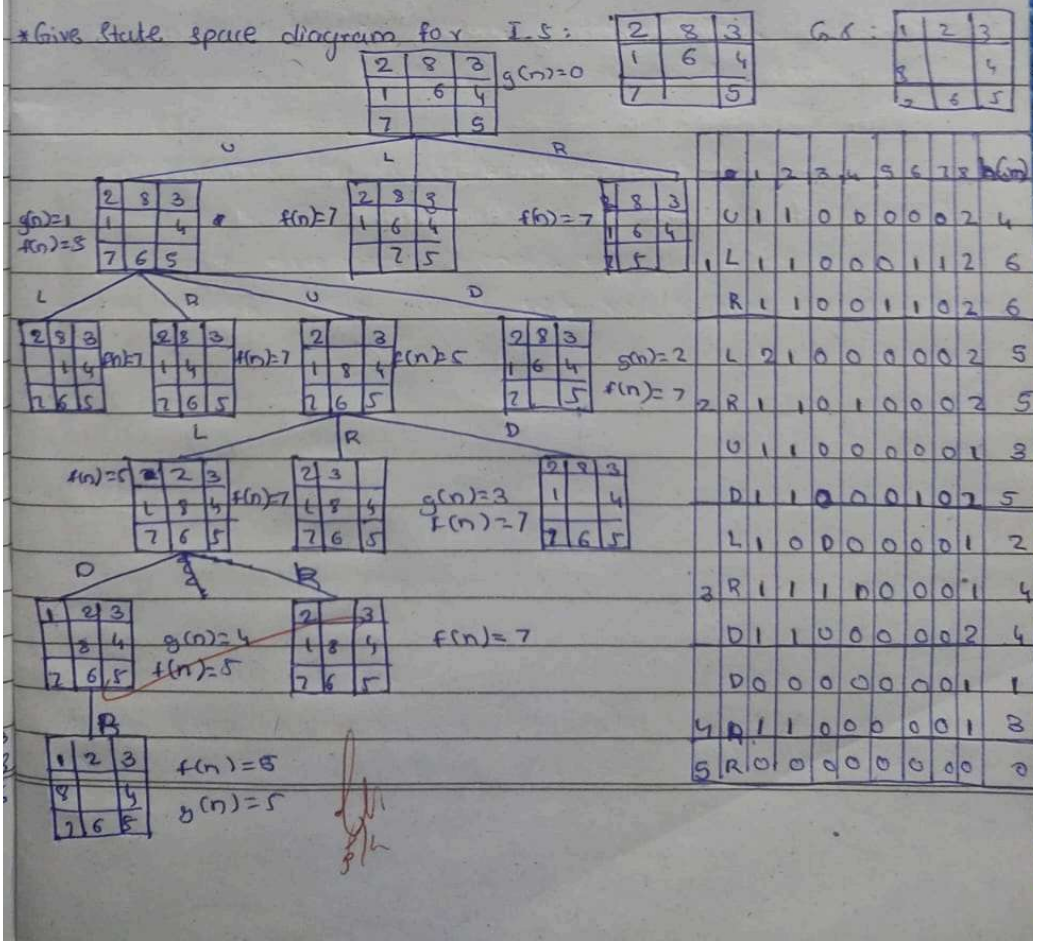
Algorithm:



Manhattan Distance:

1) Define goal state & also create a dictionary.
2) Create a list containing f(n), g(n) & path with g(n)=0.
   Define a closed set to track visited states.
3) Calculate manhattan distance,
   - for each tile from 1 to 8 in current state
   - find this current position & find target by goal state & calculated distance.
   - sum these distances to get h(n).
4) Expand nodes, while list is not empty, extract node with low frequency & return path.

*Give state space diagram for I.S: G.S:




| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | h(n) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | U | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 4 |
| 1 | L | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 6 |
| | R | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 2 | 6 |
| | L | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 5 |
| 2 | R | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 5 |
| | U | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| | D | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 5 |
| | L | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| 3 | R | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 4 |
| | D | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 4 |
| | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 4 | R | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| 5 | R | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Code:

Misplaced Tiles :

```
class Node:
    def __init__(self, state, parent=None, move=None, cost=0):
        self.state = state
        self.parent = parent
        self.move = move
        self.cost = cost

    def heuristic(self):
        goal_state = [[1,2,3], [8,0,4], [7,6,5]]
        count = 0
        for i in range(len(self.state)):
            for j in range(len(self.state[i])):
                if self.state[i][j] != 0 and self.state[i][j] != goal_state[i][j]:
                    count += 1
        return count

def get_blank_position(state):
    for i in range(len(state)):
        for j in range(len(state[i])):
            if state[i][j] == 0:
                return i, j

def get_possible_moves(position):
    x, y = position
    moves = []
    if x > 0: moves.append((x - 1, y, 'Down'))
    if x < 2: moves.append((x + 1, y, 'Up'))
    if y > 0: moves.append((x, y - 1, 'Right'))
    if y < 2: moves.append((x, y + 1, 'Left'))
    return moves

def generate_new_state(state, blank_pos, new_blank_pos):
    new_state = [row[:] for row in state]
    new_state[blank_pos[0]][blank_pos[1]], new_state[new_blank_pos[0]][new_blank_pos[1]] = \
        new_state[new_blank_pos[0]][new_blank_pos[1]], new_state[blank_pos[0]][blank_pos[1]]
    return new_state

def a_star_search(initial_state):
    open_list = []
    closed_list = set()

    initial_node = Node(state=initial_state, cost=0)
    open_list.append(initial_node)
```

```
    while open_list:

        open_list.sort(key=lambda node: node.cost + node.heuristic())
        current_node = open_list.pop(0)


        move_description = current_node.move if current_node.move else "Start"
        print("Current state:")
        for row in current_node.state:
            print(row)
        print(f"Move: {move_description}")
        print(f"Heuristic value (misplaced tiles): {current_node.heuristic()}")
        print(f"Cost to reach this node: {current_node.cost}\n")

        if current_node.heuristic() == 0:

            path = []
            while current_node:
                path.append(current_node)
                current_node = current_node.parent
            return path[::-1]
        closed_list.add(tuple(map(tuple, current_node.state)))

        blank_pos = get_blank_position(current_node.state)
        for new_blank_pos in get_possible_moves(blank_pos):
            new_state = generate_new_state(current_node.state, blank_pos, (new_blank_pos[0],
new_blank_pos[1]))

            if tuple(map(tuple, new_state)) in closed_list:
                continue

            cost = current_node.cost + 1
            move_direction = new_blank_pos[2]
            new_node = Node(state=new_state, parent=current_node, move=move_direction, cost=cost)

            if new_node not in open_list:
                open_list.append(new_node)

    return None

initial_state = [[2,8,3], [1,6,4], [7,0,5]]
solution_path = a_star_search(initial_state)

if solution_path:
    print("Solution path:")
    for step in solution_path:
        for row in step.state:
```

```
        print(row)
    print()
else:
  print("No solution found.")
```

Output :

```
Current state:
[2, 8, 3]
[1, 6, 4]
[7, 0, 5]
Move: Start
Heuristic value (misplaced tiles): 4
Cost to reach this node: 0

Current state:
[2, 8, 3]
[1, 0, 4]
[7, 6, 5]
Move: Down
Heuristic value (misplaced tiles): 3
Cost to reach this node: 1

Current state:
[2, 0, 3]
[1, 8, 4]
[7, 6, 5]
Move: Down
Heuristic value (misplaced tiles): 3
Cost to reach this node: 2

Current state:
[2, 8, 3]
[0, 1, 4]
[7, 6, 5]
Move: Right
Heuristic value (misplaced tiles): 3
Cost to reach this node: 2

Current state:
[0, 2, 3]
[1, 8, 4]
[7, 6, 5]
Move: Right
Heuristic value (misplaced tiles): 2
Cost to reach this node: 3

Current state:
[1, 2, 3]
[0, 8, 4]
[7, 6, 5]
Move: Up
Heuristic value (misplaced tiles): 1
Cost to reach this node: 4

Current state:
[1, 2, 3]
[8, 0, 4]
[7, 6, 5]
Move: Left
Heuristic value (misplaced tiles): 0
Cost to reach this node: 5

Solution path:
[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]
```

Code :

Manhattan distance approach

```
class Node:
    def __init__(self, state, parent=None, move=None, cost=0):
        self.state = state
        self.parent = parent
        self.move = move
        self.cost = cost

    def heuristic(self):
        goal_positions = {
            1: (0, 0), 2: (0, 1), 3: (0, 2),
            8: (1, 0), 0: (1, 1), 4: (1, 2),
            7: (2, 0), 6: (2, 1), 5: (2, 2)
        }
        manhattan_distance = 0
        for i in range(len(self.state)):
            for j in range(len(self.state[i])):
                value = self.state[i][j]
                if value != 0:
                    goal_i, goal_j = goal_positions[value]
                    manhattan_distance += abs(i - goal_i) + abs(j - goal_j)
        return manhattan_distance

def get_blank_position(state):
    for i in range(len(state)):
        for j in range(len(state[i])):
            if state[i][j] == 0:
                return i, j

def get_possible_moves(position):
    x, y = position
    moves = []
    if x > 0: moves.append((x - 1, y, 'Down'))
    if x < 2: moves.append((x + 1, y, 'Up'))
    if y > 0: moves.append((x, y - 1, 'Right'))
    if y < 2: moves.append((x, y + 1, 'Left'))
    return moves

def generate_new_state(state, blank_pos, new_blank_pos):
    new_state = [row[:] for row in state]
    new_state[blank_pos[0]][blank_pos[1]], new_state[new_blank_pos[0]][new_blank_pos[1]] = \
        new_state[new_blank_pos[0]][new_blank_pos[1]], new_state[blank_pos[0]][blank_pos[1]]
    return new_state
```

```
def a_star_search(initial_state):
    open_list = []
    closed_list = set()

    initial_node = Node(state=initial_state, cost=0)
    open_list.append(initial_node)

    while open_list:

        open_list.sort(key=lambda node: node.cost + node.heuristic())
        current_node = open_list.pop(0)


        move_description = current_node.move if current_node.move else "Start"
        print("Current state:")
        for row in current_node.state:
            print(row)
        print(f"Move: {move_description}")
        print(f"Heuristic value (Manhattan distance): {current_node.heuristic()}")
        print(f"Cost to reach this node: {current_node.cost}\n")

        if current_node.heuristic() == 0:

            path = []
            while current_node:
                path.append(current_node)
                current_node = current_node.parent
            return path[::-1]
        closed_list.add(tuple(map(tuple, current_node.state)))

        blank_pos = get_blank_position(current_node.state)
        for new_blank_pos in get_possible_moves(blank_pos):
            new_state = generate_new_state(current_node.state, blank_pos, (new_blank_pos[0],
new_blank_pos[1]))

            if tuple(map(tuple, new_state)) in closed_list:
                continue

            cost = current_node.cost + 1
            move_direction = new_blank_pos[2]
            new_node = Node(state=new_state, parent=current_node, move=move_direction, cost=cost)

            if new_node not in open_list:
                open_list.append(new_node)

    return None
```

```
initial_state = [[2,8,3], [1,6,4], [7,0,5]]
solution_path = a_star_search(initial_state)

if solution_path:
    print("Solution path:")
    for step in solution_path:
        for row in step.state:
            print(row)
        print()
else:
    print("No solution found.")
```

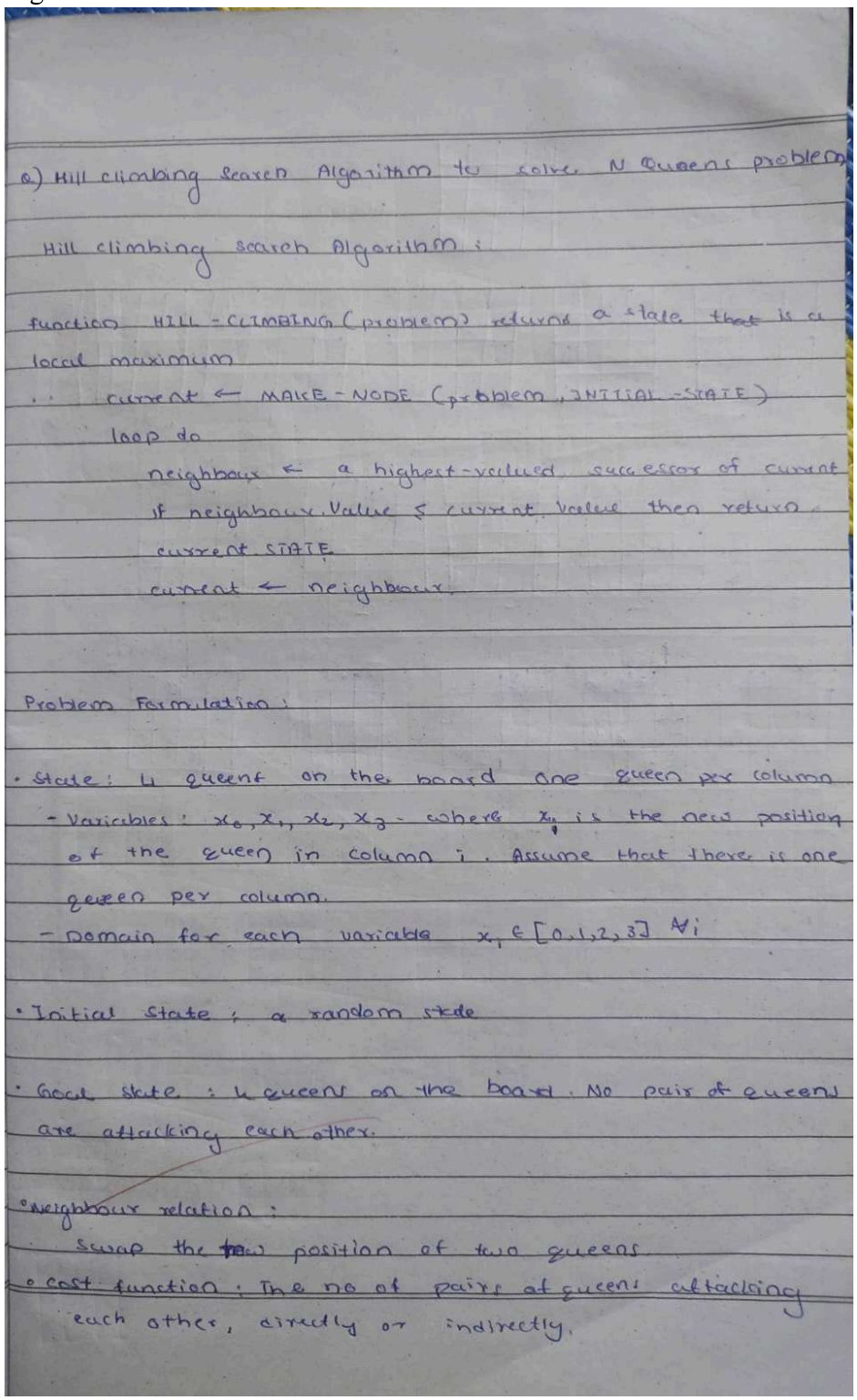
Output :

```
Current state:
[2, 8, 3]
[1, 6, 4]
[7, 0, 5]
Move: Start
Heuristic value (Manhattan distance): 5
Cost to reach this node: 0

Current state:
[2, 8, 3]
[1, 0, 4]
[7, 6, 5]
Move: Down
Heuristic value (Manhattan distance): 4
Cost to reach this node: 1

Current state:
[2, 0, 3]
[1, 8, 4]
[7, 6, 5]
Move: Down
Heuristic value (Manhattan distance): 3
Cost to reach this node: 2

Current state:
[0, 2, 3]
[1, 8, 4]
[7, 6, 5]
Move: Right
Heuristic value (Manhattan distance): 2
Cost to reach this node: 3

Current state:
[1, 2, 3]
[8, 0, 4]
[7, 6, 5]
Move: Left
Heuristic value (Manhattan distance): 0
Cost to reach this node: 5

Solution path:
[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 4**

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:



Q) Hill climbing search Algorithm to solve N Queens problem

Hill climbing search Algorithm :

function HILL-CLIMBING (problem) returns a state that is a local maximum

current ← MAKE-NODE (problem, INITIAL-STATE)

loop do

neighbour ← a highest-valued successor of current

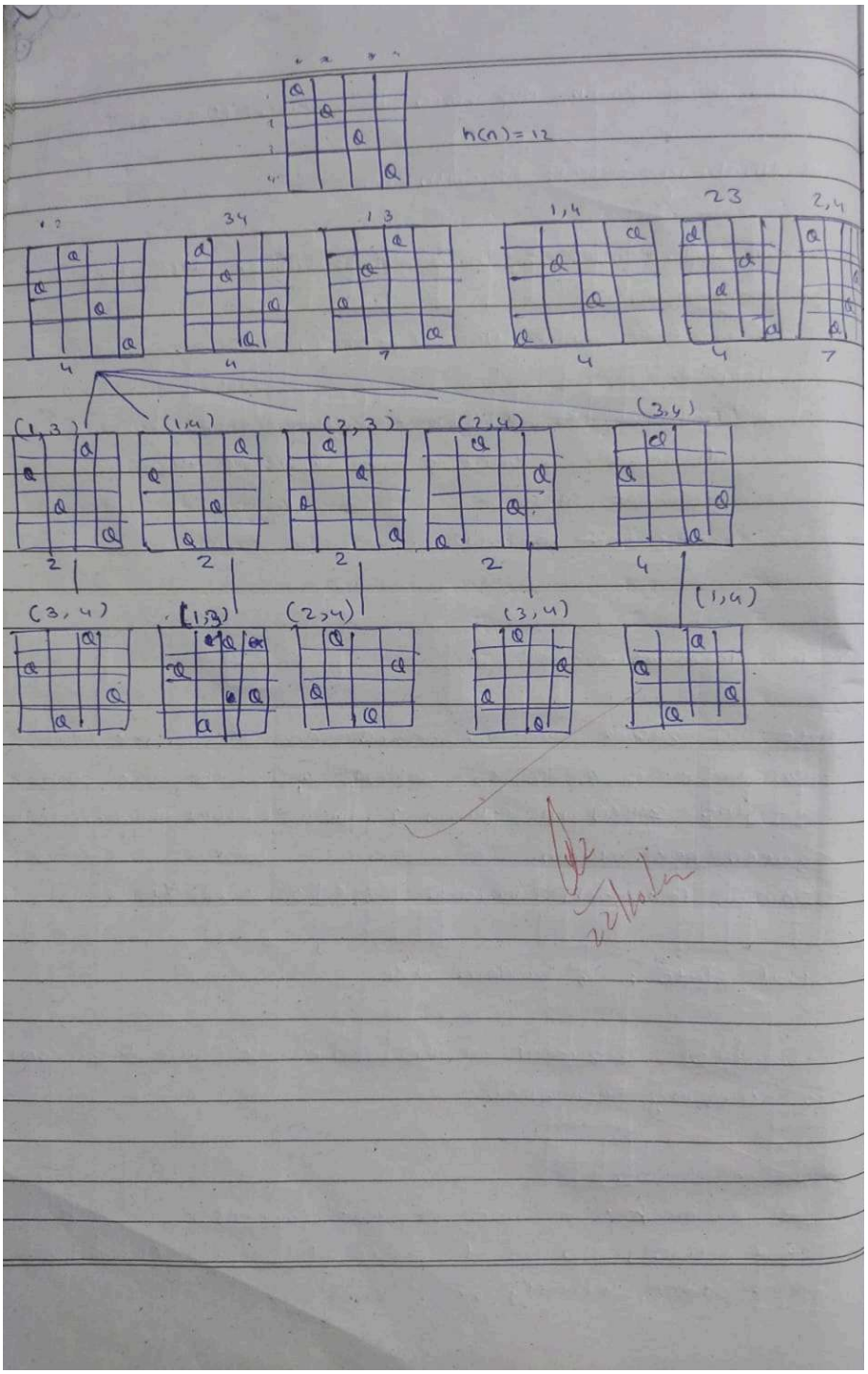
if neighbour.Value ≤ current.Value then return current.STATE

current ← neighbour

Problem Formulation :

- State : 4 queens on the board one queen per column
  - Variables : $x_0, x_1, x_2, x_3$ - where $x_i$ is the new position of the queen in column i. Assume that there is one queen per column.
  - Domain for each variable $x_i \in [0,1,2,3]$ $\forall i$
- Initial State : a random state
- Goal state : 4 queens on the board. No pair of queens are attacking each other.
- Neighbour relation :

  Swap the two position of two queens
- Cost function : The no of pairs of queens attacking each other, directly or indirectly.


h(n) = 12
1,4
23
2,4
34
1 3
(1,3)
(1,4)
(2,3)
(2,4)
(3,4)
(3,4)
(1,3)
(2,4)
(3,4)
(1,4)

Code:

```
import random
def calculate_cost(board):
    n = len(board)
    attacks = 0
    for i in range(n):
        for j in range(i + 1, n):
            if board[i] == board[j]:  # Same column
                attacks += 1
            if abs(board[i] - board[j]) == abs(i - j):  # Same diagonal
                attacks += 1
    return attacks


def get_neighbors(board):
    neighbors = []
    n = len(board)
    for col in range(n):
        for row in range(n):
            if row != board[col]:  # Only change the row of the queen
                new_board = board[:]
                new_board[col] = row
                neighbors.append(new_board)
    return neighbors
```

```
def hill_climb(board, max_restarts=100):
    current_cost = calculate_cost(board)
    print("Initial board configuration:")
    print_board(board, current_cost)
    iteration = 0
    restarts = 0

    while restarts < max_restarts:  # Add limit to the number of restarts
        while current_cost != 0:  # Continue until cost is zero
            neighbors = get_neighbors(board)
            best_neighbor = None
            best_cost = current_cost

            for neighbor in neighbors:
                cost = calculate_cost(neighbor)
                if cost < best_cost:  # Looking for a lower cost
                    best_cost = cost
                    best_neighbor = neighbor

            if best_neighbor is None:  # No better neighbor found
                break  # Break the loop if we are stuck at a local minimum

            board = best_neighbor
            current_cost = best_cost
```

```
            iteration += 1
            print(f"Iteration {iteration}:")
            print_board(board, current_cost)

        if current_cost == 0:
            break  # We found the solution, no need for further restarts
        else:
            # Restart with a new random configuration
            board = [random.randint(0, len(board)-1) for _ in range(len(board))]
            current_cost = calculate_cost(board)
            restarts += 1
            print(f"Restart {restarts}:")
            print_board(board, current_cost)

    return board, current_cost

def print_board(board, cost):
    n = len(board)
    display_board = [['.'] * n for _ in range(n)]  # Create an empty board
    for col in range(n):
        display_board[board[col]][col] = 'Q'  # Place queens on the board
    for row in range(n):
        print(' '.join(display_board[row]))  # Print the board
```

```
    print(f"Cost: {cost}\n")


if __name__ == "__main__":
    n = int(input("Enter the number of queens (N): "))  # User input for N
    initial_state = list(map(int, input(f"Enter the initial state (row numbers for each column, space-separated): ").split()))
    if len(initial_state) != n or any(r < 0 or r >= n for r in initial_state):
        print("Invalid initial state. Please ensure it has N elements with values from 0 to N-1.")
    else:
        solution, cost = hill_climb(initial_state)
        if cost == 0:
            print(f"Solution found with no conflicts:")
        else:
            print(f"No solution found within the restart limit:")
        print_board(solution, cost)
```

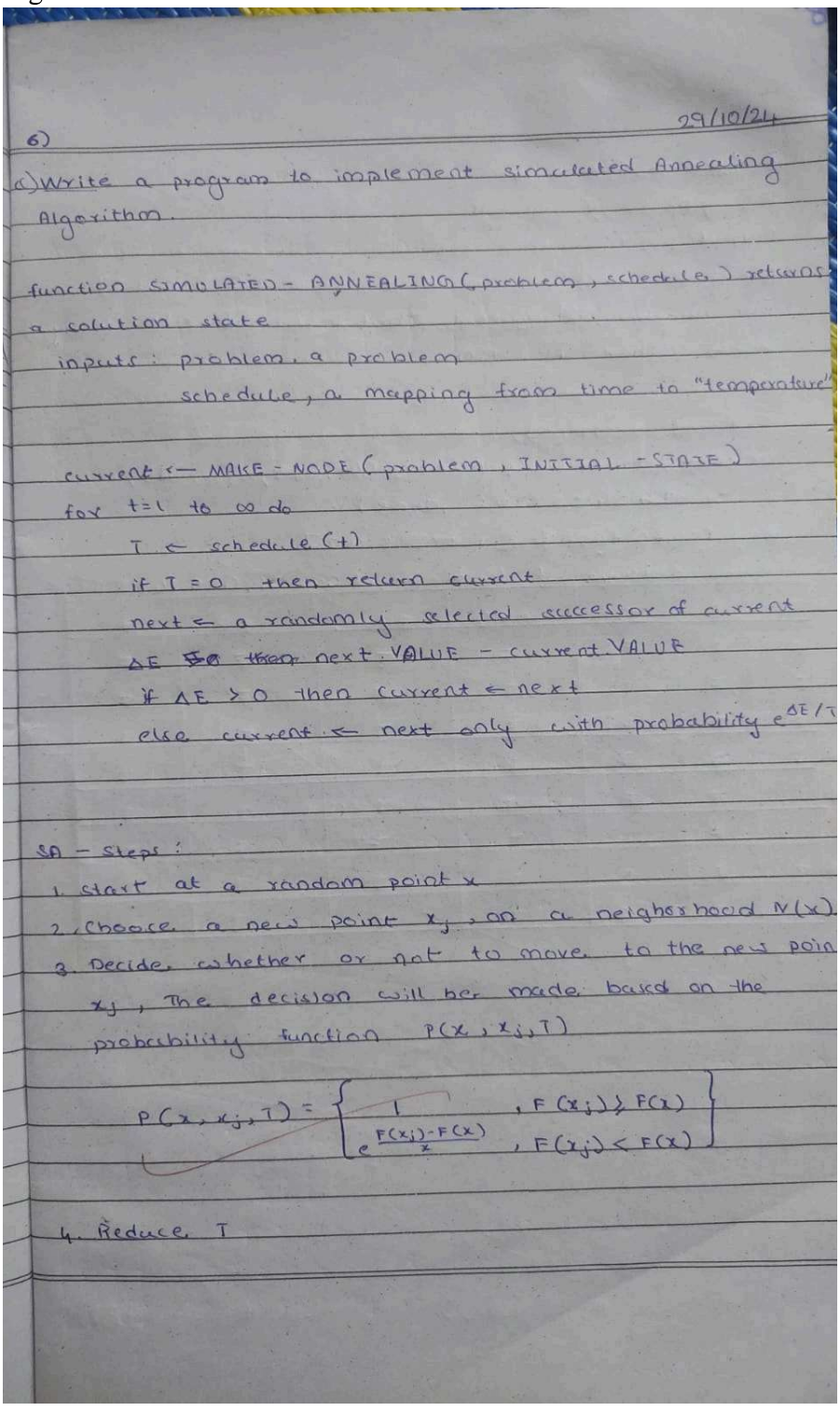
Output :

```
Enter the number of queens (N): 4
Enter the initial state (row numbers for each column, space-separated): 0 1 2 3
Initial board configuration:
Q . . .
. Q . .
. . Q .
. . . Q
Cost: 6

Iteration 1:
. . . .
Q Q . .
. . Q .
. . . Q
Cost: 4

Iteration 2:
. Q . .
Q . . .
. . Q .
. . . Q
Cost: 2

Restart 1:
. Q Q Q
. . . .
. . . .
Q . . .
Cost: 4

Iteration 3:
. Q . Q
. . . .
. . Q .
Q . . .
Cost: 2

Iteration 4:
. Q . .
. . . Q
. . Q .
Q . . .
Cost: 1

Restart 2:
. . . Q
. Q . .
. . . .
Q . Q .
Cost: 2

Iteration 6:
. . . .
. Q . .
. . Q Q
Q . . .
Cost: 2

Iteration 7:
. . Q .
. Q . .
. . . Q
Q . . .
Cost: 1

Restart 4:
Q . . .
. Q . Q
. . Q .
. . . .
Cost: 5

Iteration 8:
Q . . .
. Q . Q
. . . .
. . Q .
Cost: 2

Iteration 9:
Q Q . .
. . . Q
. . . .
. . Q .
Cost: 1

Iteration 10:
. Q . .
. . . Q
Q . . .
. . Q .
Cost: 0

Solution found with no conflicts:
. Q . .
. . . Q
Q . . .
. . Q .
Cost: 0
```

**Program 5**

Simulated Annealing to Solve 8-Queens problem

Algorithm:



6) 29/10/24

a) Write a program to implement simulated Annealing Algorithm.

function SIMULATED-ANNEALING(problem, schedule) returns a solution state

inputs: problem, a problem

schedule, a mapping from time to "temperature"

current ← MAKE-NODE(problem, INITIAL-STATE)

for t=1 to ∞ do

T ← schedule(t)

if T = 0 then return current

next ← a randomly selected successor of current

ΔE ← next.VALUE − current.VALUE

if ΔE > 0 then current ← next

else current ← next only with probability $e^{\Delta E/T}$

SA - Steps:

1. Start at a random point x
2. Choose a new point $x_j$, on a neighborhood N(x)
3. Decide whether or not to move to the new point $x_j$. The decision will be made based on the probability function $P(x, x_j, T)$

$$P(x, x_j, T) = \begin{cases} 1 & , F(x_j) \geq F(x) \\ e^{\frac{F(x_j)-F(x)}{x}} & , F(x_j) < F(x) \end{cases}$$

4. Reduce T

8-Queens Problem

Output:

The best position found is : [4 0 7 5 2 6 1 3]

The number of queens that are not attacking each other is : 8.0

TSP :

Result structure : (array([1, 0, 3, 5, 4, 2]), 21.029348553206, None)

Best route found : [1 0 3 5 4 2]

Total distance of best route : 21.029348553206

Date 29/10/24

Code:

```
#!pip install mlrose-hiive joblib
#!pip install --upgrade joblib
#!pip install joblib==1.1.0
import mlrose_hiive as mlrose
import numpy as np

def queens_max(position):
    no_attack_on_j = 0
    queen_not_attacking = 0
    for i in range(len(position) - 1):
        no_attack_on_j = 0
        for j in range(i + 1, len(position)):
            if (position[j] != position[i]) and (position[j] != position[i] + (j - i)) and (position[j] !=
            position[i] - (j - i)):
                no_attack_on_j += 1
        if (no_attack_on_j == len(position) - 1 - i):
            queen_not_attacking += 1
    if (queen_not_attacking == 7):
        queen_not_attacking += 1
    return queen_not_attacking

objective = mlrose.CustomFitness(queens_max)

problem = mlrose.DiscreteOpt(length=8, fitness_fn=objective, maximize=True, max_val=8)
T = mlrose.ExpDecay()

initial_position = np.array([4, 6, 1, 5, 2, 0, 3, 7])

#The simulated_annealing function returns 3 values, we need to capture all 3
best_position, best_objective, fitness_curve = mlrose.simulated_annealing(problem=problem,
schedule=T, max_attempts=500,
                                          init_state=initial_position)

print('The best position found is:', best_position)
print('The number of queens that are not attacking each other is:', best_objective)
```

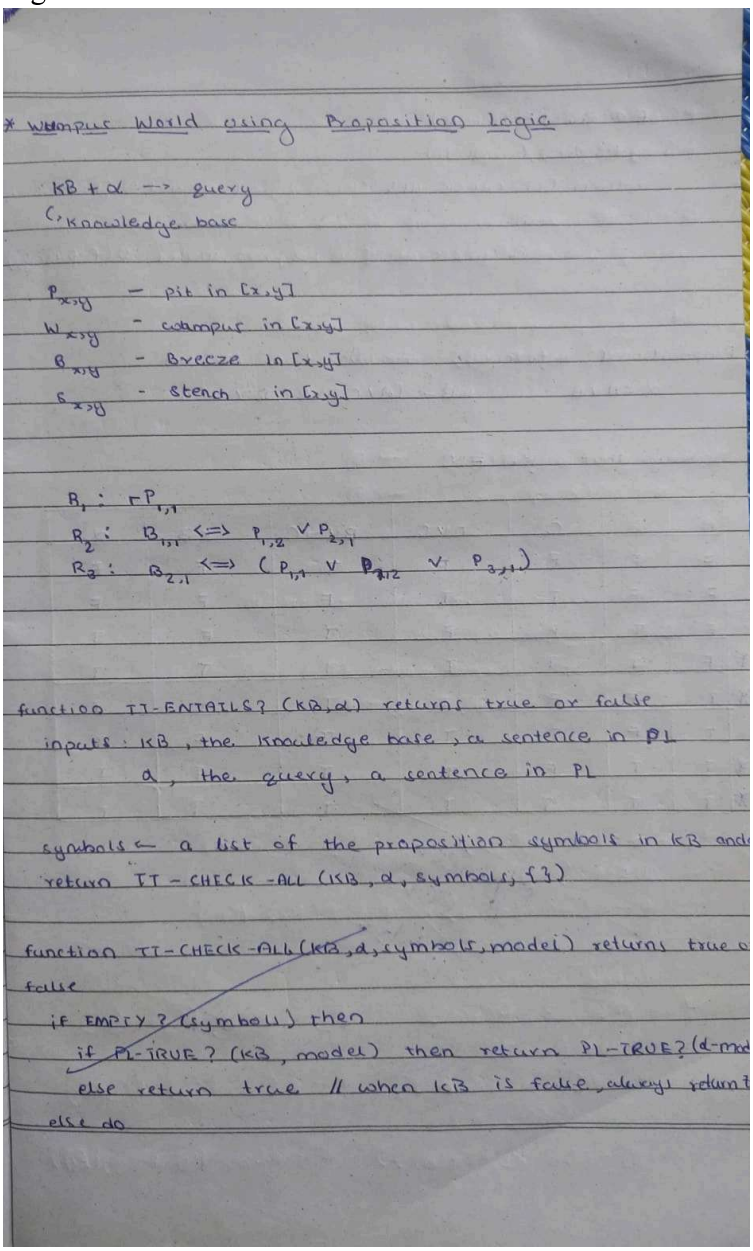
Output :

```
The best position found is: [4 0 7 5 2 6 1 3]
The number of queens that are not attacking each other is: 8.0
```

## Program 6

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

Algorithm:



* Wumpus World using Propositional Logic

KB ⊢ α --> query
KB --> Knowledge base

$P_{x,y}$ - pit in [x,y]
$W_{x,y}$ - wumpus in [x,y]
$B_{x,y}$ - Breeze in [x,y]
$S_{x,y}$ - Stench in [x,y]

$R_1$ : $\neg P_{1,1}$
$R_2$ : $B_{1,1} \Leftrightarrow P_{1,2} \vee P_{2,1}$
$R_3$ : $B_{2,1} \Leftrightarrow (P_{1,1} \vee P_{2,2} \vee P_{3,1})$

function TT-ENTAILS? (KB, α) returns true or false
inputs: KB, the knowledge base, a sentence in PL
α, the query, a sentence in PL

symbols ← a list of the proposition symbols in KB and
return TT-CHECK-ALL (KB, α, symbols, {})

function TT-CHECK-ALL (KB, α, symbols, model) returns true o
false
if EMPTY? (symbols) then
if PL-TRUE? (KB, model) then return PL-TRUE? (α, mo
else return true // when KB is false, always return
else do

P ← FIRST (symbols)

rest ← REST (symbols)

return (TT-CHECK-ALL (KB, α, rest, model ∪ {P=true}))

and

TT-CHECK-ALL (KB, α, rest, model ∪ {P=false}))

Propositional Inference : Enumeration Method

$\alpha = A \vee B$ $\quad KB = (A \vee C) \wedge (B \vee \neg C)$

checking that $KB \models \alpha$

| | A | B | C | A∨C | B∨¬C | KB | α |
|---|---|---|---|---|---|---|---|
| | F | F | F | F | T | F | F |
| | F | F | T | T | F | F | F |
| | F | T | F | F | T | F | F |
| * | F | T | T | T | T | T | T |
| * | T | F | F | T | T | T | T |
| | T | F | T | T | F | F | T |
| * | T | T | F | T | T | T | T |
| * | T | T | T | T | T | T | T |

O/P seen

SSD

12/11/24

Code:

```
import pandas as pd

# Define the truth table for all combinations of A, B, C
truth_values = [(False, False, False),
                (False, False, True),
                (False, True, False),
                (False, True, True),
                (True, False, False),
                (True, False, True),
                (True, True, False),
                (True, True, True)]

# Columns: A, B, C
table = pd.DataFrame(truth_values, columns=["A", "B", "C"])

# Calculate intermediate columns
table["A or C"] = table["A"] | table["C"]          # A ∨ C
table["B or not C"] = table["B"] | ~table["C"]     # B ∨ ¬C

# Knowledge Base (KB): (A ∨ C) ∧ (B ∨ ¬C)
table["KB"] = table["A or C"] & table["B or not C"]

# Alpha (α): A ∨ B
table["Alpha (α)"] = table["A"] | table["B"]

# Define a highlighting function
def highlight_rows(row):
    if row["KB"] and row["Alpha (α)"]:
        return ['font-weight: bold; color: black'] * len(row)
    else:
        return [''] * len(row)

# Apply the highlighting function
styled_table = table.style.apply(highlight_rows, axis=1)

# Display the styled table
styled_table
```

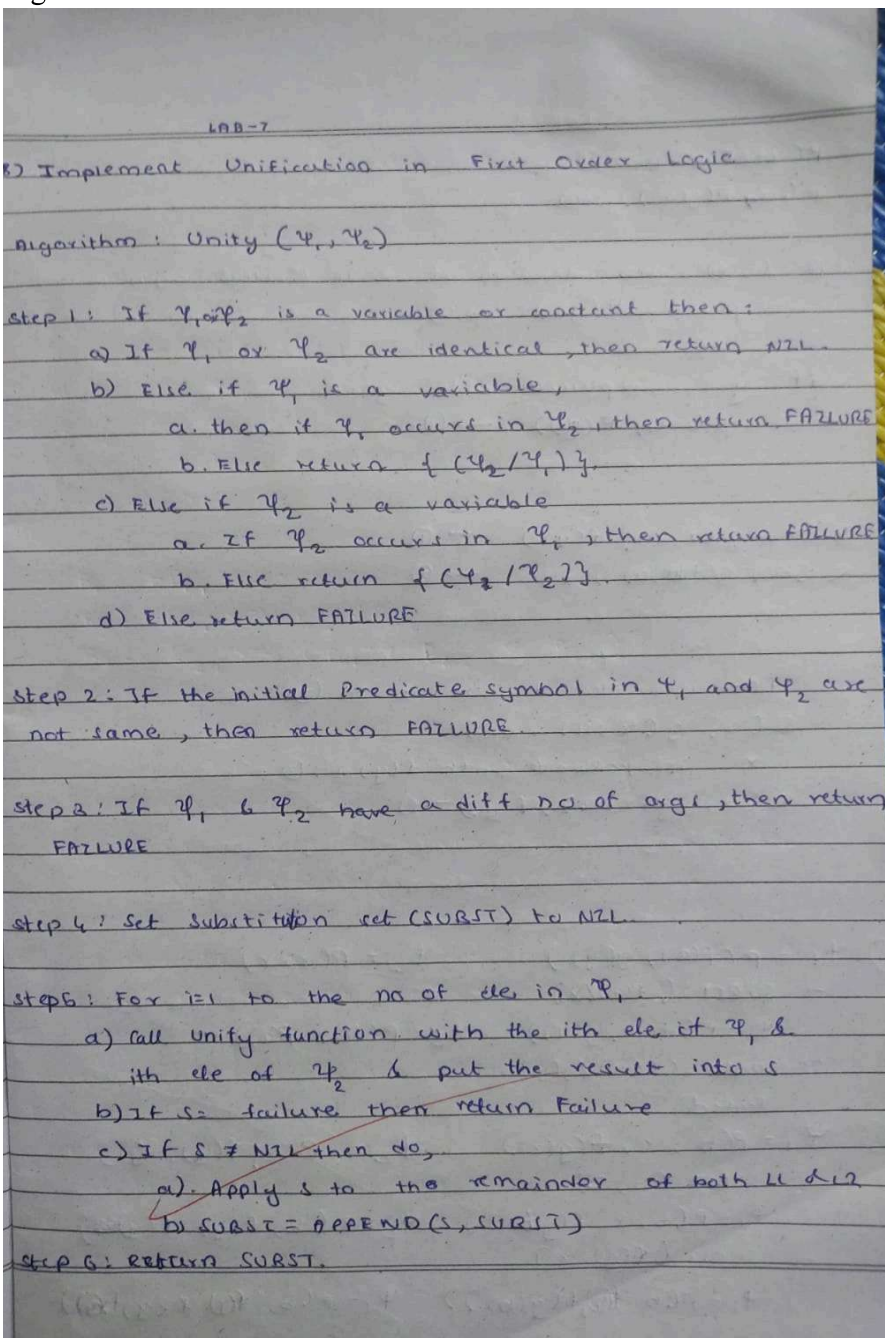
Output :

| | A | B | C | A or C | B or not C | KB | Alpha (α) |
|---|---|---|---|---|---|---|---|
| 0 | False | False | False | False | True | False | False |
| 1 | False | False | True | True | False | False | False |
| 2 | False | True | False | False | True | False | True |
| 3 | **False** | **True** | **True** | **True** | **True** | **True** | **True** |
| 4 | **True** | **False** | **False** | **True** | **True** | **True** | **True** |
| 5 | True | False | True | True | False | False | True |
| 6 | **True** | **True** | **False** | **True** | **True** | **True** | **True** |
| 7 | **True** | **True** | **True** | **True** | **True** | **True** | **True** |

**Program 7**

Implement unification in first order logic

Algorithm:



LAB-7

1) Implement Unification in First Order Logic

Algorithm : Unify ($\psi_1$, $\psi_2$)

Step 1 : If $\psi_1$ or $\psi_2$ is a variable or constant then :
a) If $\psi_1$ or $\psi_2$ are identical, then return NIL.
b) Else if $\psi_1$ is a variable,
a. then if $\psi_1$ occurs in $\psi_2$, then return FAILURE
b. Else return $\{(\psi_2/\psi_1)\}$.
c) Else if $\psi_2$ is a variable
a. If $\psi_2$ occurs in $\psi_1$, then return FAILURE
b. Else return $\{(\psi_1/\psi_2)\}$.
d) Else return FAILURE

Step 2 : If the initial Predicate symbol in $\psi_1$ and $\psi_2$ are not same, then return FAILURE.

Step 3 : If $\psi_1$ & $\psi_2$ have a diff no. of args, then return FAILURE

Step 4 : Set Substitution set (SUBST) to NIL.

Step 5 : For i=1 to the no of ele in $\psi_1$.
a) Call Unify function with the ith ele of $\psi_1$ & ith ele of $\psi_2$ & put the result into S
b) If S= failure then return 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.

P(x, F(y)) → ①

P(a, F(g(x))) → ②

① & ② are identical if x is replaced with a in ①

P(a, F(y)) → ①

if y is replaced with g(x)

P(a, F(g(x)) → ①

Q(a, g(x,a), f(y)) → ①

Q(a, g(f(b),a), x) → ②

f(b) is replaced with x in ②

Q(a, g(x,a), x)

x is replaced with f(y) in ②

Q(a, g(x,a), f(y)) → ①

① $\psi_1 = P(f(a), g(y))$ $\psi_2 = P(x, x)$

→ SUBST (f(a)/x)

$\psi_1 = P(f(a), g(y))$ $\psi_2 = P(f(a), f(a))$

→ SUBST (f(a)/g(y)

Failed

② $\psi_1 = P(b, x, f(g(z))$ $\psi_2 = P(z, f(y), f(y))$

→ SUBST (b, z)

$\psi_1 = P(b, x, f(g(b)))$ $\psi_2 = P(b, f(y), f(y))$

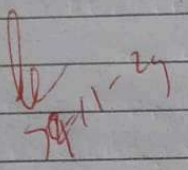
→ SUBST (f(y), x)

$\psi_1 = P(b, f(y), f(g(b)))$ $\psi_2 = P(b, f(y), f(y))$

subst $(g(b)/y)$

$\psi_1 = p(b, f(g(b)), F(g(b)))$

$\psi_2 = p(b, f(g(b)), f(g(b)))$



Code:

```
import re

def occurs_check(var, x):
    """Checks if var occurs in x (to prevent circular substitutions)."""
    if var == x:
        return True
    elif isinstance(x, list):  # If x is a compound expression (like a function or predicate)
        return any(occurs_check(var, xi) for xi in x)
    return False


def unify_var(var, x, subst):
    """Handles unification of a variable with another term."""
    if var in subst:  # If var is already substituted
        return unify(subst[var], x, subst)
    elif isinstance(x, (list, tuple)) and tuple(x) in subst:  # Handle compound expressions
        return unify(var, subst[tuple(x)], subst)
    elif occurs_check(var, x):  # Check for circular references
        return "FAILURE"
    else:
        # Add the substitution to the set (convert list to tuple for hashability)
        subst[var] = tuple(x) if isinstance(x, list) else x
        return subst


def unify(x, y, subst=None):
    """
    Unifies two expressions x and y and returns the substitution set if they can be unified.
    Returns 'FAILURE' if unification is not possible.
    """
    if subst is None:
        subst = {}  # Initialize an empty substitution set

    # Step 1: Handle cases where x or y is a variable or constant
    if x == y:  # If x and y are identical
        return subst
    elif isinstance(x, str) and x.islower():  # If x is a variable
        return unify_var(x, y, subst)
    elif isinstance(y, str) and y.islower():  # If y is a variable
        return unify_var(y, x, subst)
    elif isinstance(x, list) and isinstance(y, list):  # If x and y are compound expressions (lists)
        if len(x) != len(y):  # Step 3: Different number of arguments
            return "FAILURE"

        # Step 2: Check if the predicate symbols (the first element) match
        if x[0] != y[0]:  # If the predicates/functions are different
```

```
            return "FAILURE"

        # Step 5: Recursively unify each argument
        for xi, yi in zip(x[1:], y[1:]):  # Skip the predicate (first element)
            subst = unify(xi, yi, subst)
            if subst == "FAILURE":
                return "FAILURE"
        return subst
    else:  # If x and y are different constants or non-unifiable structures
        return "FAILURE"


def unify_and_check(expr1, expr2):
    """
    Attempts to unify two expressions and returns a tuple:
    (is_unified: bool, substitutions: dict or None)
    """
    result = unify(expr1, expr2)
    if result == "FAILURE":
        return False, None
    return True, result


def display_result(expr1, expr2, is_unified, subst):
    print("Expression 1:", expr1)
    print("Expression 2:", expr2)
    if not is_unified:
        print("Result: Unification Failed")
    else:
        print("Result: Unification Successful")
        print("Substitutions:", {k: list(v) if isinstance(v, tuple) else v for k, v in subst.items()})


def parse_input(input_str):
    """Parses a string input into a structure that can be processed by the unification algorithm."""
    # Remove spaces and handle parentheses
    input_str = input_str.replace(" ", "")

    # Handle compound terms (like p(x, f(y)) -> ['p', 'x', ['f', 'y']])
    def parse_term(term):
        # Handle the compound term
        if '(' in term:
            match = re.match(r'([a-zA-Z0-9_]+)\((.*)\)', term)
            if match:
                predicate = match.group(1)
                arguments_str = match.group(2)
                arguments = [parse_term(arg.strip()) for arg in arguments_str.split(',')]
```

```
            return [predicate] + arguments
        return term

    return parse_term(input_str)


# Main function to interact with the user
def main():
    while True:
        # Get the first and second terms from the user
        expr1_input = input("Enter the first expression (e.g., p(x, f(y))): ")
        expr2_input = input("Enter the second expression (e.g., p(a, f(z))): ")

        # Parse the input strings into the appropriate structures
        expr1 = parse_input(expr1_input)
        expr2 = parse_input(expr2_input)

        # Perform unification
        is_unified, result = unify_and_check(expr1, expr2)

        # Display the results
        display_result(expr1, expr2, is_unified, result)

        # Ask the user if they want to run another test
        another_test = input("Do you want to test another pair of expressions? (yes/no): ").strip().lower()
        if another_test != 'yes':
            break


if __name__ == "__main__":
    main()
```

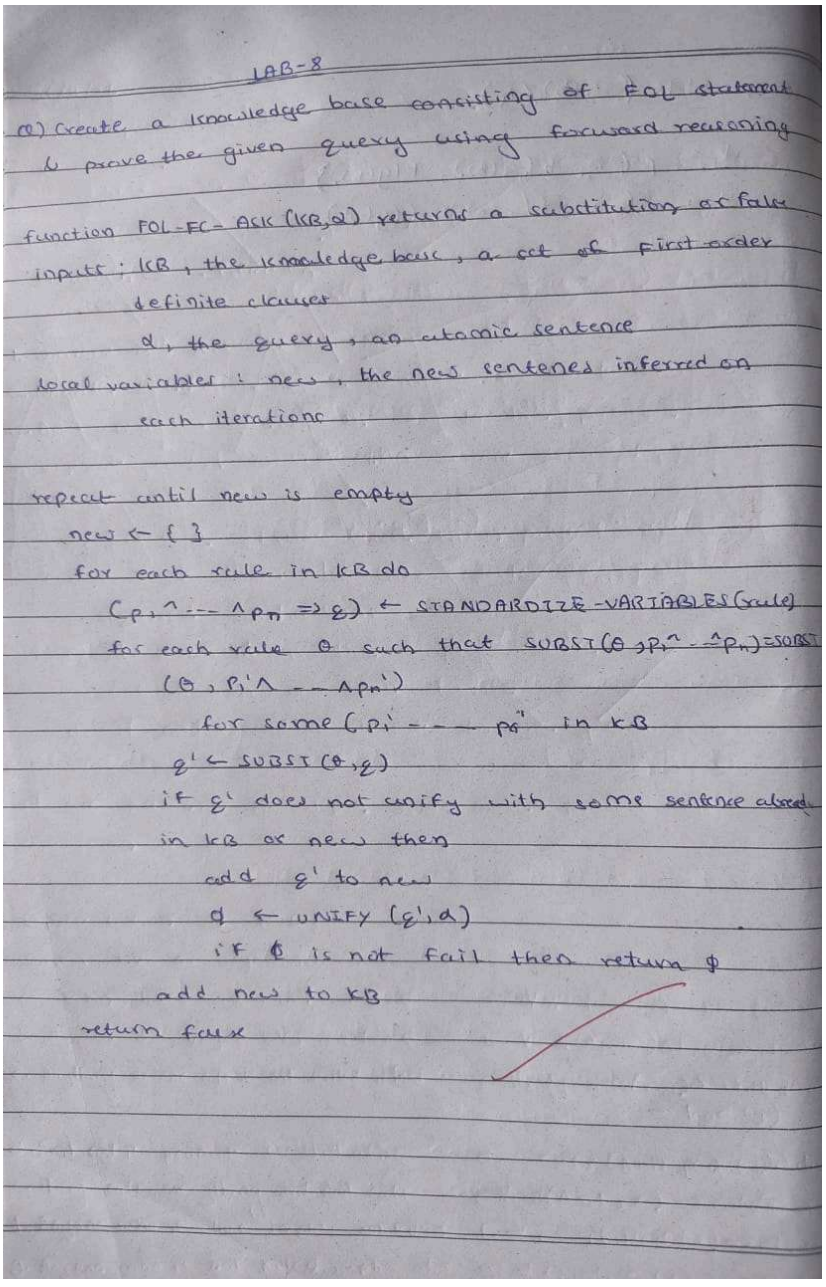
Output :

```
Enter the first expression (e.g., p(x, f(y))): p(b,x,f(g(z)))
Enter the second expression (e.g., p(a, f(z))): p(z,f(y),f(y))
Expression 1: ['p', 'b', 'x', ['f', ['g', 'z']]]
Expression 2: ['p', 'z', ['f', 'y'], ['f', 'y']]
Result: Unification Successful
Substitutions: {'b': 'z', 'x': ['f', 'y'], 'y': ['g', 'z']}
Do you want to test another pair of expressions? (yes/no): yes
Enter the first expression (e.g., p(x, f(y))): p(x,h(y))
Enter the second expression (e.g., p(a, f(z))): p(a,f(z))
Expression 1: ['p', 'x', ['h', 'y']]
Expression 2: ['p', 'a', ['f', 'z']]
Result: Unification Failed
Do you want to test another pair of expressions? (yes/no): yes
Enter the first expression (e.g., p(x, f(y))): p(f(a),g(y))
Enter the second expression (e.g., p(a, f(z))): p(x,x)
Expression 1: ['p', ['f', 'a'], ['g', 'y']]
Expression 2: ['p', 'x', 'x']
Result: Unification Failed
Do you want to test another pair of expressions? (yes/no): no
```

**Program 8**

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

Algorithm:

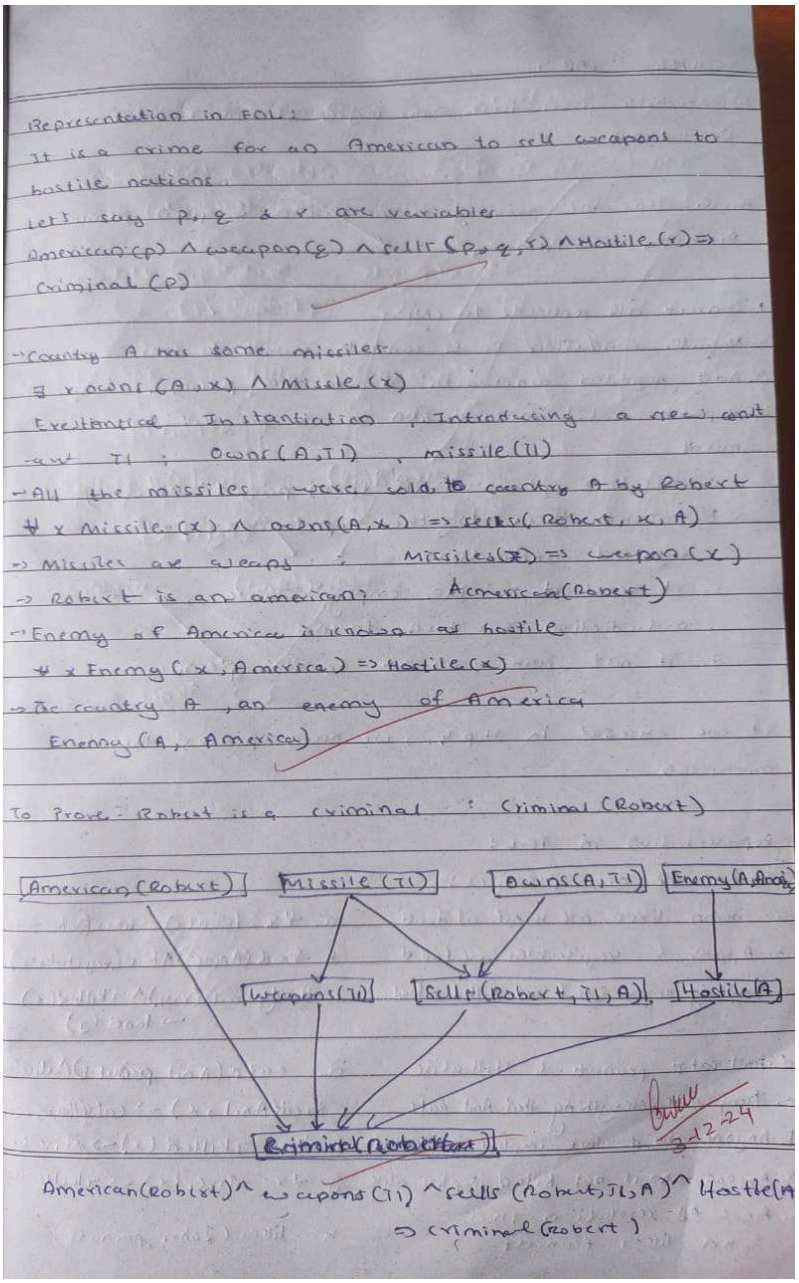


LAB-8

a) Create a knowledge base consisting of FOL statement & 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 sentences inferred on each iteration

repeat until new is empty
new ← { }
for each rule in KB do
$(p_1 \wedge \dots \wedge p_n \Rightarrow q) \leftarrow$ STANDARDIZE-VARIABLES(rule)
for each rule θ such that SUBST(θ, $p_1' \wedge \dots \wedge p_n'$) = SUBST(θ, $p_1 \wedge \dots \wedge p_n$)
for some $p_1', \dots, p_n'$ 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 $\phi$ is not fail then return $\phi$
add new to KB
return false


Representation in FOL:
It is a crime for an American to sell weapons to hostile nations.
Let's say p, q & r are variables
American(p) ∧ weapon(q) ∧ sells(p, q, r) ∧ Hostile(r) ⇒ Criminal(p)
→ Country A has some missiles
∃ x owns(A, x) ∧ Missile(x)
Existential Instantiation : Introducing a new constant T1 : Owns(A, T1) , missile(T1)
→ All the missiles were sold to country A by Robert
∀ x Missile(x) ∧ owns(A, x) ⇒ sells(Robert, x, A)
→ Missiles are weapons : Missiles(x) ⇒ weapons(x)
→ Robert is an american? American(Robert)
→ Enemy of America is known as hostile
∀ x Enemy(x, America) ⇒ Hostile(x)
→ The country A, an enemy of America
Enemy(A, America)
To Prove: Robert is a criminal : Criminal(Robert)
American(Robert)
Missile(T1)
Owns(A, T1)
Enemy(A, America)
Weapons(T1)
Sells(Robert, T1, A)
Hostile(A)
Criminal(Robert)
3-12-24
American(Robert) ∧ weapons(T1) ∧ sells(Robert, T1, A) ∧ Hostile(A
⇒ Criminal(Robert)

Code:

```
class KnowledgeBase:
    def __init__(self):
        self.facts = set()   # Set of known facts
        self.rules = []      # List of rules

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

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

    def infer(self):
        inferred = True
        while inferred:
            inferred = False
            for rule in self.rules:
                if rule.apply(self.facts):
                    inferred = True

# Define the Rule class
class Rule:
    def __init__(self, premises, conclusion):
        self.premises = premises  # List of conditions
        self.conclusion = conclusion  # Conclusion to add if premises are met

    def apply(self, facts):
        if all(premise in facts for premise in self.premises):
            if self.conclusion not in facts:
                facts.add(self.conclusion)
                print(f"Inferred: {self.conclusion}")
                return True
        return False

# Initialize the knowledge base
kb = KnowledgeBase()

# Facts in the problem
kb.add_fact("American(Robert)")
kb.add_fact("Missile(T1)")
kb.add_fact("Owns(A, T1)")
kb.add_fact("Enemy(A, America)")

# Rules based on the problem
# 1. Missile(x) implies Weapon(x)
kb.add_rule(Rule(["Missile(T1)"], "Weapon(T1)"))
```

```
# 2. Enemy(x, America) implies Hostile(x)
kb.add_rule(Rule(["Enemy(A, America)"], "Hostile(A)"))

# 3. Missile(x) and Owns(A, x) imply Sells(Robert, x, A)
kb.add_rule(Rule(["Missile(T1)", "Owns(A, T1)"], "Sells(Robert, T1, A)"))

# 4. American(p) and Weapon(q) and Sells(p, q, r) and Hostile(r) imply Criminal(p)
kb.add_rule(Rule(["American(Robert)", "Weapon(T1)", "Sells(Robert, T1, A)", "Hostile(A)"],
"Criminal(Robert)"))

# Infer new facts based on the rules
kb.infer()

# Check if Robert is a criminal
if "Criminal(Robert)" in kb.facts:
    print("Conclusion: Robert is a criminal.")
else:
    print("Conclusion: Unable to prove Robert is a criminal.")
```

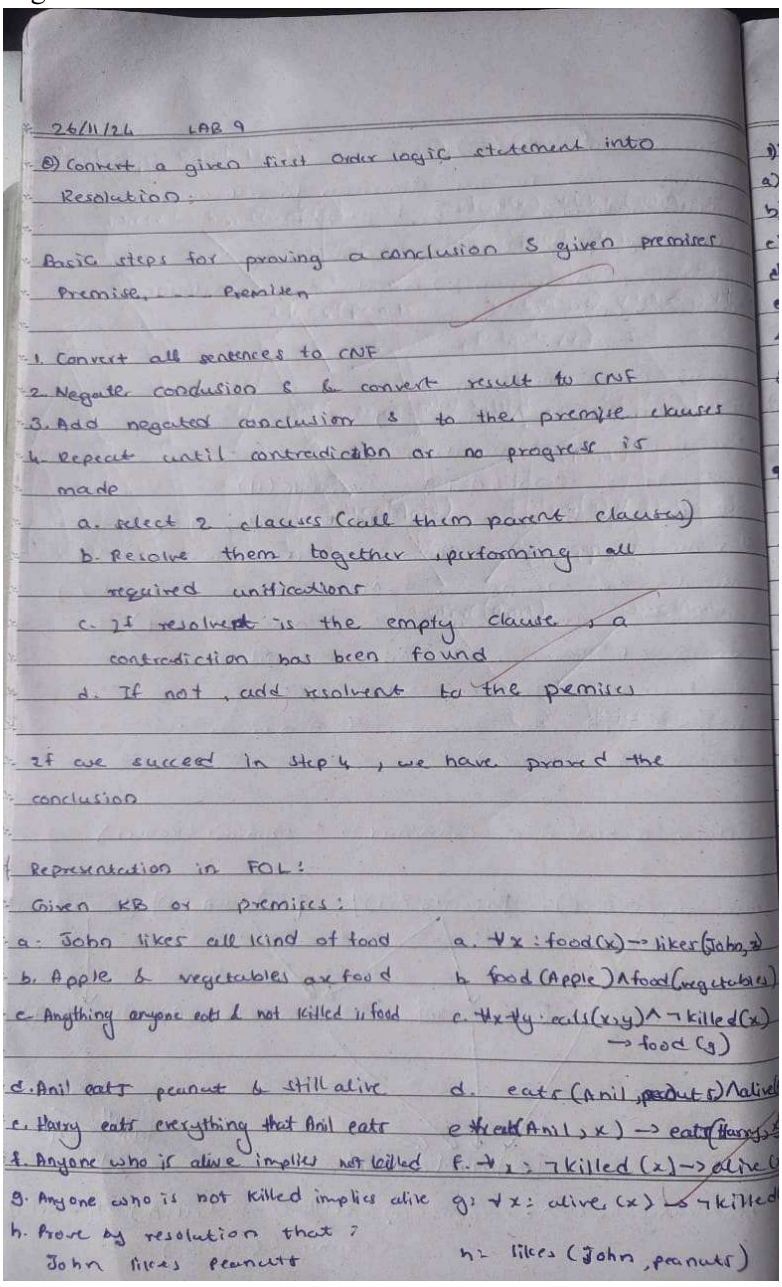
Output :

```
Inferred: Weapon(T1)
Inferred: Hostile(A)
Inferred: Sells(Robert, T1, A)
Inferred: Criminal(Robert)
Conclusion: Robert is a criminal.
```

**Program 9**

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

Algorithm:



26/11/24 LAB 9

8) Convert a given first order logic statement into Resolution:

Basic steps for proving a conclusion S given premises

Premise, ---- Premise$_n$

1. Convert all sentences to CNF
2. Negate conclusion S & convert result to CNF
3. Add negated conclusion S to the premise clauses
4. Repeat until contradiction or no progress is made
   a. Select 2 clauses (call them parent clauses)
   b. Resolve them together, performing all required unifications
   c. If resolvent is the empty clause, a contradiction has been found
   d. If not, add resolvent to the premises

If we succeed in step 4, we have proved the conclusion

Representation in FOL:

Given KB or premises:

a: John likes all kind of food — a. $\forall x : food(x) \rightarrow likes(John, x)$

b. Apple & vegetables are food — b. $food(Apple) \wedge food(vegetables)$

c. Anything anyone eats & not killed is food — c. $\forall x \forall y : eats(x,y) \wedge \neg killed(x) \rightarrow food(y)$

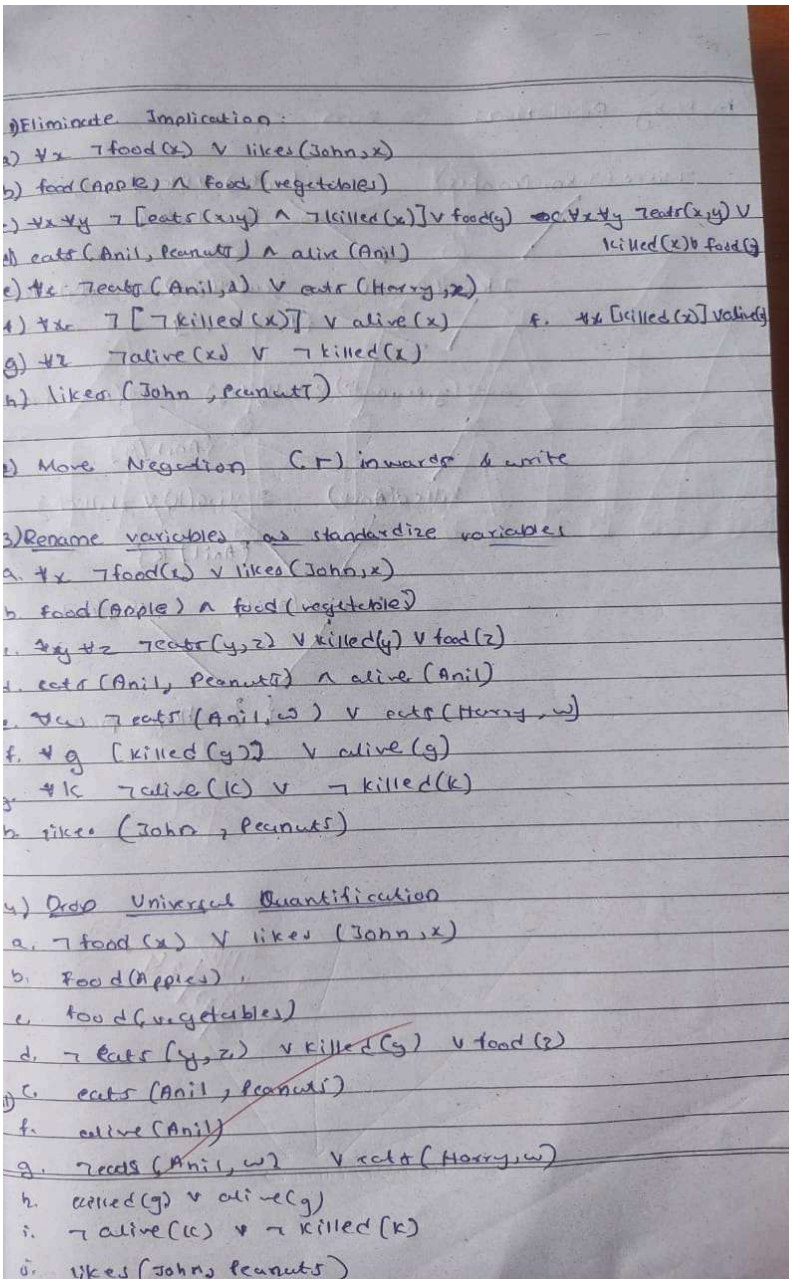
d. Anil eats peanut & still alive — d. $eats(Anil, peanuts) \wedge alive$

e. Harry eats everything that Anil eats — e. $\forall x : eats(Anil, x) \rightarrow eats(Harry, x)$

f. Anyone who is alive implies not killed — f. $\forall x : \neg killed(x) \rightarrow alive$

g. Anyone who is not killed implies alive — g: $\forall x : alive(x) \rightarrow \neg killed$

h. Prove by resolution that: John likes peanuts — h: $likes(John, peanuts)$

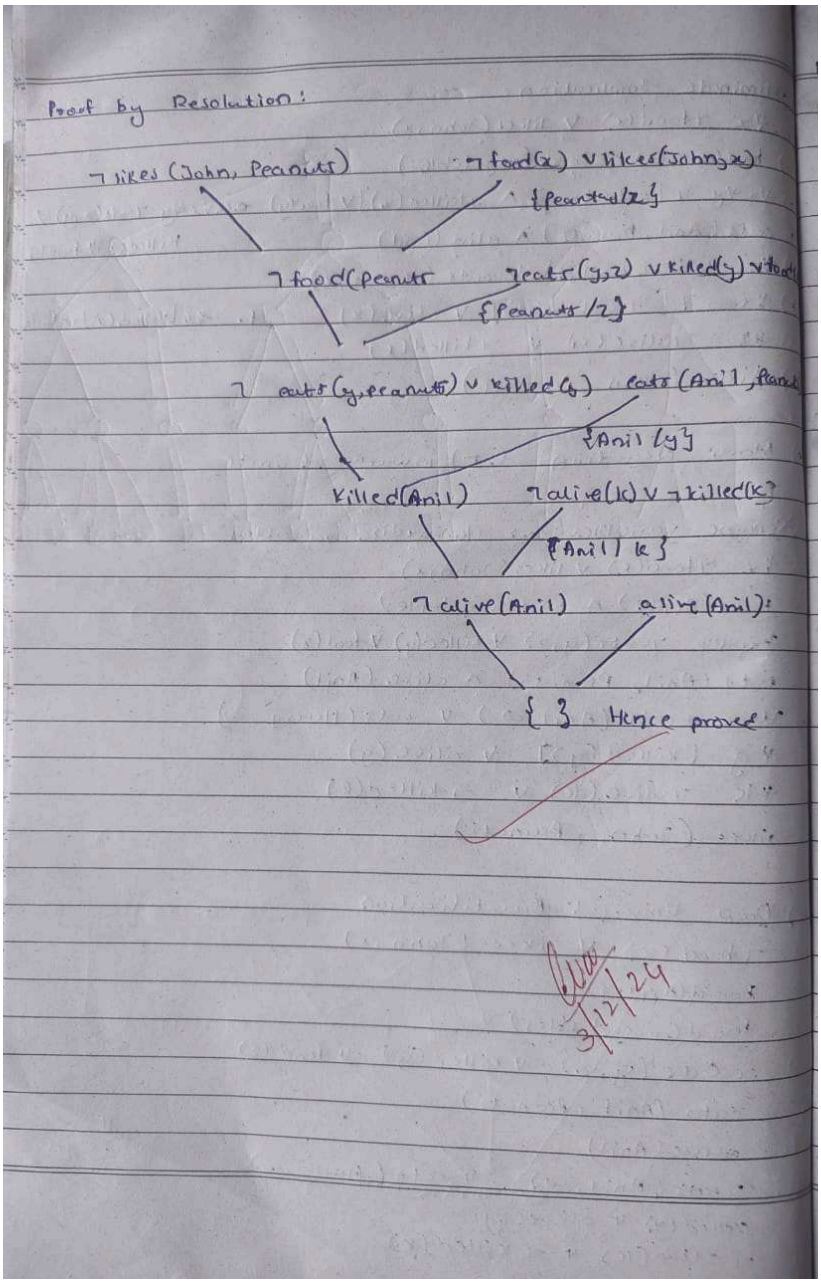


1) Eliminate Implication :
a) $\forall x \neg food(x) \vee likes(John, x)$
b) $food(Apple) \wedge food(vegetables)$
c) $\forall x \forall y \neg [eats(x,y) \wedge \neg killed(x)] \vee food(y)$ $\Rightarrow$ $\forall x \forall y \neg eats(x,y) \vee killed(x) \vee food(y)$
d) $eats(Anil, Peanuts) \wedge alive(Anil)$
e) $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$
f) $\forall x \neg [\neg killed(x)] \vee alive(x)$ $\Rightarrow$ $\forall x [killed(x)] \vee alive(x)$
g) $\forall x \neg alive(x) \vee \neg killed(x)$
h) $likes(John, Peanuts)$

2) Move Negation ($\neg$) inwards & write

3) Rename variables, or standardize variables
a. $\forall x \neg food(x) \vee likes(John, x)$
b. $food(Apple) \wedge food(vegetables)$
c. $\forall y \forall z \neg eats(y,z) \vee killed(y) \vee food(z)$
d. $eats(Anil, Peanuts) \wedge alive(Anil)$
e. $\forall w \neg eats(Anil, w) \vee eats(Harry, w)$
f. $\forall g [killed(g)] \vee alive(g)$
g. $\forall k \neg alive(k) \vee \neg killed(k)$
h. $likes(John, Peanuts)$

4) Drop Universal Quantification
a. $\neg food(x) \vee likes(John, x)$
b. $food(Apples)$
c. $food(vegetables)$
d. $\neg eats(y,z) \vee killed(g) \vee food(z)$
e. $eats(Anil, Peanuts)$
f. $alive(Anil)$
g. $\neg eats(Anil, w) \vee eats(Harry, w)$
h. $killed(g) \vee alive(g)$
i. $\neg alive(k) \vee \neg killed(k)$
j. $likes(John, Peanuts)$


Proof by Resolution:
¬likes(John, Peanuts)
¬food(x) ∨ likes(John, x)
{Peanuts/x}
¬food(Peanuts)
¬eats(y,z) ∨ killed(y) ∨ food
{Peanuts/z}
¬eats(y, Peanuts) ∨ killed(y)
eats(Anil, Peanuts)
{Anil/y}
killed(Anil)
¬alive(k) ∨ ¬killed(k)
{Anil/k}
¬alive(Anil)
alive(Anil)
{ } Hence proved
3/12/24

Code:

```
KB = {
    "food(Apple)": True,
    "food(vegetables)": True,
    "eats(Anil, Peanuts)": True,
    "alive(Anil)": True,
    "likes(John, X)": "food(X)",  # Rule: John likes all food
    "food(X)": "eats(Y, X) and not killed(Y)",  # Rule: Anything eaten and not killed is food
    "eats(Harry, X)": "eats(Anil, X)",  # Rule: Harry eats what Anil eats
    "alive(X)": "not killed(X)",  # Rule: Alive implies not killed
    "not killed(X)": "alive(X)",  # Rule: Not killed implies alive
}

# Function to evaluate if a predicate is true based on the KB
def resolve(predicate):
    # If it's a direct fact in KB
    if predicate in KB and isinstance(KB[predicate], bool):
        return KB[predicate]

    # If it's a derived rule
    if predicate in KB:
        rule = KB[predicate]
        if " and " in rule:  # Handle conjunction
            sub_preds = rule.split(" and ")
            return all(resolve(sub.strip()) for sub in sub_preds)
        elif " or " in rule:  # Handle disjunction
            sub_preds = rule.split(" or ")
            return any(resolve(sub.strip()) for sub in sub_preds)
        elif "not " in rule:  # Handle negation
            sub_pred = rule[4:]  # Remove "not "
            return not resolve(sub_pred.strip())
        else:  # Handle single predicate
            return resolve(rule.strip())

    # If the predicate is a specific query (e.g., likes(John, Peanuts))
    if "(" in predicate:
        func, args = predicate.split("(")
        args = args.strip(")").split(", ")
        if func == "food" and args[0] == "Peanuts":
            return resolve("eats(Anil, Peanuts)") and not resolve("killed(Anil)")
        if func == "likes" and args[0] == "John" and args[1] == "Peanuts":
            return resolve("food(Peanuts)")

    # Default to False if no rule or fact applies
    return False
```

```
# Query to prove: John likes Peanuts
query = "likes(John, Peanuts)"
result = resolve(query)

# Print the result
print(f"Does John like peanuts? {'Yes' if result else 'No'}")
```

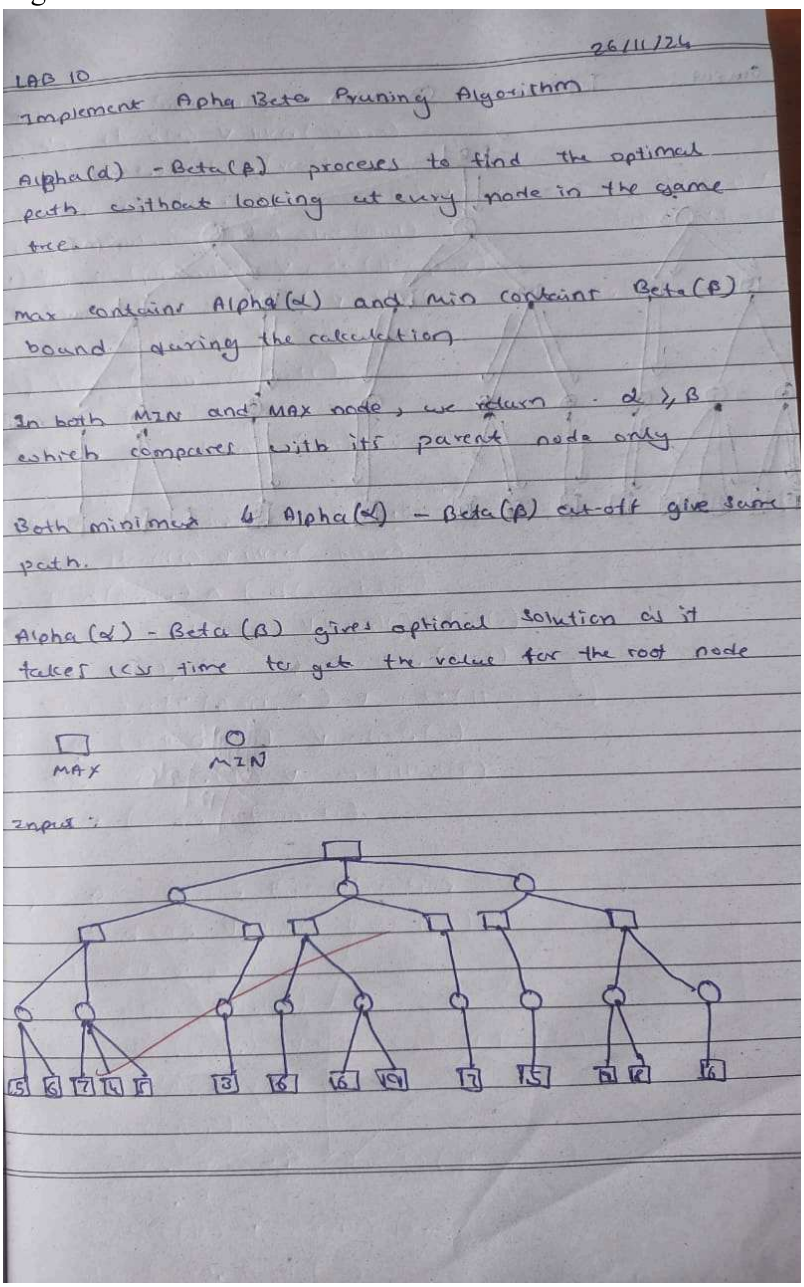
Output :

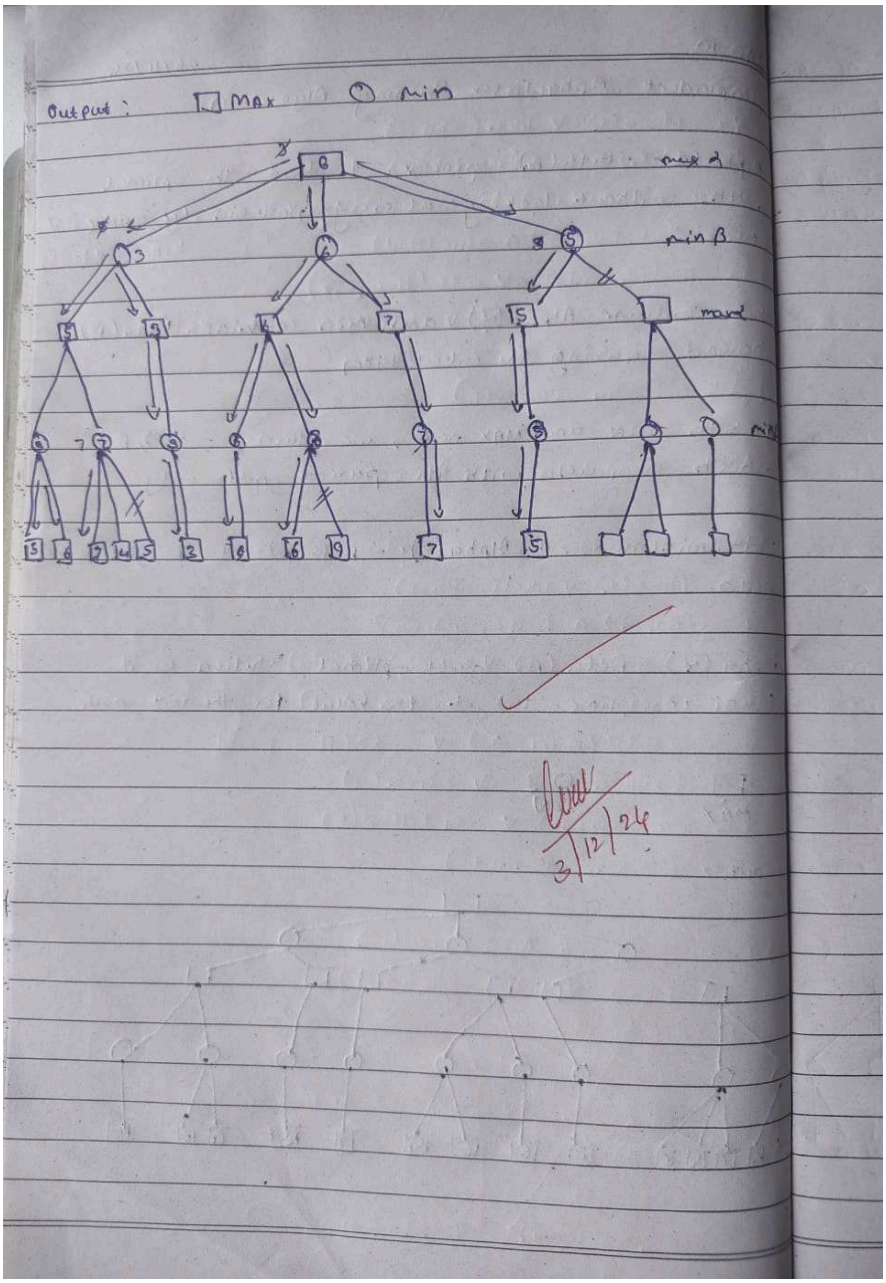
```
Does John like peanuts? Yes
```

**Program 10**

Implement Alpha-Beta Pruning.

Algorithm:




Output:
Max
Min
max α
min β
max
min
3/12/24

Code:

```
import math
def minimax(node, depth, is_maximizing):
    """
    Implement the Minimax algorithm to solve the decision tree.

    Parameters:
    node (dict): The current node in the decision tree, with the following structure:
        {
            'value': int,
            'left': dict or None,
            'right': dict or None
        }
    depth (int): The current depth in the decision tree.
    is_maximizing (bool): Flag to indicate whether the current player is the maximizing player.

    Returns:
    int: The utility value of the current node.
    """
    # Base case: Leaf node
    if node['left'] is None and node['right'] is None:
        return node['value']

    # Recursive case
    if is_maximizing:
        best_value = -math.inf
        if node['left']:
            best_value = max(best_value, minimax(node['left'], depth + 1, False))
        if node['right']:
            best_value = max(best_value, minimax(node['right'], depth + 1, False))
        return best_value
    else:
        best_value = math.inf
        if node['left']:
            best_value = min(best_value, minimax(node['left'], depth + 1, True))
        if node['right']:
            best_value = min(best_value, minimax(node['right'], depth + 1, True))
        return best_value

# Example usage
decision_tree = {
    'value': 5,
    'left': {
        'value': 6,
        'left': {
            'value': 7,
```

```
        'left': {
            'value': 4,
            'left': None,
            'right': None
        },
        'right': {
            'value': 5,
            'left': None,
            'right': None
        }
    },
    'right': {
        'value': 3,
        'left': {
            'value': 6,
            'left': None,
            'right': None
        },
        'right': {
            'value': 9,
            'left': None,
            'right': None
        }
    }
},
'right': {
    'value': 8,
    'left': {
        'value': 7,
        'left': {
            'value': 6,
            'left': None,
            'right': None
        },
        'right': {
            'value': 9,
            'left': None,
            'right': None
        }
    },
    'right': {
        'value': 8,
        'left': {
            'value': 6,
            'left': None,
            'right': None
        },
```

```
            'right': None
        }
    }
}

# Find the best move for the maximizing player
best_value = minimax(decision_tree, 0, True)
print(f"The best value for the maximizing player is: {best_value}")
```

Output :

```
The best value for the maximizing player is: 6
```