VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

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

(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 **Shreyansh Sethiya (1BM22CS269),** 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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Index

Github Link: https://github.com/Shreyanshsethiya/AILAB

Program 1

Implement Tic –Tac –Toe Game

Algorithm:

LAB-1

TIC TAC TOE

Algorithm:

1) Initialize board as a 3×3 grid of empty spaces

2) Set current-player to "X".

3) Print enter instruction for players.

4) Repeat until game over

- Print the current board
- Prompt current-player to enter a move (1-9)
- convert input to board position (row, col)
- if position is valid (empty), place the player's marker, else repeat input.
- check if current player wins by checking rows, columns and diagonals
- If wins, declare that winner and endgame
- If full, declare a tie and end game
- Switch current player from X to O or vice versa.

5) End

Code:

```
def print_board(board):
    print("\n")
    for row in board:
        print("|".join(row))
        print("-" * 5)
    print("\n")


def check_winner(board, player):
    for row in board:
        if all([cell == player for cell in row]):
            return True
    for col in range(3):
        if all([board[row][col] == player for row in range(3)]):
            return True
    if board[0][0] == player and board[1][1] == player and board[2][2] == player:
        return True
    if board[0][2] == player and board[1][1] == player and board[2][0] == player:
        return True
    return False


def is_board_full(board):
    return all([cell != ' ' for row in board for cell in row])
```

```
def player_move(board, player):
    while True:
        try:
            move = int(input(f"Player {player}, enter your move (1-9): ")) - 1
            if move < 0 or move >= 9:
                raise ValueError
            row, col = divmod(move, 3)
            if board[row][col] == ' ':
                board[row][col] = player
                break
            else:
                print("This spot is already taken. Try again.")
        except ValueError:
            print("Invalid input. Enter a number between 1 and 9.")


def play_game():
    board = [[' ' for _ in range(3)] for _ in range(3)]
    current_player = 'X'
    game_over = False
    print("Welcome to Tic Tac Toe!")
    print("Player X goes first.")
    print("Enter a number between 1-9 to make your move (1 is top-left and 9 is bottom-right).")
    print_board(board)
```

```
    while not game_over:
        player_move(board, current_player)
        print_board(board)
        if check_winner(board, current_player):
            print(f"Player {current_player} wins!")
            game_over = True
        elif is_board_full(board):
            print("It's a tie!")
            game_over = True
        else
   current_player = 'O' if current_player == 'X' else 'X'
 if __name__ == "__main__":
    play_game()
```

```
Player X, enter your move (1-9):
Invalid input. Enter a number between 1 and 9.
Player X, enter your move (1-9): 6


X|O|X
-----
O|X|X
-----
 | |O
-----

Player O, enter your move (1-9): 7

X|O|X
-----
O|X|X
-----
O| |O
-----

Player X, enter your move (1-9): 8

X|O|X
-----
O|X|X
-----
O|X|O
-----

It's a tie!
```

```
Player X, enter your move (1-9): 4

X|O|
-----
X| |
-----
 | |
-----

Player O, enter your move (1-9): 5

X|O|
-----
X|O|
-----
 | |
-----

Player X, enter your move (1-9): 7

X|O|
-----
X|O|
-----
X| |
-----

Player X wins!
```

Implement Vaccum Cleaner Agent

LAB - 2

VACCUM CLEANER

Algorithm:

1) Initialize a global counter to track the number of cleaning actions and create a state dictionary to hold the cleanliness status of rooms A and B.

2) Define the recursive function that take the current state and location as parameter

3) In the function, check if both rooms A and B are clean (both values are 0). If they are, print "Turning Vacuum off" and return

4) If the current location is dirty, clean it by setting its value to 0, increment the counter

5) Ask user if current location clean (0 for clean, 1 for dirty) update state

6) If current location still dirty, recursively call the function

7) If next location dirty recursively call function, until both rooms are clean

```
count = 0
def rec(state, loc):
    global count
    if state['A'] == 0 and state['B'] == 0:
        print("Turning vacuum off")
        return
```

```
    if state[loc] == 1:
        state[loc] = 0
        count += 1
        print(f"Cleaned {loc}.")
        next_loc = 'B' if loc == 'A' else 'A'
        state[loc] = int(input(f"Is {loc} clean now? (0 if clean, 1 if dirty): "))
        if(state[next_loc]!=1):
          state[next_loc]=int(input(f"Is {next_loc} dirty? (0 if clean, 1 if dirty): "))
    if(state[loc]==1):
       rec(state,loc)
    else:
      next_loc = 'B' if loc == 'A' else 'A'
      dire="left" if loc=="B" else "right"
      print(loc,"is clean")
      print(f"Moving vacuum {dire}")
      if state[next_loc] == 1:
          rec(state, next_loc)


state = {}
state['A'] = int(input("Enter state of A (0 for clean, 1 for dirty): "))
state['B'] = int(input("Enter state of B (0 for clean, 1 for dirty): "))
loc = input("Enter location (A or B): ")
rec(state, loc)
print("Cost:",count)
```

print(state)

```
Enter state of A (0 for clean, 1 for dirty): 0
Enter state of B (0 for clean, 1 for dirty): 0
Enter location (A or B): A
Turning vacuum off
Cost: 0
{'A': 0, 'B': 0}
```

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)

8 - Puzzle Problem

DFS →

Algorithm →

→ Define the goal state as a string 012345678 representing solved puzzle

→ Initialize a stack to store current board configuration and position of empty tile

→ Created a visited set to keep track of already explored configuration to avoid cycles

→ Generate all possible moves by swapping empty tile with adjacent tiles (up, down, left, right)

→ For each new configuration created check if already visited, if not add to visited set

→ Recursively call the DFS function with new configuration and updated empty tile position

→ If solution is found in recursion call, b/w paths to solution else return no solution exist.

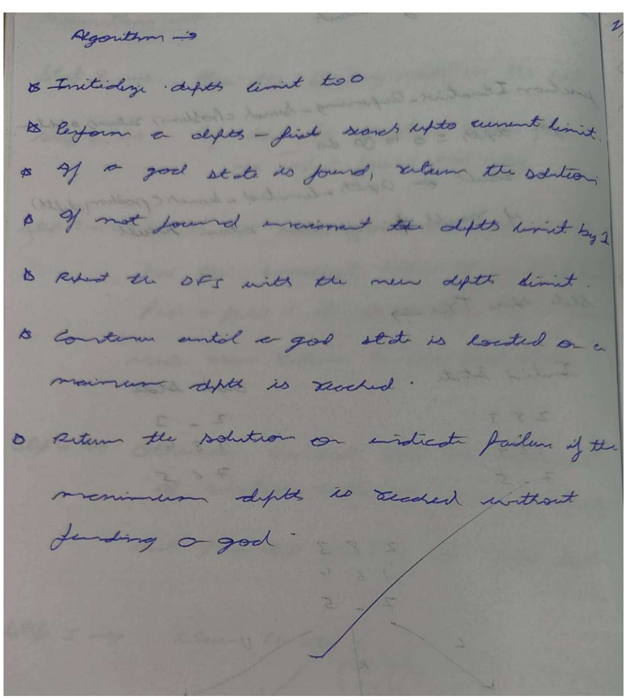
```
goal_state = [[1, 2, 3],
              [4, 5, 6],
              [7, 8, 0]]

def is_goal(state):
    return state == goal_state
def find_blank(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
def swap(state, i1, j1, i2, j2):
    new_state = [row[:] for row in state]
    new_state[i1][j1], new_state[i2][j2] = new_state[i2][j2], new_state[i1][j1]
    return new_state
def get_neighbors(state):
    neighbors = []
    i, j = find_blank(state)
    if i > 0:
        neighbors.append(swap(state, i, j, i - 1, j))
    if i < 2:
        neighbors.append(swap(state, i, j, i + 1, j))
    if j > 0:
        neighbors.append(swap(state, i, j, i, j - 1))
```

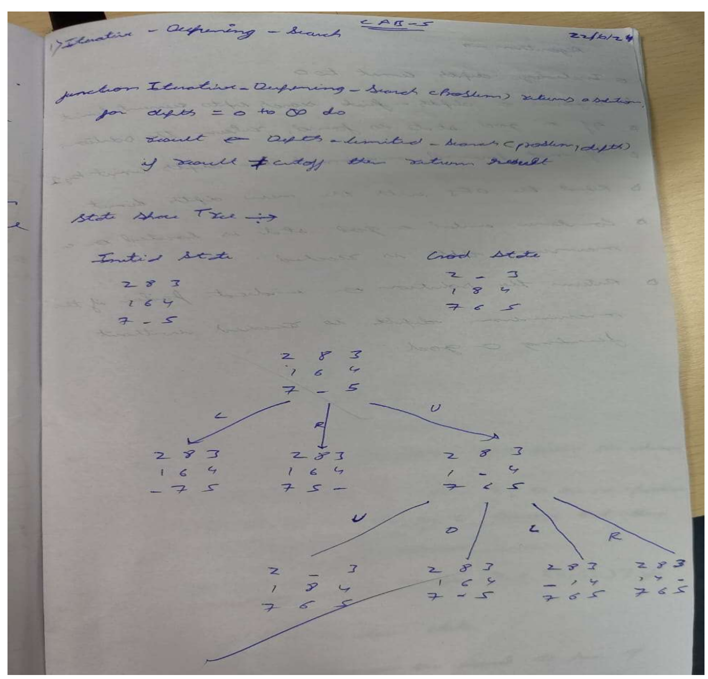
```
    if j < 2:
        neighbors.append(swap(state, i, j, i, j + 1))
    return neighbors
def dfs(state, visited, path):
    state_tuple = tuple(tuple(row) for row in state)
    if state_tuple in visited:
        return None
    visited.add(state_tuple)
    if is_goal(state):
        return path
    for neighbor in get_neighbors(state):
        result = dfs(neighbor, visited, path + [neighbor])
        if result is not None:
            return result

    return None

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

visited = set()
solution = dfs(initial_state, visited, [])
```

```
if solution:
    print("Solution found in", len(solution), "steps:")
    for step in solution:
        for row in step:
            print(row)
        print()
else:
    print("No solution found.")
```

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

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

Implement Iterative deepening search algorithm


Algorithm ->
* Initialize depth limit to 0
* Perform a depth-first search upto current limit
* If a goal state is found, return the solution
* If not found increment the depth limit by 1
* Repeat the DFS with the new depth limit.
* Continue until a goal state is located or a maximum depth is reached.
* Return the solution or indicate failure if the maximum depth is reached without finding a goal.



```
class PuzzleState:
    def __init__(self, board, moves=0):
        self.board = board
        self.blank_index = board.index(0)  # Find the index of the blank space (0)
        self.moves = moves

    def get_possible_moves(self):
        possible_moves = []
        row, col = divmod(self.blank_index, 3)

        # Define possible movements: up, down, left, right
        directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]  # (row_change, col_change)

        for dr, dc in directions:
            new_row, new_col = row + dr, col + dc
            if 0 <= new_row < 3 and 0 <= new_col < 3:
                new_blank_index = new_row * 3 + new_col
                new_board = self.board[:]
                # Swap the blank with the adjacent tile
                new_board[self.blank_index], new_board[new_blank_index] =
new_board[new_blank_index], new_board[self.blank_index]
                possible_moves.append(PuzzleState(new_board, self.moves + 1))
```

```
        return possible_moves

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

def depth_limited_search(state, depth, goal_state):
    if state.is_goal(goal_state):
        return state
    if depth == 0:
        return None

    for next_state in state.get_possible_moves():
        result = depth_limited_search(next_state, depth - 1, goal_state)
        if result is not None:
            return result

    return None

def iterative_deepening_search(initial_state, goal_state):
    depth = 0
    while True:
        result = depth_limited_search(initial_state, depth, goal_state)
        if result is not None:
            return result
```

```
        depth += 1


# Example Usage
if __name__ == "__main__":
    initial_board = [2, 8, 3, 1, 6, 4, 7, 0, 5]  # Initial state
    goal_state = [2, 0, 3, 1, 8, 4, 7, 6, 5]  # Final state
    initial_state = PuzzleState(initial_board)

    solution = iterative_deepening_search(initial_state, goal_state)

    if solution:
        print("Solution found!")
        print("Moves:", solution.moves)
        print("Final Board State:", solution.board)
    else:
        print("No solution found.")
```

```
Solution found!
Moves: 2
Final Board State: [2, 0, 3, 1, 8, 4, 7, 6, 5]
```

Program 3

Implement A* Search Algorithm

Misplaced Tiles:

Algorithm →

Step 1 → Place the starting node in the list.

Step 2 → If list is empty, return failure no output found and stop.

Step 3 → Select the node from the list which has the smallest value of evaluation $f(n) + h(n)$, if node n is goal node then return success and stop.

Step 4 → Otherwise, generate all the successors of selected node n. and if already not presented in list add into list.

Step 5 → Return to step 3

```
import heapq

def manhattan_distance(state, goal):

    distance = 0

    for i in range(3):

        for j in range(3):

            tile = state[i][j]

            if tile != 0:

                for r in range(3):

                    for c in range(3):

                        if goal[r][c] == tile:

                            target_row, target_col = r, c

                            break
```

```
            distance += abs(target_row - i) + abs(target_col - j)
    return distance


def findmin(open_list, goal):
    minv = float('inf')
    best_state = None
    for state in open_list:
        h = manhattan_distance(state['state'], goal)
        f = state['g'] + h
        if f < minv:
            minv = f
            best_state = state
    open_list.remove(best_state)
    return best_state


def operation(state):
    next_states = []
    blank_pos = find_blank_position(state['state'])
    for move in ['up', 'down', 'left', 'right']:
        new_state = apply_move(state['state'], blank_pos, move)
        if new_state:
            next_states.append({
                'state': new_state,
                'parent': state,
```

```
            'move': move,
            'g': state['g'] + 1
        })
    return next_states

def find_blank_position(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
    return None

def apply_move(state, blank_pos, move):
    i, j = blank_pos
    new_state = [row[:] for row in state]
    if move == 'up' and i > 0:
        new_state[i][j], new_state[i - 1][j] = new_state[i - 1][j], new_state[i][j]
    elif move == 'down' and i < 2:
        new_state[i][j], new_state[i + 1][j] = new_state[i + 1][j], new_state[i][j]
    elif move == 'left' and j > 0:
        new_state[i][j], new_state[i][j - 1] = new_state[i][j - 1], new_state[i][j]
    elif move == 'right' and j < 2:
        new_state[i][j], new_state[i][j + 1] = new_state[i][j + 1], new_state[i][j]
    else:
```

```
        return None
    return new_state


def print_state(state):
    for row in state:
        print(' '.join(map(str, row)))
initial_state = [[2, 8, 3], [1, 6, 4], [7, 0, 5]]
goal_state = [[1, 2, 3], [8, 0, 4], [7, 6, 5]]


open_list = [{'state': initial_state, 'parent': None, 'move': None, 'g': 0}]
visited_states = []


while open_list:
    best_state = findmin(open_list, goal_state)


    h = manhattan_distance(best_state['state'], goal_state)
    f = best_state['g'] + h


    print(f"g(n) = {best_state['g']}, h(n) = {h}, f(n) = {f}")
    print_state(best_state['state'])
    print()


    if h == 0:
        print("Goal state reached!")
```

```
        break

    visited_states.append(best_state['state'])
    next_states = operation(best_state)

    for state in next_states:
        if state['state'] not in visited_states:
            open_list.append(state)

if h == 0:
    moves = []
    goal_state_reached = best_state
    while goal_state_reached['move'] is not None:
        moves.append(goal_state_reached['move'])
        goal_state_reached = goal_state_reached['parent']
    moves.reverse()
    print("\nMoves to reach the goal state:", moves)
else:
    print("No solution found.")
```

```
g(n) = 0, h(n) = 5, f(n) = 5
2 8 3
1 6 4
7 0 5

g(n) = 1, h(n) = 4, f(n) = 5
2 8 3
1 0 4
7 6 5

g(n) = 2, h(n) = 3, f(n) = 5
2 0 3
1 8 4
7 6 5

g(n) = 3, h(n) = 2, f(n) = 5
0 2 3
1 8 4
7 6 5

g(n) = 4, h(n) = 1, f(n) = 5
1 2 3
0 8 4
7 6 5

g(n) = 5, h(n) = 0, f(n) = 5
1 2 3
8 0 4
7 6 5

Goal state reached!

Moves to reach the goal state: ['up', 'up', 'left', 'down', 'right']
```

Misplaced Tiles:

```
import heapq


def find_blank_tile(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
    return None


def count_misplaced_tiles(state, goal):
    misplaced = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != 0 and state[i][j] != goal[i][j]:
                misplaced += 1
```

```
    return misplaced


def generate_moves(state):
    moves = []
    x, y = find_blank_tile(state)
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]

    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]
            moves.append(new_state)
    return moves


def print_state(state):
    for row in state:
        print(row)
    print()


def a_star_8_puzzle(start, goal):

    open_list = []
```

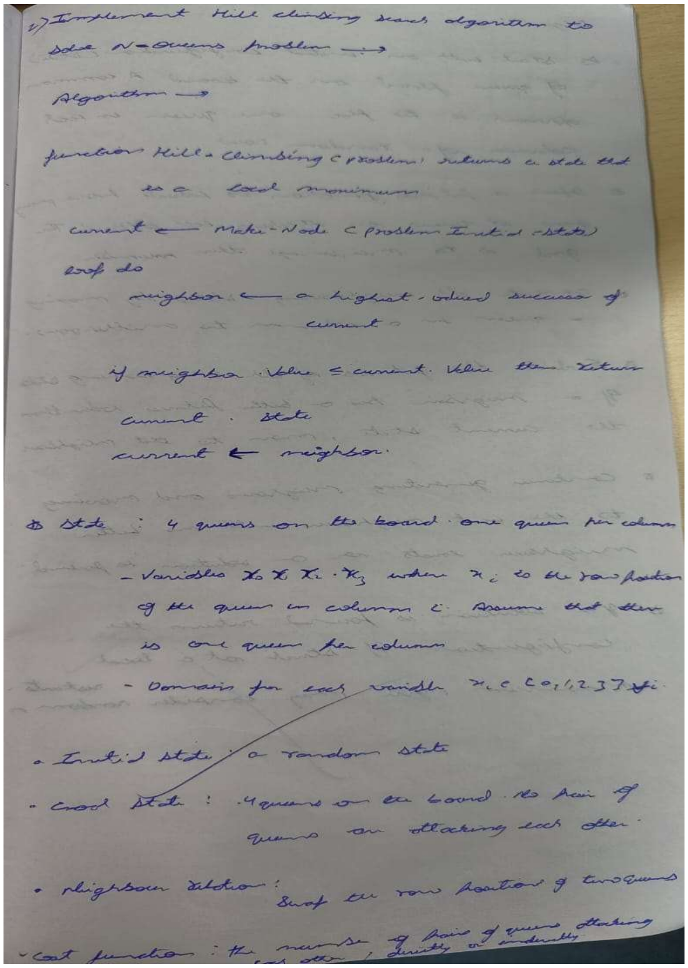
```
heapq.heappush(open_list, (count_misplaced_tiles(start, goal), 0, start, None))

visited = set()

while open_list:

    f_n, g_n, current_state, previous_state = heapq.heappop(open_list)

    print(f"g(n) = {g_n}, h(n) = {f_n - g_n}, f(n) = {f_n}")
    print_state(current_state)

    if current_state == goal:
        print("Goal state reached!")
        return

    visited.add(tuple(map(tuple, current_state)))

    for move in generate_moves(current_state):
        move_tuple = tuple(map(tuple, move))
        if move_tuple not in visited:

            g_move = g_n + 1
            h_move = count_misplaced_tiles(move, goal)
```

```
            f_move = g_move + h_move
            heapq.heappush(open_list, (f_move, g_move, move, current_state))


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


a_star_8_puzzle(start_state, goal_state)
```

```
g(n) = 0, h(n) = 4, f(n) = 4
[2, 8, 3]
[1, 6, 4]
[7, 0, 5]

g(n) = 1, h(n) = 3, f(n) = 4
[2, 8, 3]
[1, 0, 4]
[7, 6, 5]

g(n) = 2, h(n) = 3, f(n) = 5
[2, 0, 3]
[1, 8, 4]
[7, 6, 5]

g(n) = 2, h(n) = 3, f(n) = 5
[2, 8, 3]
[0, 1, 4]
[7, 6, 5]

g(n) = 3, h(n) = 2, f(n) = 5
[0, 2, 3]
[1, 8, 4]
[7, 6, 5]

g(n) = 4, h(n) = 1, f(n) = 5
[1, 2, 3]
[0, 8, 4]
[7, 6, 5]

g(n) = 5, h(n) = 0, f(n) = 5
[1, 2, 3]
[8, 0, 4]
[7, 6, 5]

Goal state reached!
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem.



2) Implement Hill climbing search algorithm to solve N-Queens problem →

Algorithm →

function Hill-Climbing (problem) returns a state that is a local maximum

current ← Make-Node (problem.Initial-State)

loop do

neighbor ← a highest-valued successor of current

if neighbor.Value ≤ current.Value then return current.State

current ← neighbor.

• State : 4 queens on the board. one queen per column

– Variables x_0, x_1, x_2, x_3 where x_i is the row position of the queen in column i. Assume that there is one queen per column

– Domain for each variable $x_i \in \{0,1,2,3\}$ ∀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 row position of two queens

• Cost function : the number of pairs of queens attacking each other, directly or indirectly

```
import random

class NQueens:

    def __init__(self, n):

        self.n = n

        self.board = self.init_board()

    def init_board(self):

        # Randomly place one queen in each column

        return [random.randint(0, self.n - 1) for _ in range(self.n)]


    def fitness(self, board):
```

```
        # Count the number of pairs of queens attacking each other
        conflicts = 0
        for col in range(self.n):
            for other_col in range(col + 1, self.n):
                if board[col] == board[other_col] or abs(board[col] - board[other_col]) == abs(col -
other_col):
                    conflicts += 1
        return conflicts
    def get_neighbors(self, board):
        neighbors = []
        for col in range(self.n):
            for row in range(self.n):
                if row != board[col]:  # Move queen to a different row in the same column
                    new_board = board[:]
                    new_board[col] = row
                    neighbors.append(new_board)
        return neighbors
    def hill_climbing(self):
        current_board = self.board
        current_fitness = self.fitness(current_board)

        while current_fitness > 0:
            neighbors = self.get_neighbors(current_board)
            next_board = None
            next_fitness = current_fitness
```

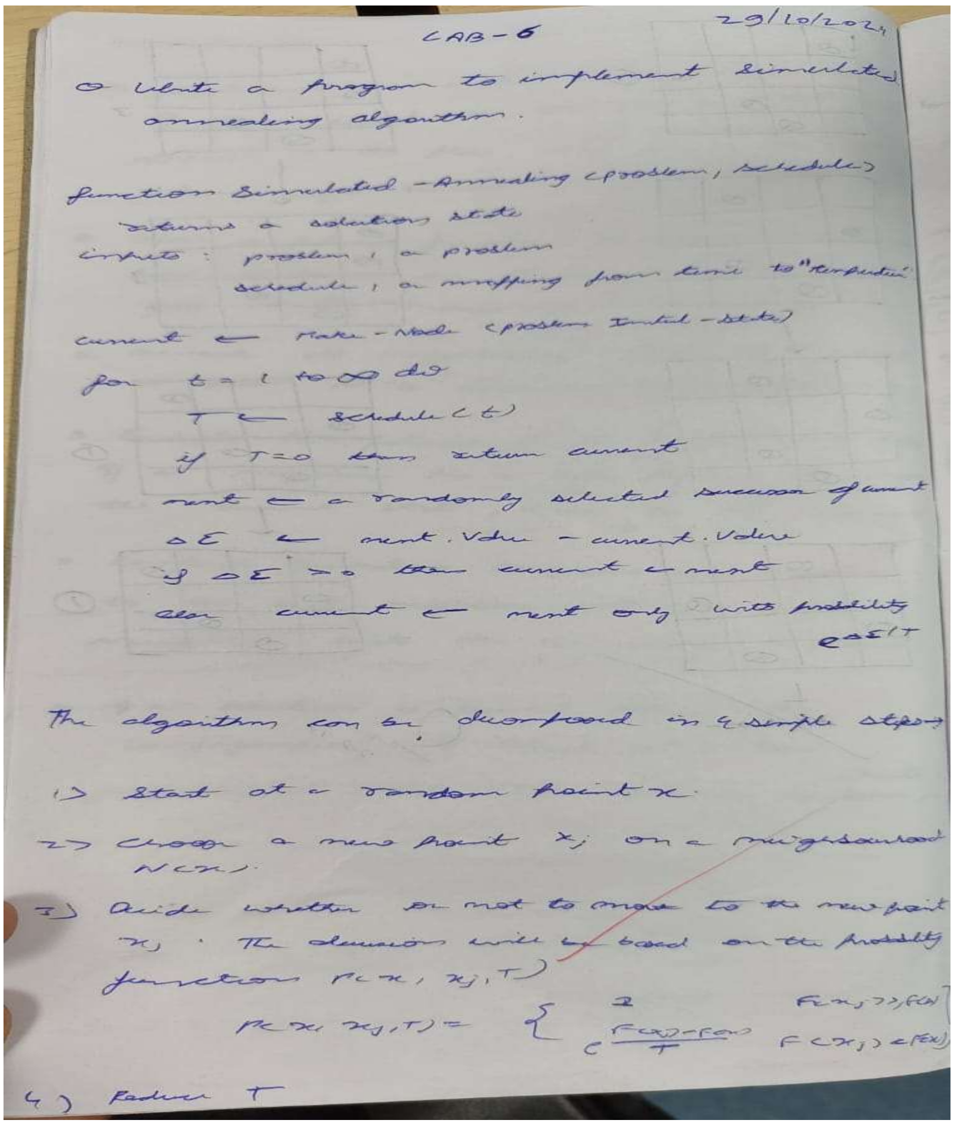
```
        for neighbor in neighbors:
            neighbor_fitness = self.fitness(neighbor)
            if neighbor_fitness < next_fitness:
                next_fitness = neighbor_fitness
                next_board = neighbor
        if next_board is None:
            # Stuck at local maximum, can either return or restart
            print("Stuck at local maximum. Restarting...")
            self.board = self.init_board()
            current_board = self.board
            current_fitness = self.fitness(current_board)
        else:
            current_board = next_board
            current_fitness = next_fitness
    return current_board
# Example usage
if __name__ == "__main__":
    n = 4  # Size of the board (N)
    n_queens_solver = NQueens(n)
    solution = n_queens_solver.hill_climbing()

    print("Solution:")
    for row in solution:
        line = ['Q' if i == row else '.' for i in range(n)]
```

```
        print(' '.join(line))
```

```
Solution:
. Q . .
. . . Q
Q . . .
. . Q .
```

Program 5

Simulated Annealing to Solve 8-Queens problem.



LAB-6 29/10/2024

Q 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 $e^{\Delta E/T}$

The algorithm can be decomposed in 4 simple steps →

1> Start at a random point x.

2> Choose a new point x_j on a neighbourhood N(x).

3) Decide whether or not to move to the new point x_j. The decision will be based on the probability function $P(x, x_j, T)$

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

4) Reduce T

```
import random

import math
```

```
def print_board(state):
    size = len(state)
    for i in range(size):
        row = ['.'] * size
        row[state[i]] = 'Q'
        print(' '.join(row))
    print()

def calculate_conflicts(state):
    conflicts = 0
    size = len(state)
    for i in range(size):
        for j in range(i + 1, size):
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts

def random_state(size):
    return [random.randint(0, size - 1) for _ in range(size)]

def neighbor(state):
    new_state = state[:]
    idx = random.randint(0, len(state) - 1)
```

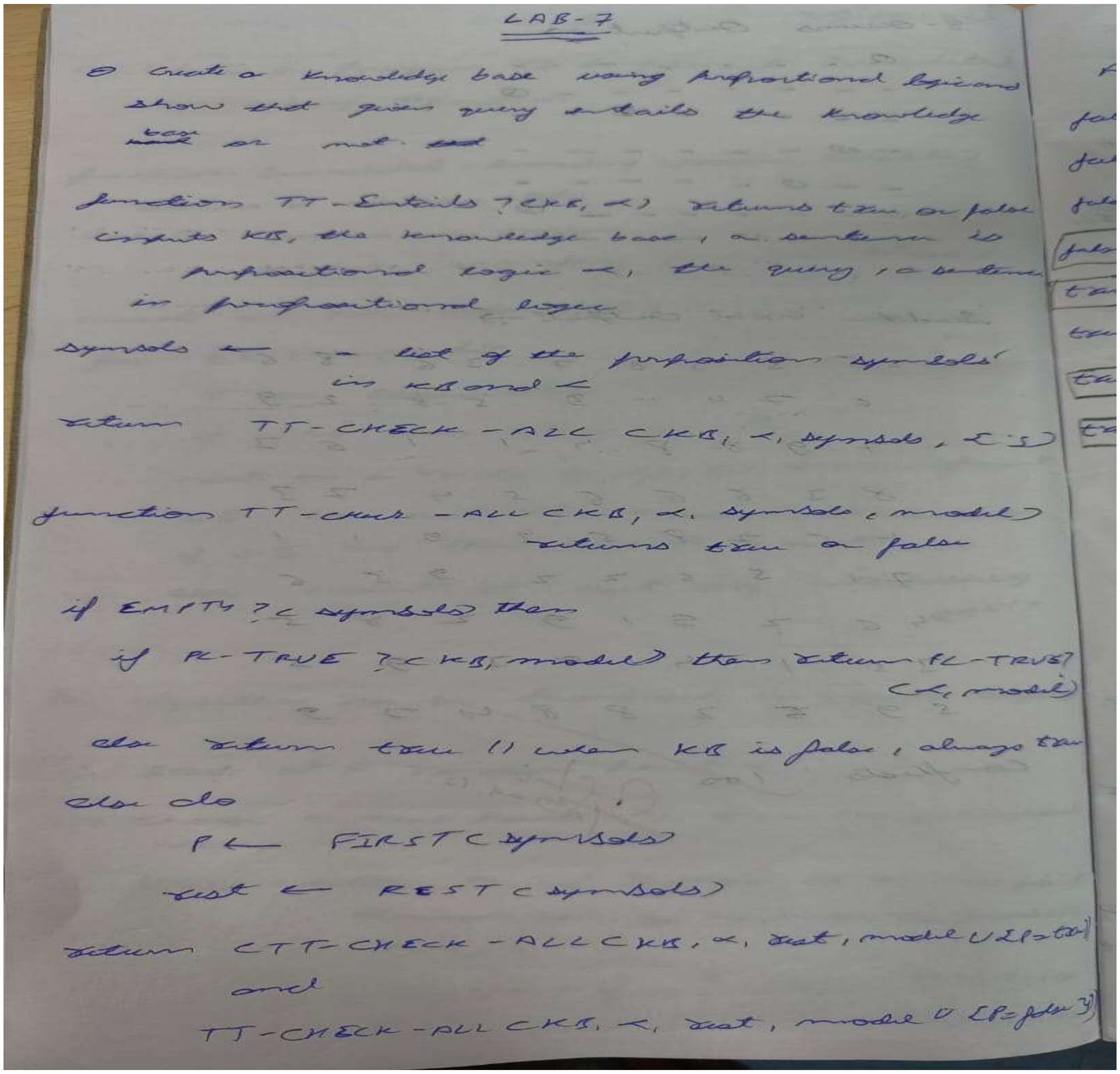
```
    new_state[idx] = random.randint(0, len(state) - 1)
    return new_state


def simulated_annealing(size, initial_temp, cooling_rate):
    current_state = random_state(size)
    current_conflicts = calculate_conflicts(current_state)
    temperature = initial_temp

    while temperature > 1:
        new_state = neighbor(current_state)
        new_conflicts = calculate_conflicts(new_state)

        # If new state is better, accept it
        if new_conflicts < current_conflicts:
            current_state, current_conflicts = new_state, new_conflicts
        else:
            # Accept with a probability based on temperature
            acceptance_probability = math.exp((current_conflicts - new_conflicts) / temperature)
            if random.random() < acceptance_probability:
                current_state, current_conflicts = new_state, new_conflicts

        temperature *= cooling_rate

    return current_state
```

```
def main():
    size = 8
    initial_temp = 1000
    cooling_rate = 0.995

    solution = simulated_annealing(size, initial_temp, cooling_rate)
    print("Solution found:")
    print_board(solution)
    print("Conflicts:", calculate_conflicts(solution))

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

```
Solution found:
. . . . . . Q .
. . Q . . . . .
. . . . . . . Q
Q . . . . . . .
. . . . Q . . .
. . . Q . . . .
. . . . Q . . .
. . . . . Q . .

Conflicts: 6
```

Program 6

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


LAB-7

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

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

symbols ← a list of the proposition symbols in KB and α

return TT-CHECK-ALL(KB, α, symbols, { })

function TT-CHECK-ALL(KB, α, symbols, model) returns true or false

if EMPTY?(symbols) then
if PL-TRUE?(KB, model) then return PL-TRUE?(α, model)
else return true // when KB is false, always true
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}))

```
def truth_table_entailment():
    print(f"{'A':<7}{'B':<7}{'C':<7}{'A or C':<12}{'B or not C':<15}{'KB':<8}{'alpha':<10}")
    print("-" * 65)
    all_entail = True
```

```
    for A in [False, True]:
        for B in [False, True]:
            for C in [False, True]:
                # Calculate individual components
                A_or_C = A or C                    # A or C
                B_or_not_C = B or (not C)          # B or not C
                KB = A_or_C and B_or_not_C         # KB = (A or C) and (B or not C)
                alpha = A or B                     # alpha = A or B

                # Determine if KB entails alpha for this row
                kb_entails_alpha = (not KB) or alpha  # True if KB implies alpha

                # If in any row KB does not entail alpha, set flag to False
                if not kb_entails_alpha:
                    all_entail = False

                # Print the results for this row
                print(f"{str(A):<7}{str(B):<7}{str(C):<7}{str(A_or_C):<12}{str(B_or_not_C):<15}{str(KB)
:<8}{str(alpha):<10}")

    # Final result based on all rows
    if all_entail:
        print("\nKB entails alpha for all cases.")
    else:
        print("\nKB does not entail alpha for all cases.")
```

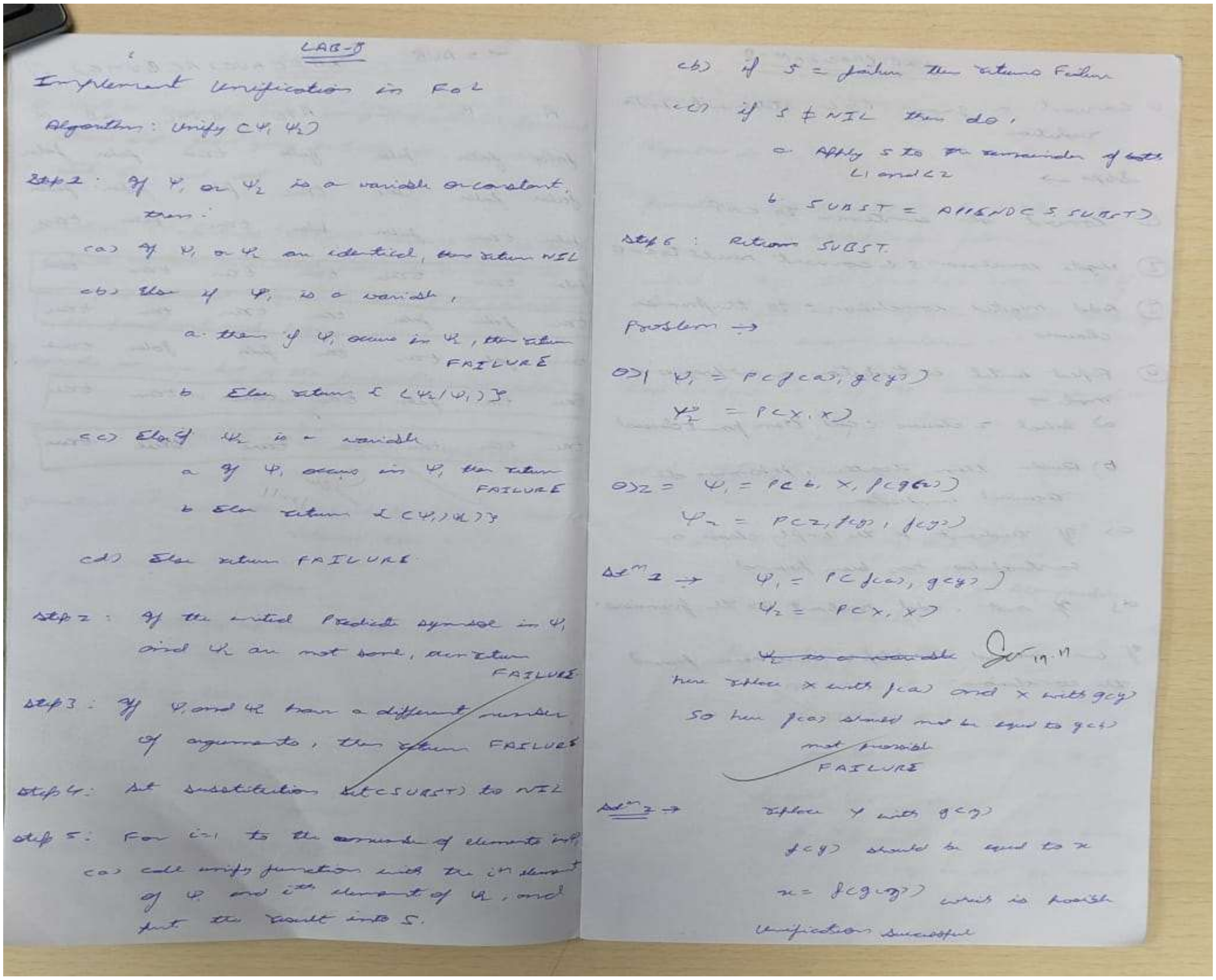
Run the function to display the truth table and final result

truth_table_entailment()

```
A      B      C      A or C      B or not C      KB      alpha
----------------------------------------------------------------
False  False  False  False       True            False   False
False  False  True   True        False           False   False
False  True   False  False       True            False   True
False  True   True   True        True            True    True
True   False  False  True        True            True    True
True   False  True   True        False           False   True
True   True   False  True        True            True    True
True   True   True   True        True            True    True

KB entails alpha for all cases.
```

Program 7

Implement unification in first order logic.



LAB-8

Implement Unification in FOL

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 and L2

b. SUBST = APPEND(S, SUBST)

Step 6: Return SUBST.

Problem →

Q1) Ψ_1 = P(f(a), g(y))

Ψ_2 = P(x, x)

Q2) Ψ_1 = P(b, x, f(g(z)))

Ψ_2 = P(z, f(y), f(y))

Ans 1 → Ψ_1 = P(f(a), g(y))

Ψ_2 = P(x, x)

~~Ψ_2 is a variable~~ 19.11

here replace x with f(a) and x with g(y)

So here f(a) should not be equal to g(y)

not possible

FAILURE

Ans 2 → replace y with g(z)

f(y) should be equal to x

x = f(g(z)) which is possible

Unification successful

def unify(expr1, expr2, substitution=None):

"""

Perform unification on two expressions in first-order logic.

Args:

expr1: The first expression (can be a variable, constant, or list representing a function).

expr2: The second expression.

substitution: The current substitution (dictionary).

```
    Returns:
        A dictionary representing the most general unifier (MGU), or None if unification fails.
    """
    if substitution is None:
        substitution = {}

    # Debug: Print inputs and current substitution
    print(f"Unifying {expr1} and {expr2} with substitution {substitution}")

    # Apply existing substitutions to both expressions
    expr1 = apply_substitution(expr1, substitution)
    expr2 = apply_substitution(expr2, substitution)

    # Debug: Print expressions after applying substitution
    print(f"After substitution: {expr1} and {expr2}")

    # Case 1: If expressions are identical, no substitution is needed
    if expr1 == expr2:
        return substitution

    # Case 2: If expr1 is a variable
    if is_variable(expr1):
        return unify_variable(expr1, expr2, substitution)
```

```
    # Case 3: If expr2 is a variable
    if is_variable(expr2):
        return unify_variable(expr2, expr1, substitution)

    # Case 4: If both are compound expressions (e.g., functions or predicates)
    if is_compound(expr1) and is_compound(expr2):
        if expr1[0] != expr2[0] or len(expr1) != len(expr2):
            print(f"Failure: Predicate names or arity mismatch {expr1[0]} != {expr2[0]}")
            return None  # Function names or arity mismatch
        for arg1, arg2 in zip(expr1[1:], expr2[1:]):
            substitution = unify(arg1, arg2, substitution)
            if substitution is None:
                print(f"Failure: Could not unify arguments {arg1} and {arg2}")
                return None
        return substitution

    # Case 5: Otherwise, unification fails
    print(f"Failure: Could not unify {expr1} and {expr2}")
    return None

def unify_variable(var, expr, substitution):
    """
    Handles the unification of a variable with an expression.
```

```
    Args:
        var: The variable.
        expr: The expression to unify with.
        substitution: The current substitution.

    Returns:
        The updated substitution, or None if unification fails.
    """
    if var in substitution:
        # Apply substitution recursively
        return unify(substitution[var], expr, substitution)
    elif occurs_check(var, expr):
        # Occurs check fails if the variable appears in the term it's being unified with
        print(f"Occurs check failed: {var} in {expr}")
        return None
    else:
        substitution[var] = expr
        print(f"Substitution added: {var} -> {expr}")
        return substitution

def occurs_check(var, expr):
    """
    Checks if a variable occurs in an expression (to prevent cyclic substitutions).
```

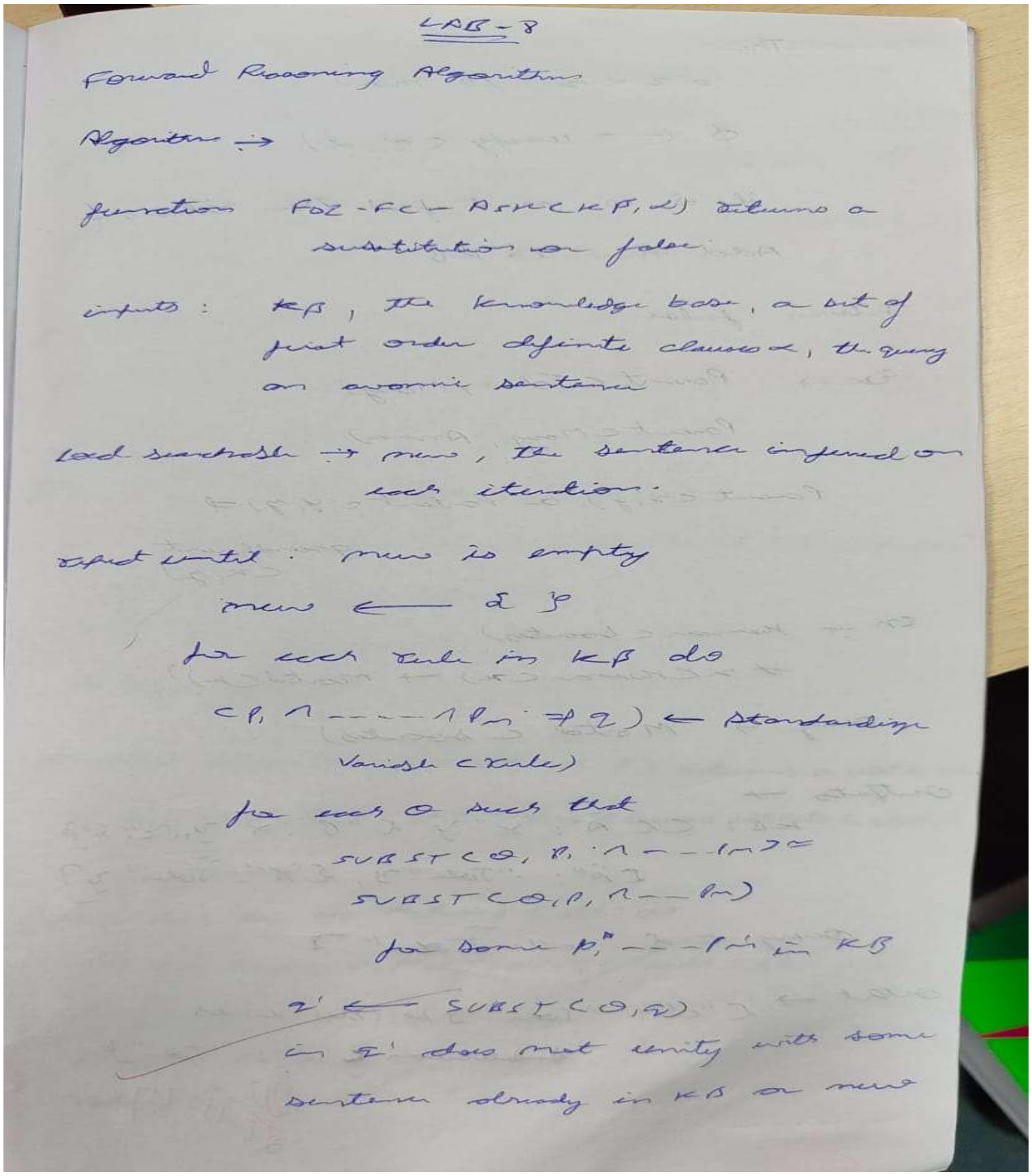
```
    Args:
        var: The variable to check.
        expr: The expression to check against.

    Returns:
        True if the variable occurs in the expression, otherwise False.
    """
    if var == expr:
        return True
    elif is_compound(expr):
        return any(occurs_check(var, arg) for arg in expr[1:])
    return False


def is_variable(expr):
    """Checks if the expression is a variable."""
    return isinstance(expr, str) and expr[0].islower()


def is_compound(expr):
    """Checks if the expression is compound (e.g., function or predicate)."""
    return isinstance(expr, list) and len(expr) > 0


def apply_substitution(expr, substitution):
    """
```

```
    Applies a substitution to an expression.

    Args:
        expr: The expression to apply the substitution to.
        substitution: The current substitution.

    Returns:
        The updated expression with substitutions applied.
    """
    if is_variable(expr) and expr in substitution:
        return apply_substitution(substitution[expr], substitution)
    elif is_compound(expr):
        return [apply_substitution(arg, substitution) for arg in expr]
    return expr

# Example Usage:
expr1 = ['P', 'X', 'Y']
expr2 = ['P', 'a', 'Z']
result = unify(expr1, expr2)
print("Unification Result:", result)
```

```
Unifying ['P', 'X', 'Y'] and ['P', 'a', 'Z'] with substitution {}
After substitution: ['P', 'X', 'Y'] and ['P', 'a', 'Z']
Unifying X and a with substitution {}
After substitution: X and a
Substitution added: a -> X
Unifying Y and Z with substitution {'a': 'X'}
After substitution: Y and Z
Failure: Could not unify Y and Z
Failure: Could not unify arguments Y and Z
Unification Result: None
```

Program 8

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



LAB - 8

Forward Reasoning Algorithm

Algorithm →

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 sentences inferred on each iteration.

repeat until : new is empty

new ← { }

for each rule in KB do

$(p_1 \wedge \ldots \wedge p_n \Rightarrow q) \leftarrow$ Standardize Variables (rule)

for each θ such that

SUBST(θ, $p_1 \wedge \ldots \wedge p_n$) = SUBST(θ, $p_1' \wedge \ldots \wedge p_n'$)

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

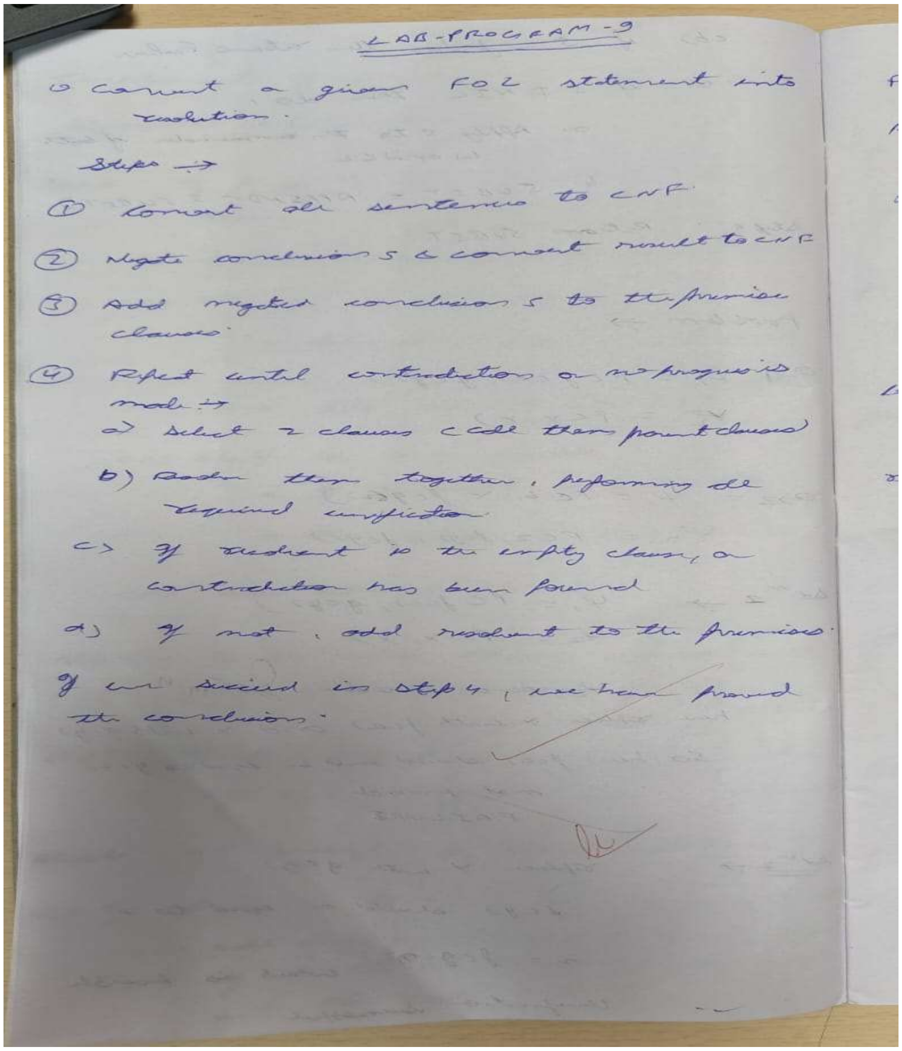
```
class ForwardReasoning:
    def __init__(self, rules, facts):
        self.rules = rules  # List of rules (condition -> result)
        self.facts = set(facts)  # Known facts

    def infer(self):
        applied_rules = True

        while applied_rules:
            applied_rules = False
            for rule in self.rules:
```

```
            condition, result = rule
            if condition.issubset(self.facts) and result not in self.facts:
                self.facts.add(result)
                applied_rules = True
                print(f"Applied rule: {condition} -> {result}")
        return self.facts


# Define rules as (condition, result) where condition is a set
rules = [
    ({"A"}, "B"),
    ({"B"}, "C"),
    ({"C", "D"}, "E"),
    ({"E"}, "F")
]

# Define initial facts
facts = {"A", "D"}

# Initialize and run forward reasoning
reasoner = ForwardReasoning(rules, facts)
final_facts = reasoner.infer()

print("\nFinal facts:")
print(final_facts)
```

```
Applied rule: {'A'} -> B
Applied rule: {'B'} -> C
Applied rule: {'C', 'D'} -> E
Applied rule: {'E'} -> F

Final facts:
{'C', 'E', 'B', 'F', 'A', 'D'}
```

Program 9

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



LAB-PROGRAM-9

Q) Convert a given FOL statement into resolution.

Steps →

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 unification

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.

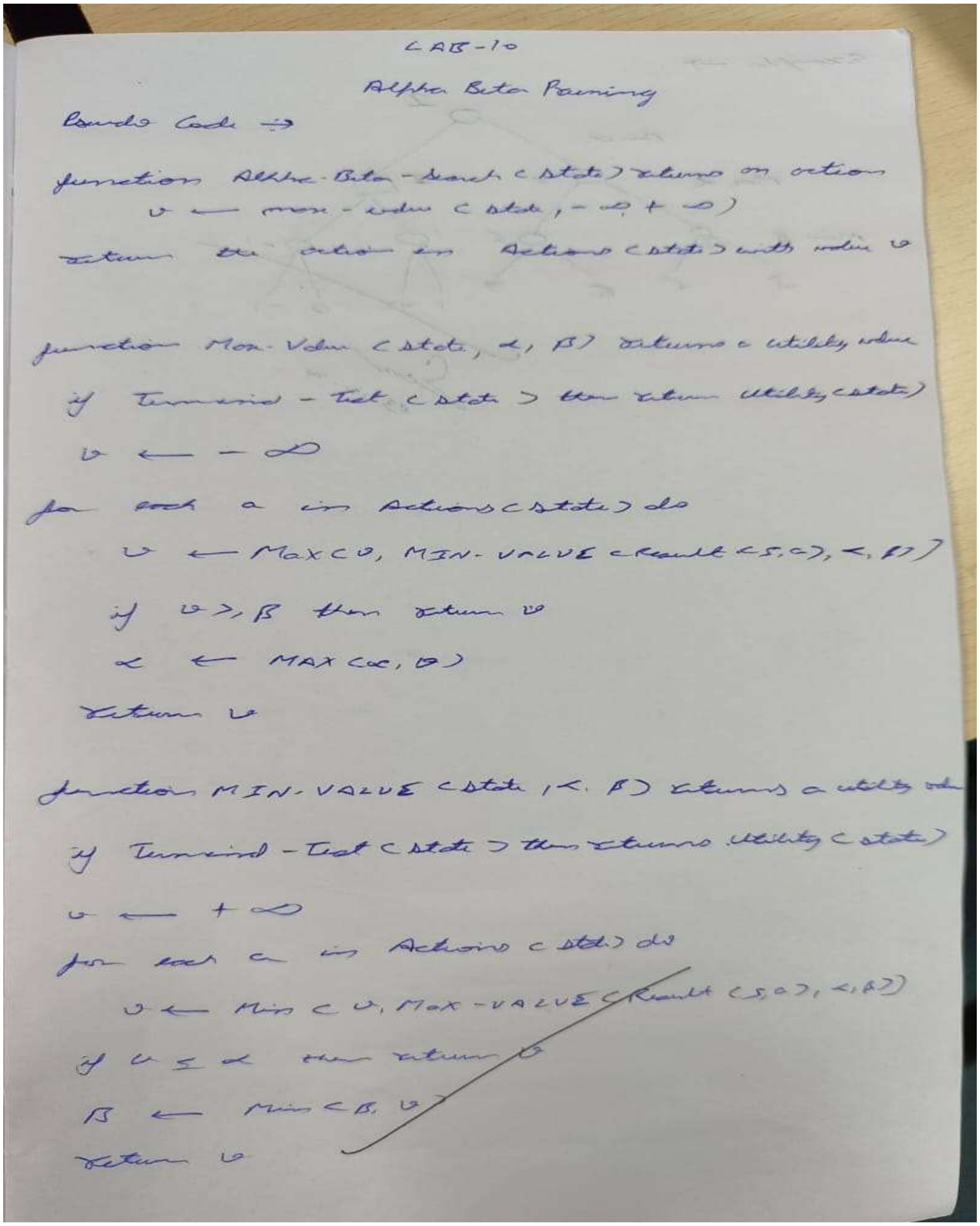
```
# Define the knowledge base (KB) as a set of facts
KB = set()
# Premises based on the provided FOL problem
KB.add('American(Robert)')
KB.add('Enemy(America, A)')
KB.add('Missile(T1)')
KB.add('Owns(A, T1)')
# Define inference rules
def modus_ponens(fact1, fact2, conclusion):
""" Apply modus ponens inference rule: if fact1 and fact2 are true, then conclude conclusion
"""
if fact1 in KB and fact2 in KB:
KB.add(conclusion)
print(f"Inferred: {conclusion}")
```

```
def forward_chaining():
""" Perform forward chaining to infer new facts until no more inferences can be made """
# 1. Apply: Missile(x) → Weapon(x)
if 'Missile(T1)' in KB:
KB.add('Weapon(T1)')
print(f"Inferred: Weapon(T1)")
1
# 2. Apply: Sells(Robert, T1, A) from Owns(A, T1) and Weapon(T1)
if 'Owns(A, T1)' in KB and 'Weapon(T1)' in KB:
KB.add('Sells(Robert, T1, A)')
print(f"Inferred: Sells(Robert, T1, A)")
# 3. Apply: Hostile(A) from Enemy(A, America)
if 'Enemy(America, A)' in KB:
KB.add('Hostile(A)')
print(f"Inferred: Hostile(A)")
# 4. Now, check if the goal is reached (i.e., if 'Criminal(Robert)' can be inferred)
if 'American(Robert)' in KB and 'Weapon(T1)' in KB and 'Sells(Robert, T1, A)' in KB and
'Hostile(A)' in KB:
KB.add('Criminal(Robert)')
print("Inferred: Criminal(Robert)")
# Check if we've reached our goal
if 'Criminal(Robert)' in KB:
print("Robert is a criminal!")
else:
print("No more inferences can be made.")
# Run forward chaining to attempt to derive the conclusion
forward_chaining()
```

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

<u>Program 10</u>

Implement Alpha-Beta Pruning.



LAB-10

Alpha Beta Pruning

Pseudo Code ⇒

function Alpha-Beta-Search(state) returns an action
v ← max-value(state, $-\infty$, $+\infty$)
return the action in Actions(state) with value v

function Max-Value(state, α, β) returns a utility value
if Terminal-Test(state) then return Utility(state)
v ← $-\infty$
for each a in Actions(state) do
v ← Max(v, MIN-VALUE(Result(s,a), α, β))
if v $\geq \beta$ then return v
α ← MAX(α, v)
return v

function MIN-VALUE(state, α, β) returns a utility value
if Terminal-Test(state) then returns Utility(state)
v ← $+\infty$
for each a in Actions(state) do
v ← Min(v, Max-VALUE(Result(s,a), α, β))
if v $\leq \alpha$ then return v
β ← Min(β, v)
return v

# Alpha-Beta Pruning Implementation
def alpha_beta_pruning(node, alpha, beta, maximizing_player):
# Base case: If it's a leaf node, return its value (simulating evaluation of the node)
if type(node) is int:
return node
If not a leaf node, explore the children

```
if maximizing_player:
max_eval = -float('inf')
for child in node: # Iterate over children of the maximizer node
eval = alpha_beta_pruning(child, alpha, beta, False)
max_eval = max(max_eval, eval)
alpha = max(alpha, eval) # Maximize alpha
if beta <= alpha: # Prune the branch
break
return max_eval
else:
min_eval = float('inf')
for child in node: # Iterate over children of the minimizer node
eval = alpha_beta_pruning(child, alpha, beta, True)
min_eval = min(min_eval, eval)
beta = min(beta, eval) # Minimize beta
if beta <= alpha: # Prune the branch
1
break
return min_eval
# Function to build the tree from a list of numbers
def build_tree(numbers):
# We need to build a tree with alternating levels of maximizers and minimizers
# Start from the leaf nodes and work up
current_level = [[n] for n in numbers]
while len(current_level) > 1:
next_level = []
for i in range(0, len(current_level), 2):
if i + 1 < len(current_level):
next_level.append(current_level[i] + current_level[i + 1]) # Combine two nodes
else:
next_level.append(current_level[i]) # Odd number of elements, just carry forward
current_level = next_level
return current_level[0] # Return the root node, which is a maximizer
# Main function to run alpha-beta pruning
def main():
# Input: User provides a list of numbers
numbers = list(map(int, input("Enter numbers for the game tree (space-separated): ").split()))
```

2

```
# Build the tree with the given numbers
tree = build_tree(numbers)
# Parameters: Tree, initial alpha, beta, and the root node is a maximizing player
alpha = -float('inf')
beta = float('inf')
maximizing_player = True # The root node is a maximizing player
# Perform alpha-beta pruning and get the final result
result = alpha_beta_pruning(tree, alpha, beta, maximizing_player)
print("Final Result of Alpha-Beta Pruning:", result)
if __name__ == "__main__":
main()
```

```
Enter numbers for the game tree (space-separated): 10 9 14 18 5 4 50 3
Final Result of Alpha-Beta Pruning: 50
```