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**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 **Danish Kodavanti (1BM23CS086)**, 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

<b>Sl. No.</b>	<b>Date</b>	<b>Experiment Title</b>	<b>Page No.</b>
1	21-08-2025	Implement Tic –Tac –Toe Game	4-12
2	21-08-2025	Implement vacuum cleaner agent	13-15
3	28-08-2025	Implement 8 puzzle problems	16-19
4	11-09-2025	Implement Iterative deepening search algorithm	20-22
5	9-10-2025	Implement Hill Climbing search algorithm to solve N-Queens problem	23-26
6	9-10-2025	Simulated Annealing to Solve 8-Queens problem	27-30
7	16-10-2025	Create a knowledge base using propositional logic and show that the given query entails the knowledge base or not.	31-33
8	30-10-2025	Implement unification in first order logic	34-35
9	30-10-2025	Implement Alpha-Beta Pruning.	36-39
10	06-11-2025	Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.	40-43
11	06-11-2025	First order logic to CNF	43-49
12	13-11-2025	Create a knowledge base consisting of first order logic statements and prove the given query using Resolution	50-61

## Program-01

### Implement Tic Tac Toe Game

#### Algorithm:

Lab-1  
Tic-Tac-Toe

Step 1 Create a board using (-)

Step 2 Suggest the user to choose (a no. from 0-8 based on board)

0	1	2
3	4	5
6	7	8

Step 3 If the user / Comp do the first move generate 'X' or 'O' for the user randomly.

Step 4 → the Computer AI has a total of 6 ways to win.  
→ for every move the user makes the AI is supposed to calculate the best move  
→ If a user marks a 'X' or 'O' on the first move,  
→ The AI is supposed to generate such that it defends and attacks at same time. X user O AI

Step 5 AI has 3 best possibilities, So user gets 2 ways to end win.

Step 6 So, the AI

Step 7 Now AI has a win-win chance by placing it at 0<sup>th</sup> box

0	X	O
O		X

Now AI can place at 1<sup>st</sup> or 3<sup>rd</sup> box AI wins.

1 way to end

Now if the user outsmarts and tries to match the AI

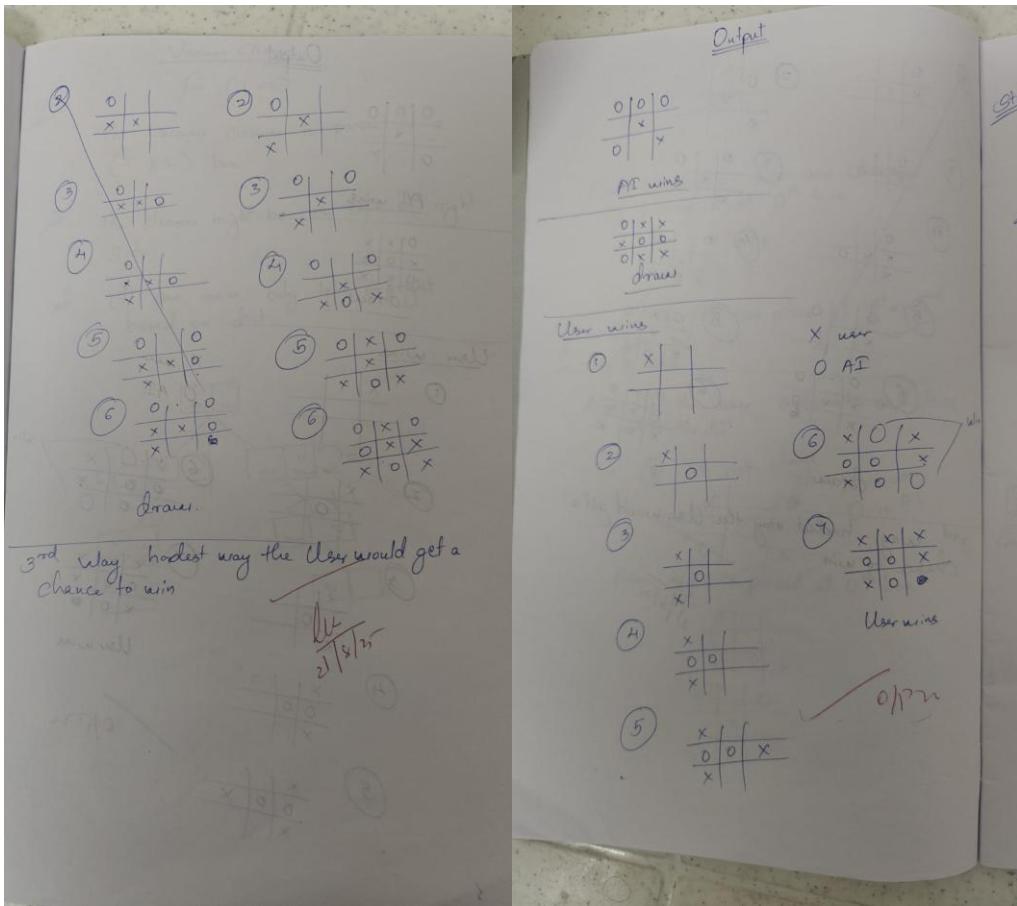
at ① let's make change  
X is user O is AI

Now if X is placed at 0<sup>th</sup> box

X		
O		X
O	X	

O		
O		X
X		

O		
O	X	
X		



**Code:**

```
import random

grid = []
line = []
for i in range(3):
    for j in range(3):
        line.append(" ")
    grid.append(line)
    line = []

# grid printing
def print_grid():
    for i in range(3):
        print("|", end="")
        for j in range(3):
            print(grid[i][j],
                  "|", end="")
        print("")

# player turn
def player_turn(turn_player1):
    if turn_player1 == True:
        turn_player1 = False
        print(f"It's {player2}'s turn")
    else:
        turn_player1 = True
        print(f"It's {player1}'s turn")
    return turn_player1

# choosing cell
def write_cell(cell, turn_player1):
    cell -= 1
    i = int(cell / 3)
    j = cell % 3
```

```

if turn_player1 == True:
    grid[i][j] = player1_symbol
else:
    grid[i][j] = player2_symbol
return grid

# checking if cell is free
def free_cell(cell):
    cell -= 1
    i = int(cell / 3)
    j = cell % 3
    if grid[i][j] == player1_symbol or grid[i][j] == player2_symbol:
        print("This cell is not free")
        return False
    return True

# system turn (AI)
def system_turn():
    empty_cells = [i for i in range(1, 10) if free_cell(i)]
    if empty_cells:
        return random.choice(empty_cells)
    return None

# win check
def win_check(grid, player1_symbol, player2_symbol):
    full_grid = True
    player1_symbol_count = 0
    player2_symbol_count = 0
    # checking rows
    for i in range(3):
        for j in range(3):
            if grid[i][j] == player1_symbol:
                player1_symbol_count += 1
                player2_symbol_count = 0
            if player1_symbol_count == 3:
                game = False
                winner = player1

```

```

        return game, winner
    if grid[i][j] == player2_symbol:
        player2_symbol_count += 1
        player1_symbol_count = 0
        if player2_symbol_count == 3:
            game = False
            winner = player2
            return game, winner
    if grid[i][j] == " ":
        full_grid = False

    player1_symbol_count = 0
    player2_symbol_count = 0
    # checking columns
    player1_symbol_count = 0
    player2_symbol_count = 0
    for i in range(3):
        for j in range(3):
            for k in range(3):
                if i + k <= 2:
                    if grid[i + k][j] == player1_symbol:
                        player1_symbol_count += 1
                        player2_symbol_count = 0
                        if player1_symbol_count == 3:
                            game = False
                            winner = player1
                            return game, winner
                    if grid[i + k][j] == player2_symbol:
                        player2_symbol_count += 1
                        player1_symbol_count = 0
                        if player2_symbol_count == 3:
                            game = False
                            winner = player2
                            return game, winner
    if grid[i][j] == " ":
        full_grid = False

```

```

player1_symbol_count = 0
player2_symbol_count = 0
# checking diagonals
player1_symbol_count = 0
player2_symbol_count = 0
for i in range(3):
    for j in range(3):
        for k in range(3):
            if j + k <= 2 and i + k <= 2:
                if grid[i + k][j + k] == player1_symbol:
                    player1_symbol_count += 1
                    player2_symbol_count = 0
                if player1_symbol_count == 3:
                    game = False
                    winner = player1
                    return game, winner
                if grid[i + k][j + k] == player2_symbol:
                    player2_symbol_count += 1
                    player1_symbol_count = 0
                if player2_symbol_count == 3:
                    game = False
                    winner = player2
                    return game, winner
            if grid[i][j] == " ":
                full_grid = False
player1_symbol_count = 0
player2_symbol_count = 0

player1_symbol_count = 0
player2_symbol_count = 0
for i in range(3):
    for j in range(3):
        for k in range(3):
            if j - k >= 0 and i + k <= 2:
                if grid[i + k][j - k] == player1_symbol:
                    player1_symbol_count += 1

```

```

player2_symbol_count = 0
if player1_symbol_count == 3:
    game = False
    winner = player1
    return game, winner
if grid[i + k][j - k] == player2_symbol:
    player2_symbol_count += 1
    player1_symbol_count = 0
    if player2_symbol_count == 3:
        game = False
        winner = player2
        return game, winner
if grid[i][j] == " ":
    full_grid = False

player1_symbol_count = 0
player2_symbol_count = 0
# full grid or not
if full_grid == True:
    game = False
    winner = ""
    return game, winner
else:
    game = True
    winner = ""
    return game, winner

# game mode selection
def game_mode_selection():
    print("Choose the game mode:")
    print("1. User vs User")
    print("2. User vs System")
    choice = input("Enter 1 or 2: ")
    if choice == "1":
        return "User vs User"
    elif choice == "2":
        return "User vs System"

```

```

else:
    print("Invalid choice! Please enter 1 or 2.")
    return game_mode_selection()

# game opening
print("Welcome to Tic-Tac-Toe!")
mode = game_mode_selection()
print("")

# input player names and symbols
player1 = input("Please enter name of player 1: ")
player1_symbol = input(f"Please enter the symbol for {player1}: ")

if mode == "User vs User":
    player2 = input("Please enter name of player 2: ")
    player2_symbol = input(f"Please enter the symbol for {player2}: ")
else:
    player2 = "System"
    player2_symbol = "O" if player1_symbol == "X" else "X" # Automatically set to the opposite symbol
of player 1

game = True
full_grid = False
turn_player1 = True
winner = ""

# game loop
while game:
    turn_player1 = player_turn(turn_player1)
    free_box = False
    while free_box == False:
        if turn_player1: # Player 1's turn
            cell = int(input(f"{player1}, enter a number (1 to 9): "))
        else:
            if mode == "User vs System": # System's turn
                print(f"{player2}'s turn (System)")
                cell = system_turn()

```

```
    print(f"System chose cell {cell}")
else: # Player 2's turn (User vs User)
    cell = int(input(f'{player2}, enter a number (1 to 9): '))

    free_box = free_cell(cell)
    grid = write_cell(cell, turn_player1)
    print_grid()

game, winner = win_check(grid, player1_symbol, player2_symbol)

# end of game
if winner == player1:
    print(f"Winner is {player1}!")
elif winner == player2:
    print(f"Winner is {player2}!")
else:
    print("It's a draw!")
```

## Output:

```
Welcome to Tic-Tac-Toe!
| | | |
| | | |
| | | |

Enter your move (1-9): 1
Player O makes a move to square 1
| O | | |
| | | |
| | | |

Computer is thinking...
Player X makes a move to square 5
| O | | |
| | X | |
| | | |

Enter your move (1-9): 2
Player O makes a move to square 2
| O | O | |
| | X | |
| | | |

Computer is thinking...
Player X makes a move to square 3
| O | O | X |
| | X | |
| | | |

Enter your move (1-9): 7
Player O makes a move to square 7
| O | O | X |
| | X | |
| O | | |

Computer is thinking...
Player X makes a move to square 4
| O | O | X |
| X | X | |
| O | | |

Enter your move (1-9): 6
Player O makes a move to square 6
| O | O | X |
| X | X | O |
| O | | |

Computer is thinking...
Player X makes a move to square 8
| O | O | X |
| X | X | O |
| O | X | |

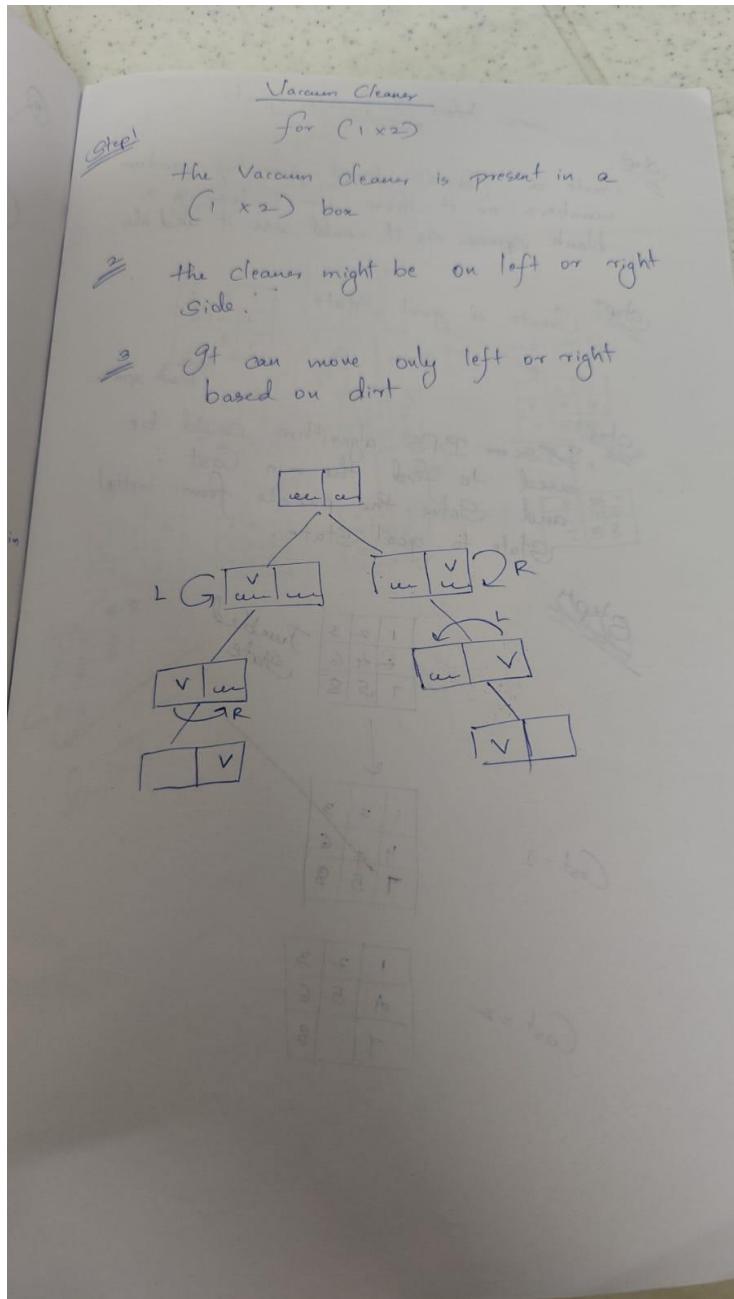
Enter your move (1-9): 9
Player O makes a move to square 9
| O | O | X |
| X | X | O |
| O | X | O |

It's a draw!
```

## Program-02

Implement Vacuum Cleaner

### Algorithm:



**Code:**

```
# Helper function: Check if all rooms are clean
def all_rooms_clean(environment):
    return all(status == "clean" for status in environment.values())

# Helper function: Clean a specific room
def clean_room(environment, room):
    print(f"Cleaning {room}")
    environment[room] = "clean"

# Helper function: Move to next room in the 2x2 grid
def move_to_next_room(current_room):
    # Predefined cyclic movement order
    if current_room == "room1":
        return "room2"
    elif current_room == "room2":
        return "room4"
    elif current_room == "room4":
        return "room3"
    elif current_room == "room3":
        return "room1"

# Vacuum cleaner agent function
def vacuum_cleaner_agent(environment):
    current_room = "room1"
    steps = 0

    print("Initial environment:", environment)
    print(f"Starting cleaning in {current_room}\n")

    while not all_rooms_clean(environment):
        if environment[current_room] == "dirty":
            clean_room(environment, current_room)
        else:
            print(f"{current_room} is already clean, moving on.")


```

```

current_room=move_to_next_room(current_room)
steps += 1
print(f"Moved to {current_room}\n")

print("All rooms cleaned!")
print("Final environment:", environment)
print(f"Total steps taken: {steps}")

# Initialize environment with all rooms dirty
environment = {
    "room1": "dirty",
    "room2": "dirty",
    "room3": "dirty",
    "room4": "dirty"
}

# Run the agent
vacuum_cleaner_agent(environment)

```

### Output:

```

Vacuum Cleaner World
Commands: LEFT, RIGHT, CLEAN, EXIT

[R:dirty] [B:dirty]

Enter command: left
Already at the leftmost room!
[R:dirty] [B:dirty]

Enter command: right
[A:dirty] [R:dirty]

Enter command: clean
Cleaned B
[A:dirty] [R:clean]

Enter command: left
[R:dirty] [B:clean]

Enter command: clean
Cleaned A
[R:clean] [B:clean]

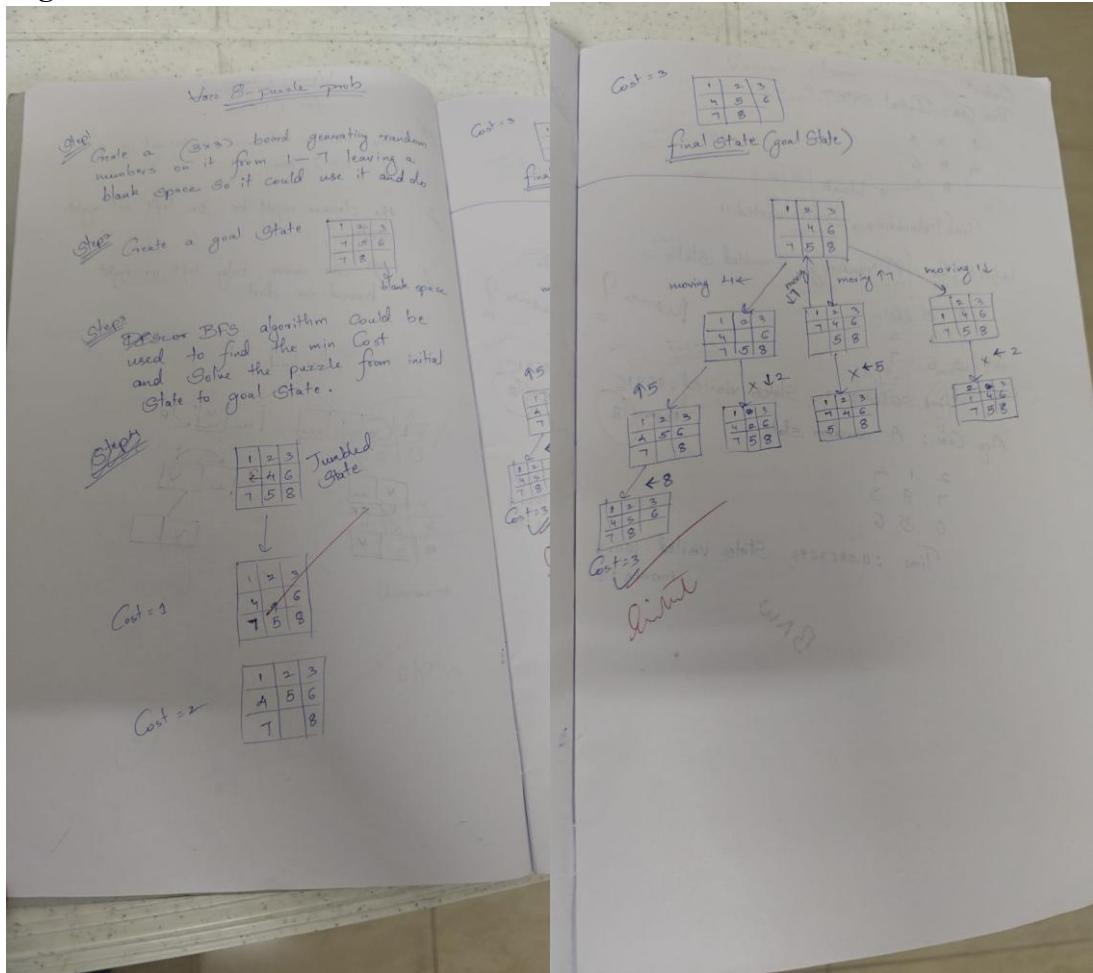
⚠ All rooms are clean!

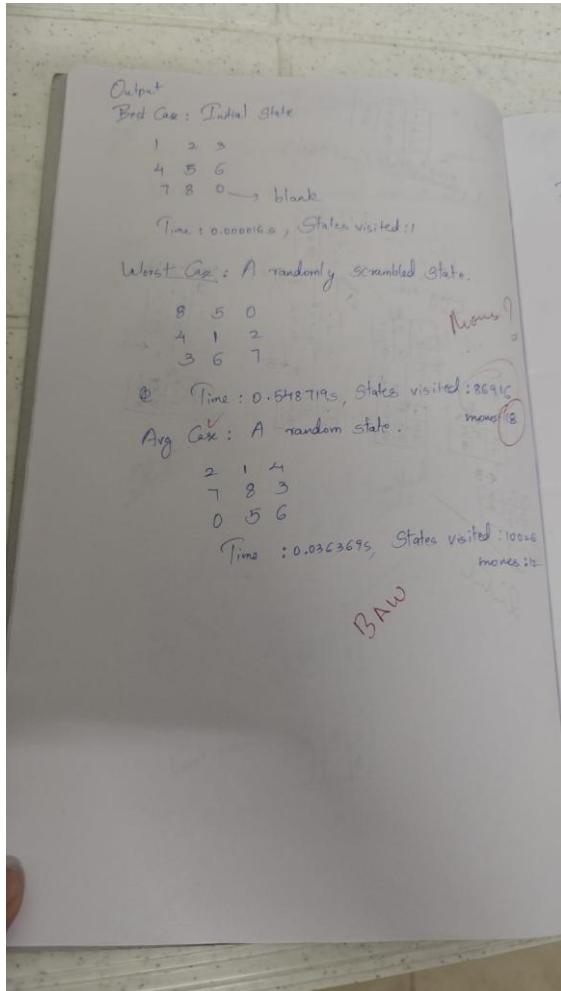
```

### Program-03

#### Implement 8 Puzzle

#### Algorithm:





### Code:

```
import heapq
```

```
# Goal state (target configuration)
```

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

```
# Manhattan Distance Heuristic
```

```
def manhattan(state):  
    distance = 0  
    for i in range(3):  
        for j in range(3):  
            val = state[i][j]
```

```

if val == 0:
    continue
goal_x = (val - 1) // 3
goal_y = (val - 1) % 3
distance += abs(goal_x - i) + abs(goal_y - j)
return distance

# Check if the current state is the goal state
def is_goal(state):
    return state == GOAL_STATE

# Find neighbors (possible moves from current state)
def get_neighbors(state):
    neighbors = []
    # Find the position of the blank tile (0)
    x, y = [(ix, iy) for ix, row in enumerate(state) for iy, i in enumerate(row) if i == 0][0]
    # Possible moves for the blank tile: up, down, left, right
    moves = [(-1, 0), (1, 0), (0, -1), (0, 1)]

    for dx, dy in moves:
        nx, ny = x + dx, y + dy
        if 0 <= nx < 3 and 0 <= ny < 3:
            new_state = [row[:] for row in state] # Create a new state
            new_state[x][y], new_state[nx][ny] = new_state[nx][ny], new_state[x][y]
            # Swap blank with neighbor
            neighbors.append(new_state)
    return neighbors

# A* search algorithm to solve the puzzle
def solve_puzzle(start):
    # Priority queue to store the states (open set)
    heap = []
    # Push initial state into the priority queue with f(n) = g(n) + h(n)
    heapq.heappush(heap, (manhattan(start), 0, start, [])) # f(n), g(n), state, path to
    get there
    visited = set() # Set to store visited states to avoid reprocessing

```

```

while heap:
    est_total, cost, state, path = heapq.heappop(heap) # Pop the state with
    lowest f(n)
    key = str(state)
    # Skip the state if it has already been visited
    if key in visited:
        continue
    visited.add(key)

    # If we reached the goal state, return the solution path
    if is_goal(state):
        return path + [state]

    # Explore the neighbors
    for neighbor in get_neighbors(state):
        # Push each neighbor to the priority queue
        heapq.heappush(heap, (cost + 1 + manhattan(neighbor), cost + 1,
        neighbor, path + [state]))

    # If no solution found
    return None

```

```

def print_state(state):
    for row in state:
        print(row)
    print()
initial_state = [
    [1, 2, 3],
    [4, 0, 6],
    [7, 5, 8]
]
print("Initial State:")
print_state(initial_state)
solution = solve_puzzle(initial_state)

```

```
if solution:  
    print("Solution found in {} steps:".format(len(solution) - 1))  
    for step, state in enumerate(solution):  
        print(f"Step {step}:")  
        print_state(state)  
else:  
    print("No solution found.")
```

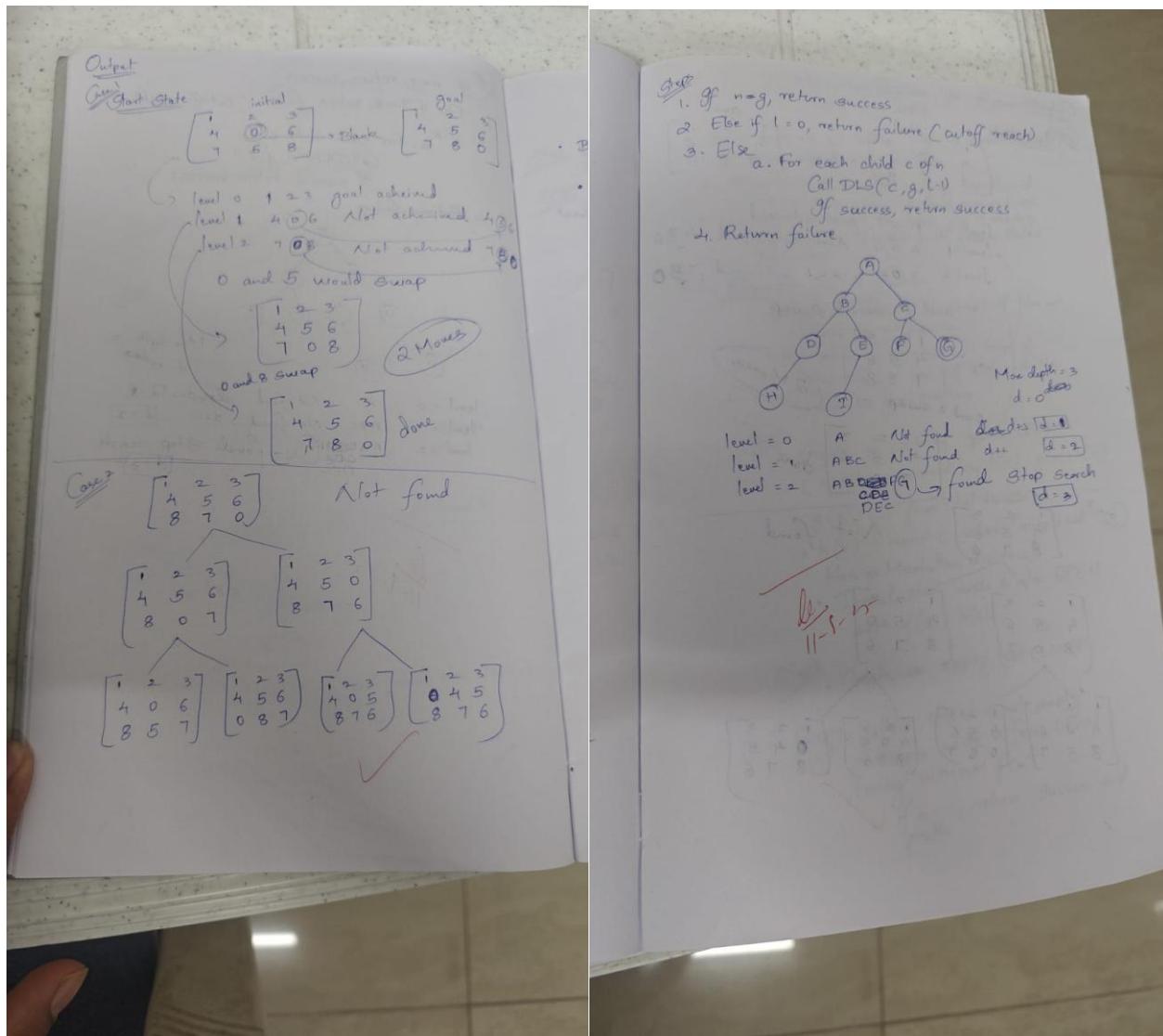
### Output:

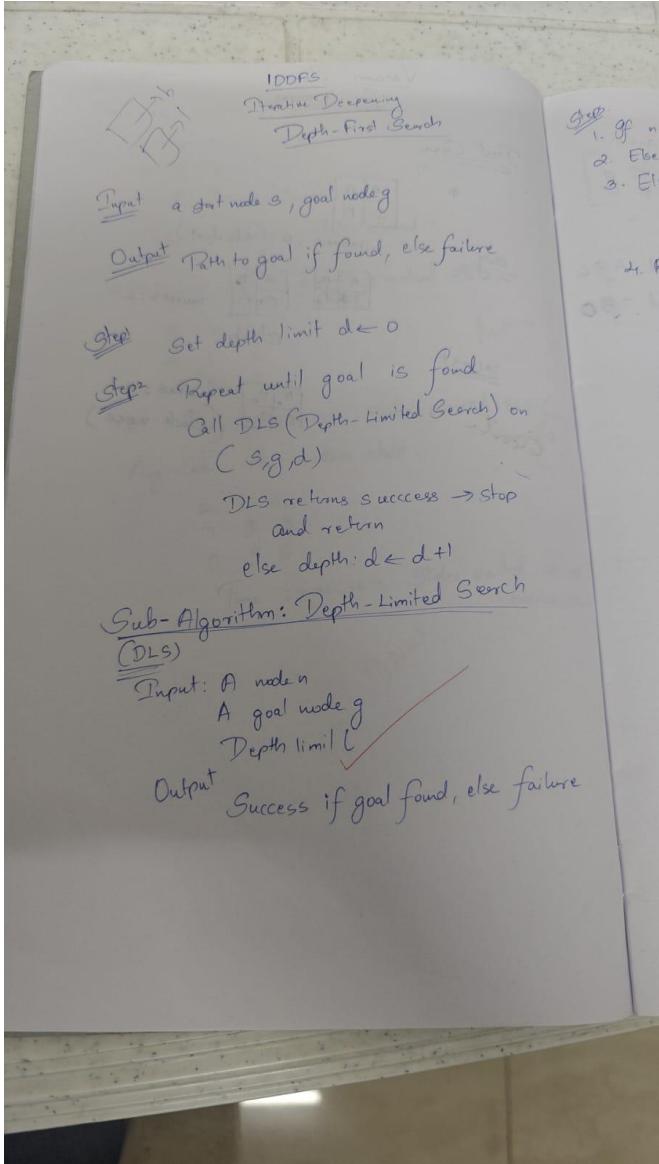
```
Output  
  
Initial State:  
[1, 2, 3]  
[4, 0, 6]  
[7, 5, 8]  
  
Solution found in 2 steps:  
Step 0:  
[1, 2, 3]  
[4, 0, 6]  
[7, 5, 8]  
  
Step 1:  
[1, 2, 3]  
[4, 5, 6]  
[7, 0, 8]  
  
Step 2:  
[1, 2, 3]  
[4, 5, 6]  
[7, 8, 0]
```

## Program-04

### Implement IDDFS

#### Algorithm:





**Code:**

```
from collections import deque
```

```
moves = {  
    'U': -3,  
    'D': 3,  
    'L': -1,  
    'R': 1  
}  
  
def get_neighbors(state):  
    neighbors = []  
    zero_idx = state.index("0")  
  
    for move, pos_change in moves.items():  
        new_idx = zero_idx + pos_change  
  
        if move == 'L' and zero_idx % 3 == 0:  
            continue  
        if move == 'R' and zero_idx % 3 == 2:  
            continue  
        if 0 <= new_idx < 9:  
            new_state = list(state)  
  
            new_state[zero_idx], new_state[new_idx] = new_state[new_idx], new_state[zero_idx]  
            neighbors.append(("".join(new_state), move))  
    return neighbors  
  
def depth_limited_search(state, goal, limit, path, visited):  
    if state == goal:  
        return path  
  
    if limit <= 0:  
        return None  
  
    visited.add(state)  
    for neighbor, move in get_neighbors(state):  
        if neighbor not in visited:  
            new_path = depth_limited_search(neighbor, goal, limit - 1, path + [move], visited.copy())  
            if new_path:
```

```

        return new_path
    return None

def iterative_deepening_search(start, goal, max_depth=30):
    for depth in range(max_depth + 1):
        print(f"\nSearching with depth limit = {depth}")
        path = depth_limited_search(start, goal, depth, [], set())
        if path:
            print(f"Goal found at depth {depth}! Moves: {'->'.join(path)}")
            return path
    print(f"Goal not found within depth {max_depth}")
    return None

```

```

start_state = "724506831"
goal_state = "012345678"

```

```
iterative_deepening_search(start_state, goal_state, max_depth=20)
```

### Output:

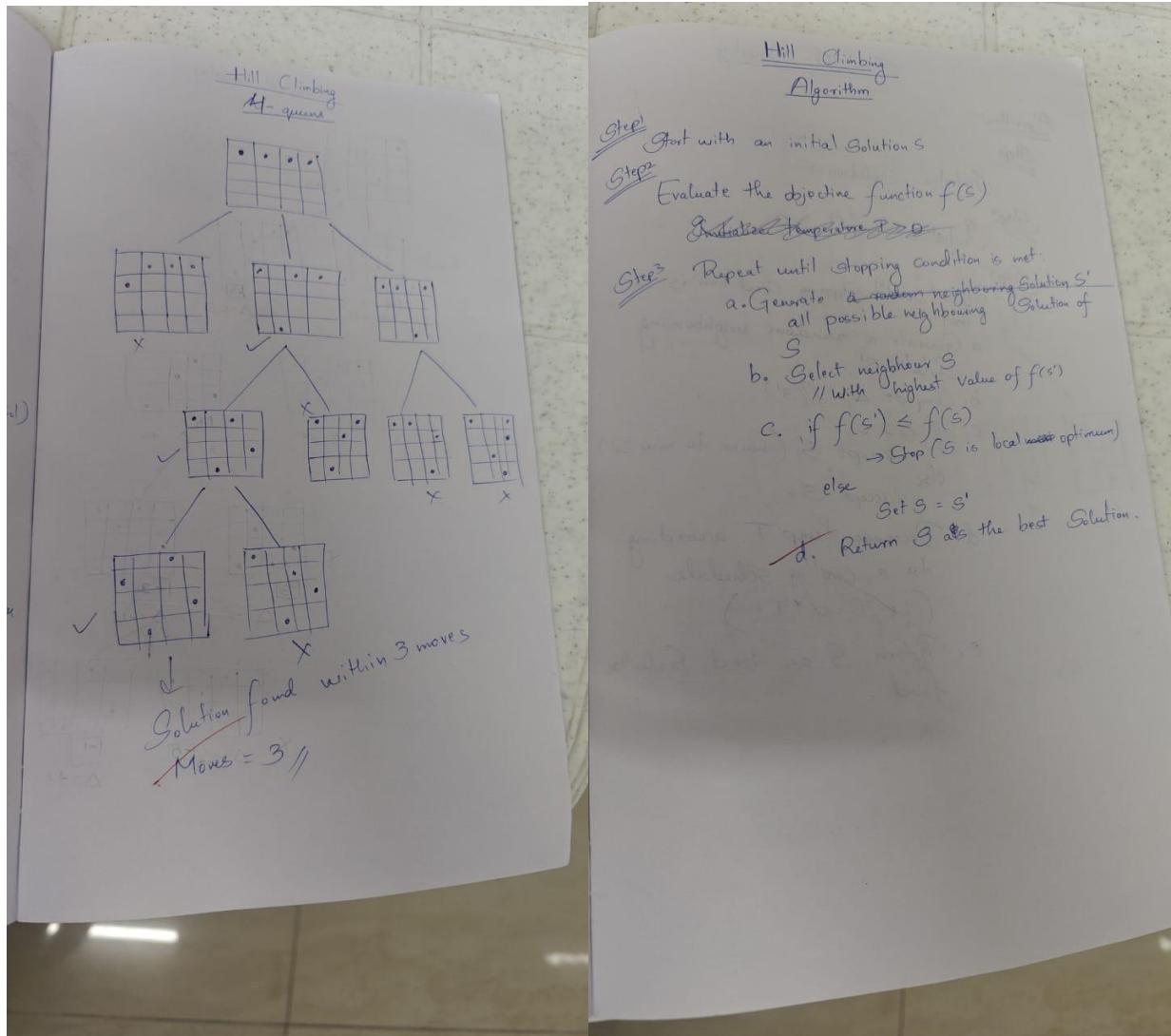
```

Searching with depth limit = 0
Searching with depth limit = 1
Searching with depth limit = 2
Searching with depth limit = 3
Searching with depth limit = 4
Searching with depth limit = 5
Searching with depth limit = 6
Searching with depth limit = 7
Searching with depth limit = 8
Searching with depth limit = 9
Searching with depth limit = 10
Searching with depth limit = 11
Searching with depth limit = 12

```

## Program-05

Implement Hill climbing algorithm using N- Queens



**Code:**

```
from random import randint

def configureUserInput(board, state, N):
    while True:
        try:
            initial_positions = input(
                f"Enter the initial row positions for queens (space-separated, 0 to {N-1}): "
            )
            initial_positions = list(map(int, initial_positions.split()))
            if len(initial_positions) == N and all(0 <= x < N for x in initial_positions):
                for i in range(N):
                    state[i] = initial_positions[i]
                    board[state[i]][i] = 1
                break
            else:
                print(f"Please enter exactly {N} valid row positions between 0 and {N-1}.")
        except ValueError:
            print("Invalid input. Please enter integers.")

def printBoard(board):
    for row in board:
        print(*row)

def compareStates(state1, state2):
    return state1 == state2

def fill(board, value):
    for i in range(len(board)):
        for j in range(len(board)):
            board[i][j] = value

def calculateObjective(board, state, N):
    attacking = 0
    for i in range(N):
        row = state[i]
        col = i
        for j in range(i + 1, N):
            other_row = state[j]
            other_col = j
            if other_row == row or abs(other_row - row) == abs(other_col - col):
                attacking += 1
```

```
return attacking
```

```
def generateBoard(board, state, N):
```

```
    fill(board, 0)
```

```
    for i in range(N):
```

```
        board[state[i]][i] = 1
```

```
def copyState(state1, state2):
```

```
    for i in range(len(state2)):
```

```
        state1[i] = state2[i]
```

```
def getNeighbour(board, state, N):
```

```
    opState = state[:]
```

```
    generateBoard(board, opState, N)
```

```
    opObjective = calculateObjective(board, opState, N)
```

```
    for col in range(N):
```

```
        for row in range(N):
```

```
            if row != state[col]:
```

```
                tempState = state[:]
```

```
                tempState[col] = row
```

```
                generateBoard(board, tempState, N)
```

```
                tempObjective = calculateObjective(board, tempState, N)
```

```
                if tempObjective < opObjective:
```

```
                    opObjective = tempObjective
```

```
                    opState = tempState[:]
```

```
copyState(state, opState)
```

```
generateBoard(board, state, N)
```

```
def hillClimbing(board, state, N):
```

```
    neighbourState = state[:]
```

```
    generateBoard(board, neighbourState, N)
```

```
while True:
```

```
    print("\nCurrent state:")
```

```
    printBoard(board)
```

```
    print(f'Number of attacking pairs: {calculateObjective(board, state, N)}\n')
```

```
    copyState(state, neighbourState)
```

```
    generateBoard(board, state, N)
```

```

getNeighbour(board, neighbourState, N)

if compareStates(state, neighbourState):
    print("\nFinal board with minimum conflicts:")
    printBoard(board)
    print(f"Number of attacking pairs: {calculateObjective(board, state, N)}")
    break

def main():
    N = int(input("Enter number of queens (N): "))
    board = [[0 for _ in range(N)] for _ in range(N)]
    state = [0] * N

    print("Enter initial positions for queens:")
    configureUserInput(board, state, N)
    hillClimbing(board, state, N)

if __name__ == "__main__":
    main()

```

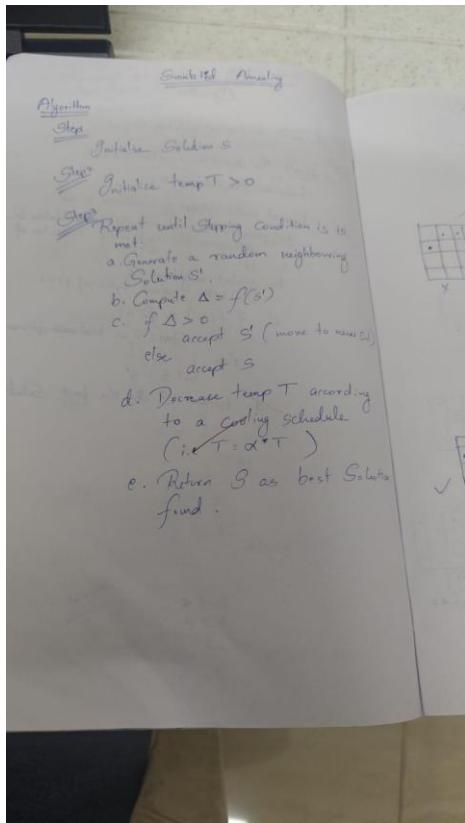
## Output:

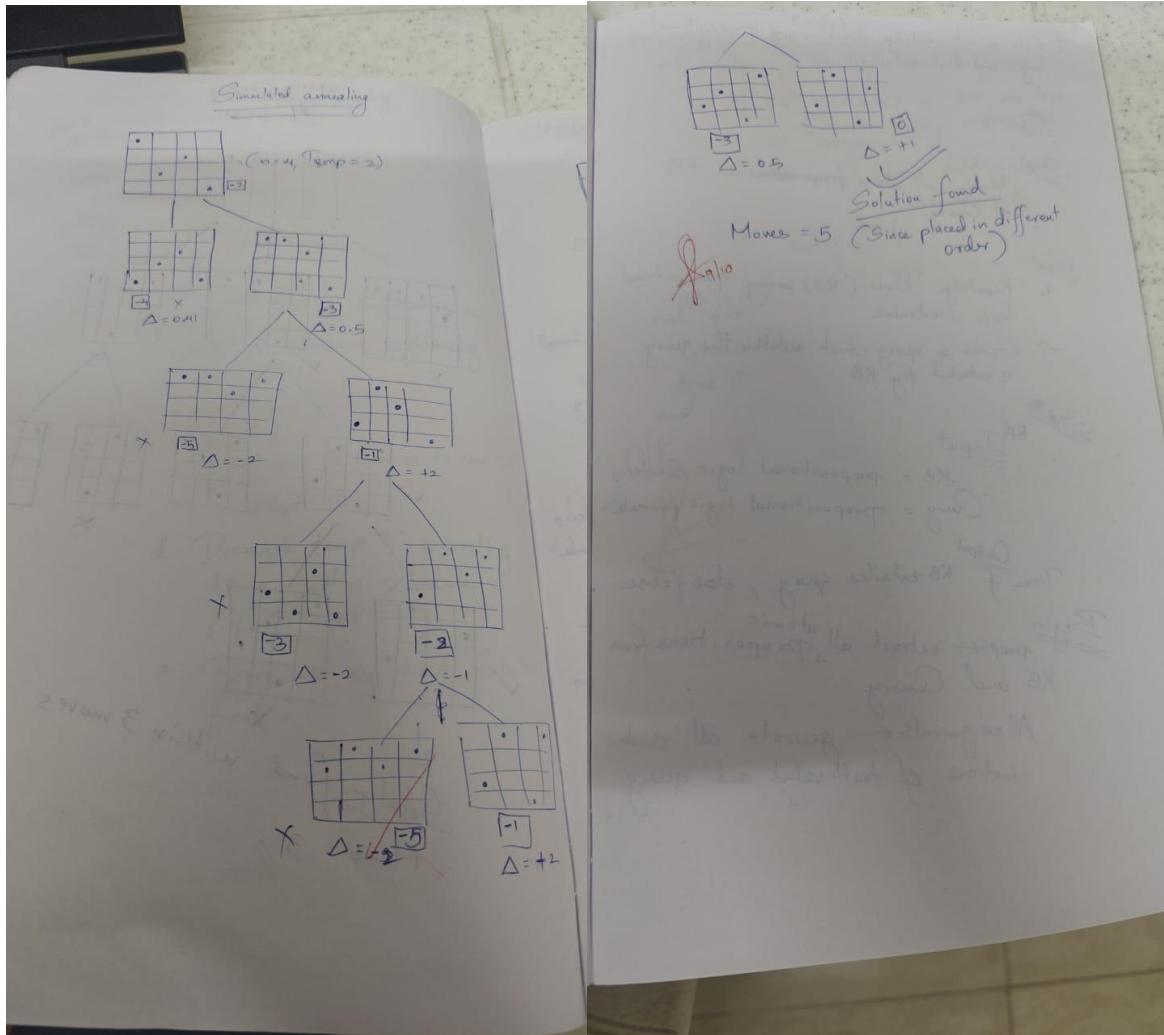
```
Initial board:  
. . .  
. Q .  
. . .  
Q . Q Q  
  
Initial heuristic (attacking pairs): 4  
  
Step 0: h = 4  
. . .  
. Q .  
. . .  
Q . Q Q  
  
Step 1: h = 2  
. . . Q  
. Q .  
. . .  
Q . Q .  
  
Step 2: h = 1  
. . . Q  
. Q .  
Q . .  
. . Q .  
  
Final board:  
. . . Q  
. Q .  
Q . .  
. . Q .  
  
Final heuristic: 1  
⚠ Local minimum reached (no solution from this start).
```

## Program-06

## Implement Simulated Annealing

### Algorithm:





### Code:

```

import random
import math

class SimulatedAnnealing:
    def __init__(self, N, initial_temp=10000, cooling_rate=0.999):
        self.N = N # Size of the board
        self.initial_temp = initial_temp # Initial temperature
        self.cooling_rate = cooling_rate # Cooling rate
        self.state = self.random_state() # Initial state

    def random_state(self):
        """ Generate a random state with one queen per column. """
        return [random.randint(0, self.N - 1) for _ in range(self.N)]

```

```

def calculate_conflicts(self, state):
    """ Calculate the number of pairs of queens that are attacking each
    other. """
    conflicts = 0
    for i in range(self.N):
        for j in range(i + 1, self.N):
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts

def get_neighbors(self, state):
    """ Generate neighboring states by moving one queen to a random
    new position. """
    neighbors = []
    for i in range(self.N):
        new_state = state[:]
        new_pos = random.randint(0, self.N - 1)
        while new_pos == new_state[i]: # Prevent moving the queen to
        the same row
            new_pos = random.randint(0, self.N - 1)
        new_state[i] = new_pos
        neighbors.append(new_state)
    return neighbors

def acceptance_probability(self, current_conflicts,
neighbor_conflicts, temp):
    """ Calculate the probability of accepting a worse solution. """
    if neighbor_conflicts < current_conflicts:
        return 1.0
    else:
        return math.exp((current_conflicts - neighbor_conflicts) / temp)

def simulated_annealing(self):
    """ Perform the simulated annealing process. """
    current_state = self.state
    current_conflicts = self.calculate_conflicts(current_state)
    temp = self.initial_temp

```

```

print(f"Initial State: {current_state}")
print(f"Initial Conflicts: {current_conflicts}")

while temp > 1:
    neighbors = self.get_neighbors(current_state)
    next_state = random.choice(neighbors)
    next_conflicts = self.calculate_conflicts(next_state)

    # If the next state is better or with some probability, accept the
    worse state
    if self.acceptance_probability(current_conflicts, next_conflicts,
temp) > random.random():
        current_state = next_state
        current_conflicts = next_conflicts

    # Cooling the system down
    temp *= self.cooling_rate

    print(f"Temp: {temp:.4f} | Conflicts: {current_conflicts} |
State: {current_state}")

    # If we have found a solution (0 conflicts), stop the process
    if current_conflicts == 0:
        print("Solution found!")
        break

return current_state, current_conflicts

# Driver code
if __name__ == "__main__":
    try:
        N = int(input("Enter the number of queens (N): "))
        sa = SimulatedAnnealing(N)

        final_state, final_conflicts = sa.simulated_annealing()
        print(f"\nFinal State: {final_state}")
    
```

```
print(f'Final Conflicts: {final_conflicts}')
except ValueError:
    print("Please enter a valid number for N.")
```

**Output:**

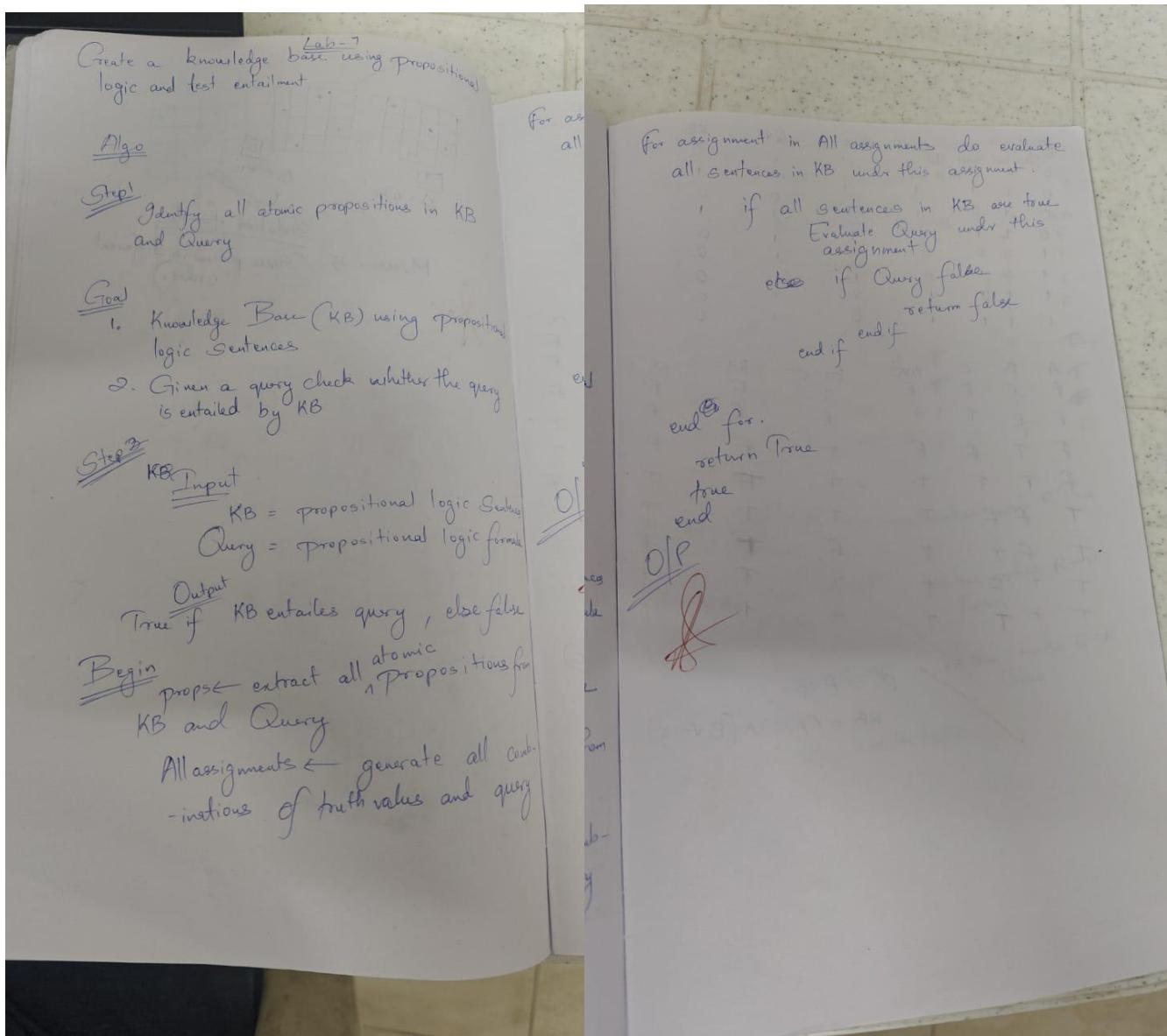
```
Final board:
. . . . . Q .
. . Q . . . .
. . . . . . Q
. Q . . . .
. . . . Q . . .
Q . . . . .
. . . . Q . .
. . . Q . . .

Final heuristic (attacking pairs): 0
✓ Solution found!
```

## Program-07

Creative knowledge based using prepositional knowledge and show the given query entries a knowledge based or not

### Algorithm:



B2

Q	P	R	$Q \rightarrow P$	$P \rightarrow \neg Q$	$Q \vee R$	KB
0	0	0	1	1	0	0
0	0	1	1	1	1	0
0	1	0	1	1	0	0
0	1	1	1	1	1	1
1	0	0	1	1	1	0
1	0	1	0	1	1	0
1	1	0	0	1	1	0
1	1	1	1	0	1	0

A	B	C	$A \vee C$	$B \vee \neg C$	KB	$\alpha$
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	F	T
T	F	F	T	T	T	T
T	F	T	T	F	F	F
T	T	F	T	T	T	T
T	T	T	T	T	T	T

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

B2 Construct a truth table that shows the truth values of each sentence in KB and indicate the models in which the KB.

Algof

P	Q	R	$Q \rightarrow P$	$P \rightarrow \neg Q$	$Q \vee R$	KB
F	F	F	T	T	F	F
F	F	T	T	T	T	T
F	T	F	F	F	T	F
F	T	T	T	T	T	F
T	F	F	F	T	F	F
T	F	T	F	T	T	T
T	T	F	T	T	F	T
T	T	T	T	T	T	T

i. KB entail R KB true makes make R True

ii. KB entail  $R \rightarrow P$  KB true makes  $R \rightarrow P$  false

iii. KB entail  $Q \rightarrow R$  KB true make  $Q \rightarrow R$  True

KB truth table

$\begin{array}{ll} \text{KB} & \rightarrow R \\ F & F \\ \checkmark T & T \\ F & F \\ F & T \\ F & F \\ \checkmark T & T \\ F & F \\ F & T \end{array}$ <p><math>\neg F</math> Condition isn't there So <math>\text{KB} \rightarrow</math> entails <math>R</math></p>	$\begin{array}{ll} \text{KB} & = R \\ F & F \\ T & T \\ F & F \\ T & T \\ F & F \\ T & T \\ F & F \end{array}$
$\begin{array}{ll} \text{KB} & \rightarrow P \\ F & T \\ T & F \\ F & F \\ F & T \\ T & F \\ F & F \\ F & T \end{array}$ <p><math>\neg F</math> Condition isn't there So <math>\text{KB} \rightarrow</math> entails <math>P</math></p>	$\begin{array}{ll} \text{KB} & \rightarrow R \\ T & T \\ F & T \\ T & T \\ T & T \\ F & T \\ T & F \\ T & T \end{array}$ <p><math>\neg F</math> Condition isn't there So <math>\text{KB} \rightarrow</math> entails <math>R</math></p>

**Code:**

```
import itertools

# ----- Helper: evaluate propositional logic sentence -----
def pl_true(expr, model):
    if isinstance(expr, str):
        return model[expr]

    op = expr[0]

    if op == 'not':
        return not pl_true(expr[1], model)
    elif op == 'and':
        return pl_true(expr[1], model) and pl_true(expr[2], model)
    elif op == 'or':
        return pl_true(expr[1], model) or pl_true(expr[2], model)
    elif op == 'implies':
        return (not pl_true(expr[1], model)) or pl_true(expr[2], model)
    else:
        raise ValueError("Unknown operator: " + op)

# ----- Truth table entailment algorithm -----
def tt_entails(KB, query, symbols):
    for values in itertools.product([False, True], repeat=len(symbols)):
        model = dict(zip(symbols, values))

        # If KB is true but query is false -> Not entailed
        if all(pl_true(sentence, model) for sentence in KB):
            if not pl_true(query, model):
                print("Counterexample model:", model)
                return False

    return True
```

```

# ----- Define your KB -----
# KB: Q → P, P → ¬Q, Q ∨ R
KB = [
    ('implies', 'Q', 'P'),           # Q → P
    ('implies', 'P', ('not', 'Q')),  # P → ¬Q
    ('or', 'Q', 'R')                # Q ∨ R
]
symbols = ['P', 'Q', 'R']

# ----- Define queries -----
queries = {
    "R": 'R',
    "R → P": ('implies', 'R', 'P'),
    "Q → R": ('implies', 'Q', 'R')
}

# ----- Run entailment tests -----
for name, q in queries.items():
    result = tt_entails(KB, q, symbols)
    print(f"KB entails {name}: {result}")

```

### Output:

```

== Propositional Logic Entailment Checker ==

Enter number of formulas in KB: 3
Formula 1 (use ~ for NOT, & for AND, | for OR, -> for IMPLIES, <-> for IFF): Q->P
Formula 2 (use ~ for NOT, & for AND, | for OR, -> for IMPLIES, <-> for IFF): P->-Q
Formula 3 (use ~ for NOT, & for AND, | for OR, -> for IMPLIES, <-> for IFF): Q|R

Enter the query formula (alpha): Q

Truth Table:
-----
P | Q | R | Q->P | P->-Q | Q|R | Q
-----
True | True | True | True | False | True | True
True | True | False | True | False | True | True
True | False | True | True | False | True | False
True | False | False | True | False | False | False
False | True | True | False | False | True | True
False | True | False | False | False | True | True
False | False | True | True | True | True | False

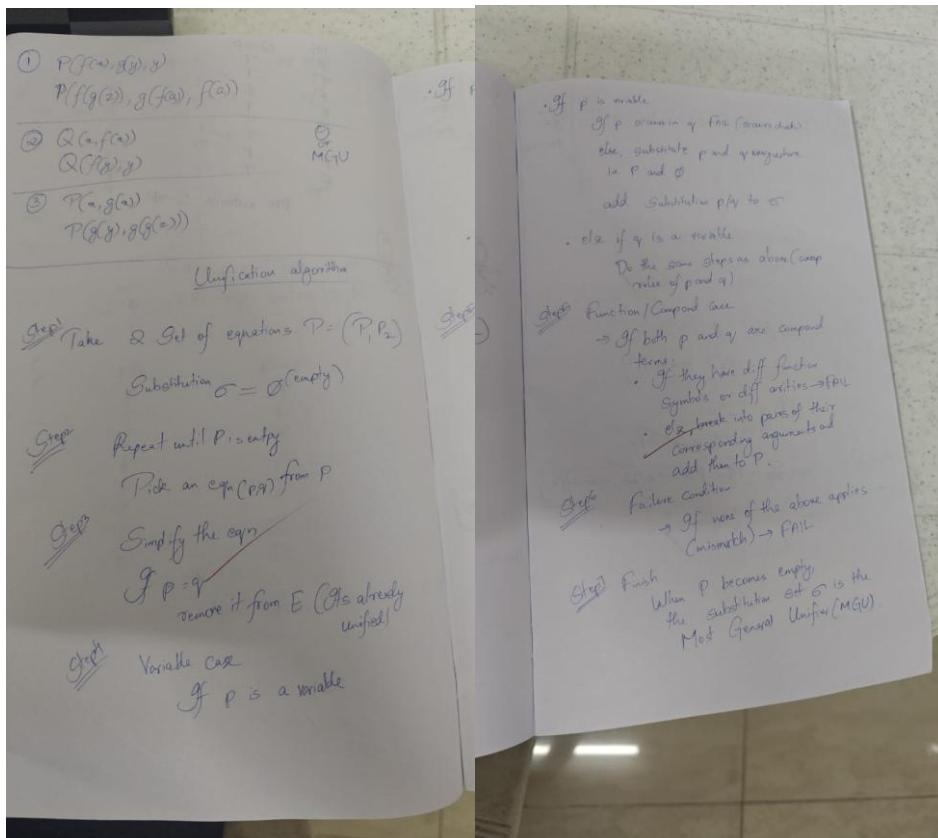
✖ Counterexample found: {'P': False, 'Q': False, 'R': True}
False | False | False | True | True | False
-----
✖ KB does NOT entail Q

```

## Program-08

Implement unification in first order logic

### Algorithm:



①  $P(f(a), g(y), y) \quad | \quad P(f(g(z)), g(f(a)), f(a))$

$\alpha: f(a) = f(g(z))$   
 $\beta_1: a = g(z)$   
 $\beta_2: a \leftarrow g(z) /$

②  $g(y) = g(f(a))$   
 $\beta_2: y \leftarrow f(a)$

③  $y = f(a)$   
 No new info  
 $\therefore \text{MGU} \boxed{a \leftarrow g(z), y \leftarrow f(a)}$   
 Unifiable //

④  $Q(a, f(a))$   
 $Q(f(y), y)$   
 $a = f(y)$   
 $f(a) = y$   
 $f(f(y)) = y$   
 $y \text{ occurs on BS} \quad \text{Not unifiable}$

⑤  $P(x, g(x))$   
 $P(g(y), g(g(z)))$   
 $x \leftarrow g(y)$   
 $(\text{MGU}) \leftarrow g(x) = g(g(z))$   
 $x = g(z)$   
 $g(y) = g(z)$   
 $y = z$   
 $\text{MGU} = \left\{ \begin{array}{l} x \leftarrow g(z), y \leftarrow z \\ z \leftarrow g(y), z \leftarrow y \end{array} \right.$   
 Unifiable //

## Code:

```
def unify(x, y, theta=None):
    if theta is None:
        theta = {}
    if x == y:
        return theta
    elif is_variable(x):
        return unify_var(x, y, theta)
    elif is_variable(y):
        return unify_var(y, x, theta)
    elif is_compound(x) and is_compound(y):
        if x[0] != y[0] or len(x[1]) != len(y[1]):
            return None
        for xi, yi in zip(x[1], y[1]):
            theta = unify(xi, yi, theta)
        if theta is None:
            return None
        return theta
    else:
        return None

def unify_var(var, x, theta):
    if var in theta:
        return unify(theta[var], x, theta)
    elif is_variable(x) and x in theta:
        return unify(var, theta[x], theta)
    elif occurs_check(var, x, theta):
        return None
    else:
        theta[var] = x
        return theta

def is_variable(x):
    return isinstance(x, str) and x.islower()

def is_compound(x):
    return isinstance(x, tuple) and len(x) == 2

def occurs_check(var, x, theta):
    """Check if var occurs inside x (to avoid infinite recursion)"""
    if var == x:
        return True
    elif is_variable(x) and x in theta:
        return occurs_check(var, theta[x], theta)
    elif is_compound(x):
```

```
    return any(occurs_check(var, arg, theta) for arg in x[1])
else:
    return False
expr1 = ('f', ('x', ('g', ('y', ))))
expr2 = ('f', (('g', ('z', )), ('g', ('a', ))))

theta = unify(expr1, expr2, {})
print("Substitution θ:", theta)
```

**Output:**

```
Substitution θ: {'x': ('g', ('z', )), 'y': 'a'}
```

==== Code Execution Successful ===

## **Program-09**

Implement Alpha Beta and Minima Maxima Using tic tac toe Game

### **Code:**

```
import math, random
```

```
# Initialize the board
```

```
board = [" " for _ in range(9)] # 0-8  
positions
```

```
def print_board():
```

```
    print()
```

```
    for i in range(3):
```

```
        row = "|".join(board[i*3:(i+1)*3])
```

```
        print(" " + row)
```

```
        if i < 2:
```

```
            print(" ----- ")
```

```
    print()
```

```
def is_winner(brd, player):
```

```
    win_positions = [
```

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

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

```
    Columns
```

```
        [0, 4, 8], [2, 4, 6] #
```

```
    Diagonals
```

```
    ]
```

```
    return any(all(brd[pos] == player for  
    pos in line) for line in win_positions)
```

```
def is_full(brd):
```

```
    return all(cell != " " for cell in brd)
```

```
def minimax(brd, depth, is_maximizing):
```

```
    if is_winner(brd, "O"):
```

```
        return 1
```

```

elif is_winner(brd, "X"):
    return -1
elif is_full(brd):
    return 0

if is_maximizing:
    best_score = -math.inf
    for i in range(9):
        if brd[i] == " ":
            brd[i] = "O"
            score = minimax(brd, depth +
1, False)
            brd[i] = " "
            best_score = max(best_score,
score)
    return best_score
else:
    best_score = math.inf
    for i in range(9):
        if brd[i] == " ":
            brd[i] = "X"
            score = minimax(brd, depth +
1, True)
            brd[i] = " "
            best_score = min(best_score,
score)
    return best_score

def best_move():
    # 70% of the time AI plays a random
    # (bad) move
    if random.random() < 0.7:
        available = [i for i in range(9) if
board[i] == " "]
        return random.choice(available)
    # 30% of the time AI plays optimally
    best_score = -math.inf
    move = None

```

```

for i in range(9):
    if board[i] == " ":
        board[i] = "O"
        score = minimax(board, 0, False)
        board[i] = " "
        if score > best_score:
            best_score = score
            move = i
return move

def play_game():
    print("Welcome to Tic Tac Toe (You
=X, AI = O)")

    print("Hint: You can win easily 🤪")
    print_board()

    while True:
        # Human move
        while True:
            try:
                move = int(input("Enter your
move (1-9): ")) - 1
                if 0 <= move <= 8 and
board[move] == " ":
                    board[move] = "X"
                    break
            else:
                print("Invalid move, try
again.")

        except ValueError:
            print("Please enter a number
from 1 to 9.")

        print_board()

        if is_winner(board, "X"):
            print("🎉 You win! (AI made
mistakes)")

```

```
        break
if is_full(board):
    print("🟡 It's a draw!")
    break

# AI move
print("AI is thinking...")
ai = best_move()
board[ai] = "O"
print_board()

if is_winner(board, "O"):
    print("🤖 AI wins (rarely)!")
    break
if is_full(board):
    print("🟡 It's a draw!")
    break

# Run the game
if __name__ == "__main__":
    play_game()
```

**Output:**

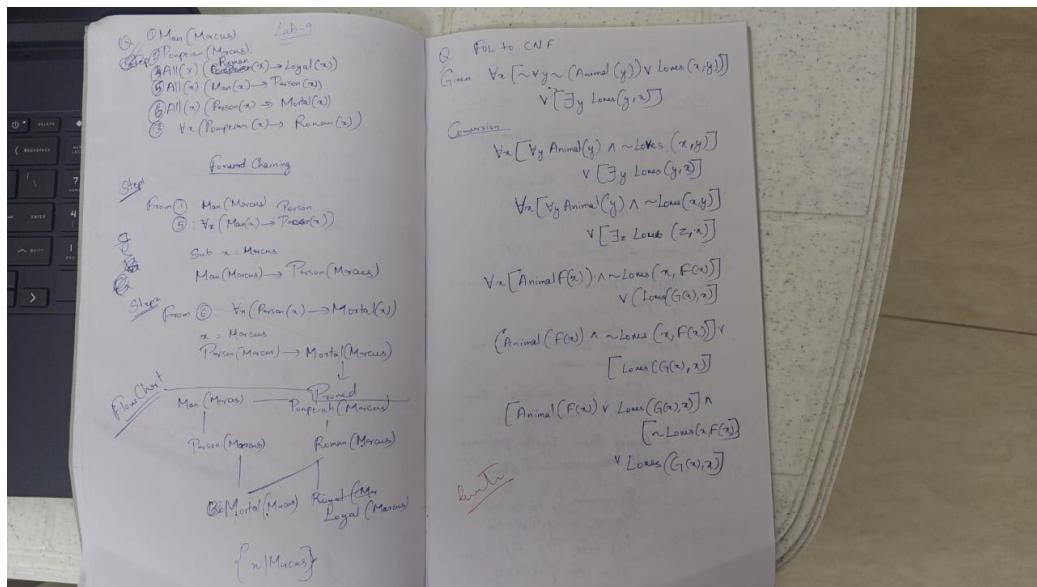
```
Welcome to Tic-Tac-Toe!
Choose the game mode:
1. User vs User
2. User vs System
Enter 1 or 2: 1

Please enter name of player 1: dhanush
Please enter the symbol for dhanush: x
Please enter name of player 2: srujan
Please enter the symbol for srujan: o
It's srujan's turn
srujan, enter a number (1 to 9): 5
| | | |
| |o| |
| | | |
It's dhanush's turn
dhanush, enter a number (1 to 9): 6
| | | |
| |o|x|
| | | |
It's srujan's turn
srujan, enter a number (1 to 9): 7
| | | |
| |o|x |
|o| | |
It's dhanush's turn
dhanush, enter a number (1 to 9): 3
| | |x|
| |o|x |
|o| | |
It's srujan's turn
srujan, enter a number (1 to 9): 9
| | |x|
| |o|x |
|o| |o|
It's dhanush's turn
dhanush, enter a number (1 to 9):
==== Session Ended. Please Run the code again ===
```

## Program-10

Create a knowledge base For the first order logic statement and prove the given query using Forward reasoning

### Algorithm:



**Code:**

```
facts = {
    "Man(Marcus)",
    "Pompeian(Marcus)"

}

rules = [
    ("Pompeian(x)", "Roman(x)"),
    ("Roman(x)", "Loyal(x)"),
    ("Man(x)", "Person(x)"),
    ("Person(x)", "Mortal(x)")
]

query = "Mortal(Marcus)"
```

```
def match(statement, fact):
```

```
    """
```

Match a statement pattern like 'Pompeian(x)' to a fact like  
 'Pompeian(Marcus)'.

Returns the substitution (x -> Marcus) if they match.

```
    """
```

```
    if "(" not in statement or "(" not in fact:
```

```
        return None
```

```
    pred1, arg1 = statement[:-1].split("(")
```

```
    pred2, arg2 = fact[:-1].split("(")
```

```
    if pred1.strip() != pred2.strip():
```

```
        return None
```

```
    if arg1.strip().islower(): # variable like x
```

```
        return {arg1.strip(): arg2.strip()}
```

```
    elif arg1.strip() == arg2.strip():
```

```
        return {}
```

```

else:
    return None

def substitute(statement, subs):
    for var, val in subs.items():
        statement = statement.replace(var, val)
    return statement

def forward_chain(facts, rules, query):
    inferred = set()
    while True:
        new_facts = set(facts)
        for antecedent, consequent in rules:
            for fact in facts:
                subs = match(antecedent, fact)
                if subs is not None:
                    new_fact = substitute(consequent, subs)
                    if new_fact not in facts:
                        print(f'Inferred: {new_fact} (from {fact} using rule
{antecedent} → {consequent})')
                        new_facts.add(new_fact)
        # If no new facts, stop
        if new_facts == facts:
            break
        facts = new_facts
    return query in facts, facts

```

```
result, all_facts = forward_chain(facts, rules, query)
```

```

print("\n--- Final Facts ---")
for f in sorted(all_facts):
    print(f)

```

```

print("\n--- Result ---")
if result:

```

```

print(f" The query '{query}' is TRUE based on forward reasoning.")
else:
    print(f"+ The query '{query}' cannot be proven from the given
knowledge base.")

```

### Output:

```

All inferred facts:
Hostile(A)
Criminal(Robert)
Weapon(T1)
Sells(Robert, T1, A)

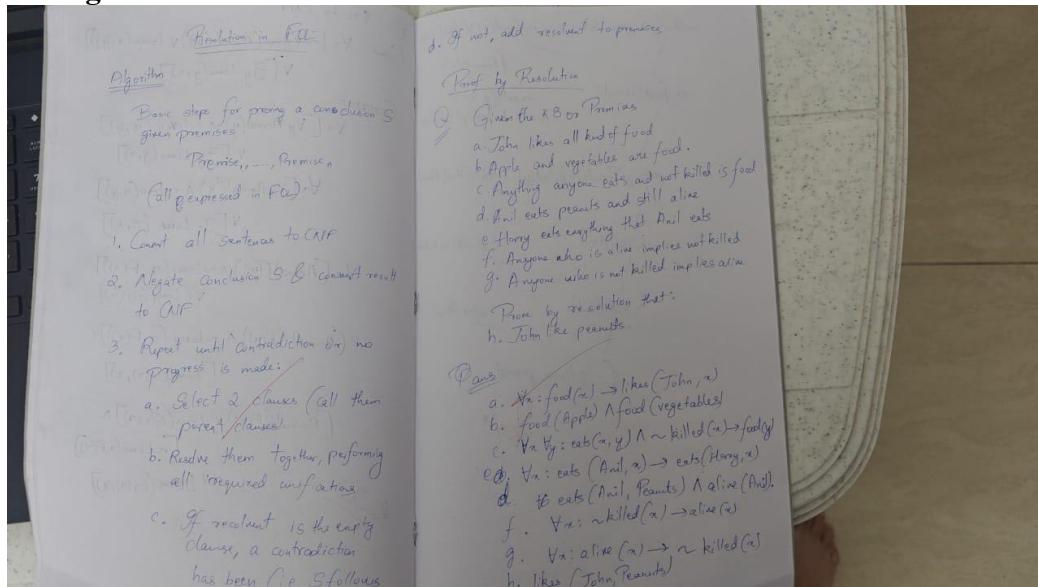
✓ Robert is a criminal

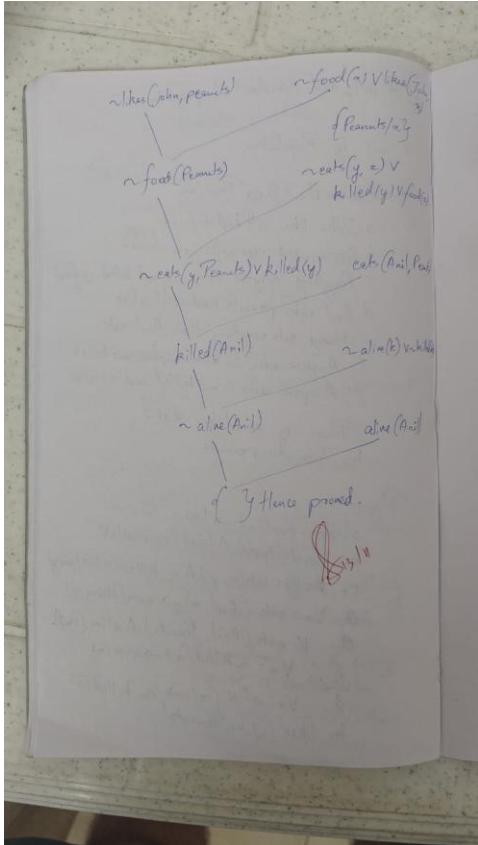
```

### Program-11

Convert the given first order logic statement to conjunctive normal form (CNF)

### Algorithm:





**Code:**

```
import copy
```

```
# Utility for deep substitution
```

```
def substitute(term, var, replacement):
```

```
    """Replace variable var with replacement inside a term."""
```

```
    if isinstance(term, str):
```

```
        return replacement if term == var else term
```

```
    elif isinstance(term, tuple):
```

```
        return tuple(substitute(t, var, replacement) for t in term)
```

```
    else:
```

```
        return term
```

```
# 1 Remove negations using equivalences
```

```
def eliminate_negations(expr):
```

```
    """Apply  $\neg \forall y P(y) \equiv \exists y \neg P(y)$  and  $\neg \exists y P(y) \equiv \forall y \neg P(y)$ ."""
```

```
    if isinstance(expr, tuple):
```

```
        op = expr[0]
```

```

if op == 'not':
    sub = expr[1]
    if isinstance(sub, tuple) and sub[0] == 'forall':
        var, inner = sub[1], sub[2]
        return ('exists', var, eliminate_negations(('not', inner)))
    elif isinstance(sub, tuple) and sub[0] == 'exists':
        var, inner = sub[1], sub[2]
        return ('forall', var, eliminate_negations(('not', inner)))
    elif isinstance(sub, tuple) and sub[0] == 'not':
        return eliminate_negations(sub[1])
    else:
        return ('not', eliminate_negations(sub))
elif op in ['and', 'or']:
    return (op, eliminate_negations(expr[1]), eliminate_negations(expr[2]))
elif op in ['forall', 'exists']:
    return (op, expr[1], eliminate_negations(expr[2]))
return expr

```

```

# Move quantifiers to front (Prenex form)
def move_quantifiers(expr):
    if isinstance(expr, tuple):
        op = expr[0]
        if op in ['and', 'or']:
            left = move_quantifiers(expr[1])
            right = move_quantifiers(expr[2])
            # If quantifiers exist in left or right, move them out
            if isinstance(left, tuple) and left[0] in ['forall', 'exists']:
                return (left[0], left[1], move_quantifiers((op, left[2], right)))
            elif isinstance(right, tuple) and right[0] in ['forall', 'exists']:
                return (right[0], right[1], move_quantifiers((op, left, right[2])))
            else:
                return (op, left, right)
        elif op in ['forall', 'exists']:
            return (op, expr[1], move_quantifiers(expr[2]))
    return expr

```

```

# 3 Skolemization
def skolemize(expr, scope_vars=None):
    """Remove existential quantifiers using Skolem functions."""
    if scope_vars is None:
        scope_vars = []
    if isinstance(expr, tuple):
        op = expr[0]
        if op == 'forall':
            return ('forall', expr[1], skolemize(expr[2], scope_vars + [expr[1]]))
        elif op == 'exists':
            func_name = f"f_{expr[1]}"
            skolem_func = func_name + "(" + ",".join(scope_vars) + ")" if scope_vars else func_name
            return skolemize(substitute(expr[2], expr[1], skolem_func), scope_vars)
        elif op in ['and', 'or']:
            return (op, skolemize(expr[1], scope_vars), skolemize(expr[2], scope_vars))
    return expr

```

```

# 4 Drop universal quantifiers
def drop_universal(expr):
    if isinstance(expr, tuple) and expr[0] == 'forall':
        return drop_universal(expr[2])
    elif isinstance(expr, tuple) and expr[0] in ['and', 'or']:
        return (expr[0], drop_universal(expr[1]), drop_universal(expr[2]))
    return expr

```

```

# 5 Distribute ∨ over ∧ to get
CNF def
distribute_or_over_and(expr):
    if not isinstance(expr, tuple):
        return expr
    op = expr[0]
    if op == 'or':
        a, b = expr[1], expr[2]
        if isinstance(a, tuple) and a[0] == 'and':
            return ('and',
                    distribute_or_over_and(('or', a[1], b)),

```

```

        distribute_or_over_and(('or', a[2], b)))
elif isinstance(b, tuple) and b[0] == 'and':
    return ('and',
            distribute_or_over_and(('or', a, b[1])),
            distribute_or_over_and(('or', a, b[2])))
else:
    return ('or', distribute_or_over_and(a), distribute_or_over_and(b))
elif op == 'and':
    return ('and', distribute_or_over_and(expr[1]), distribute_or_over_and(expr[2]))
else:
    return expr

```

```

def to_cnf(expr):
    expr = eliminate_negations(expr)
    expr = move_quantifiers(expr)
    expr = skolemize(expr)
    expr = drop_universal(expr)
    expr = distribute_or_over_and(expr)
    return expr

```

```

expr = ('forall', 'x',
        ('or',
         ('not', ('forall', 'y', ('not', ('or', ('Animal', 'y'), ('Loves', 'x', 'y'))))),
         ('exists', 'y', ('Loves', 'y', 'x'))
        )
       )

cnf = to_cnf(expr)
print("Final CNF Structure:\n", cnf)

```

## Program 12

Create knowledge piece using prepositional logic and prove the given query using resolution

### Algorithm:

#### Code:

```
import copy
import itertools

# -----
# Unification
# -----
def is_variable(x):
    return isinstance(x, str) and x[0].islower()

def unify(x, y, subs=None):
    if subs is None:
        subs = {}
    if x == y:
        return subs
    elif is_variable(x):
        return unify_var(x, y, subs)
    elif is_variable(y):
        return unify_var(y, x, subs)
    elif isinstance(x, list) and isinstance(y, list) and len(x) == len(y):
        for xi, yi in zip(x, y):
            subs = unify(xi, yi, subs)
        if subs is None:
            return None
        return subs
    else:
        return None

def unify_var(var, x, subs):
    if var in subs:
        return unify(subs[var], x, subs)
    elif x in subs:
        return unify(var, subs[x], subs)
    elif occurs_check(var, x, subs):
        return None
    else:
        subs_copy = subs.copy()
        subs_copy[var] = x
        return subs_copy
```

```

def occurs_check(var, x, subs):
    if var == x:
        return True
    elif isinstance(x, list):
        return any(occurs_check(var, xi, subs) for xi in x)
    elif x in subs:
        return occurs_check(var, subs[x], subs)
    return False

# -----
# Resolution
# -----
def negate(literal):
    if literal.startswith('~'):
        return literal[1:]
    else:
        return '~' + literal

def substitute(clause, subs):
    new_clause = []
    for literal in clause:
        pred, args = parse_predicate(literal)
        new_args = []
        for a in args:
            if a in subs:
                new_args.append(subs[a])
            else:
                new_args.append(a)
        new_clause.append(f'{ "~" if literal.startswith('~') else "" } {pred}({','.join(new_args)})')
    return new_clause

def parse_predicate(literal):
    neg = literal.startswith('~')
    if neg:
        literal = literal[1:]
    name, args = literal.split('(')
    args = args[:-1].split(',') # remove ')'
    return name, args

def resolve(ci, cj):
    for di in ci:
        for dj in cj:
            if di.startswith('~') != dj.startswith('~'): # opposite polarity
                pred_i, args_i = parse_predicate(di)
                pred_j, args_j = parse_predicate(dj)

```

```

if pred_i == pred_j:
    subs = unify(args_i, args_j)
    if subs is not None:
        new_ci = substitute(ci, subs)
        new_cj = substitute(cj, subs)
        new_clause = list(set([x for x in new_ci + new_cj if x != di and x != dj]))
        return new_clause
return None

def resolution(kb, query):
    clauses = copy.deepcopy(kb)
    clauses.append([negate(query)]) # negate query for proof by contradiction
    new = set()

    print("\n--- Resolution Steps ---")
    while True:
        pairs = [(clauses[i], clauses[j]) for i in range(len(clauses)) for j in range(i+1, len(clauses))]
        for (ci, cj) in pairs:
            resolvent = resolve(ci, cj)
            if resolvent == []:
                print("Derived empty clause ⇒ Query proven ✅")
                return True
            if resolvent is not None:
                new.add(tuple(sorted(resolvent)))

    new_clauses = [list(x) for x in new if list(x) not in clauses]
    if not new_clauses:
        print("No new clauses ⇒ Query cannot be proven ✗")
        return False
    for c in new_clauses:
        clauses.append(c)

# -----
# Example Knowledge Base
# -----
# KB:
# 1. John likes all kinds of food.
# 2. Apple and vegetable are food.
# 3. Anything anyone eats and not killed is food.
# 4. Anil eats peanuts and still alive.
# 5. Harry eats everything Anil eats.
# 6. Anyone who is alive is not killed.
# 7. Anyone who is not killed is alive.
# Query: John likes peanuts.

```

```

kb = [
    ['~Food(x)', 'Likes(John,x)'],           # John likes all food
    ['Food(Apple)'],                         # Apple is food
    ['Food(Vegetable)'],                      # Vegetable is food
    ['~Eats(x,y)', '~Alive(x)', 'Food(y)'],   # Anything eaten by alive person is food
    ['Eats(Anil,Peanuts)'],                   # Anil eats peanuts
    ['Alive(Anil)'],                          # Anil is alive
    ['~Eats(Harry,y)', 'Eats(Anil,y)'],       # Harry eats everything Anil eats
    ['~Alive(x)', '~Killed(x)'],              # Alive(x) -> not Killed(x)
    ['~Killed(x)', 'Alive(x)']                # not Killed(x) -> Alive(x)
]
query = 'Likes(John,Peanuts)'

print("Converting to CNF and proving using resolution...")
resolution(kb, query)

```

**Output:**

```

Converting to CNF and proving using resolution...

--- Resolution Steps ---
Derived empty clause => Query proven ✓

```