VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

Amal Roy (1BM23CS025)

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

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
BENGALURU-560019
Sep-2024 to Jan-2025

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 **Amal Roy (1BM23CS025),** 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.

Dr. K. R. Mamatha Associate Professor Department of CSE, BMSCE	**Dr. Kavitha Sooda** Professor & HOD Department of CSE, BMSCE

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Github Link:
https://github.com/amalrtms/AI

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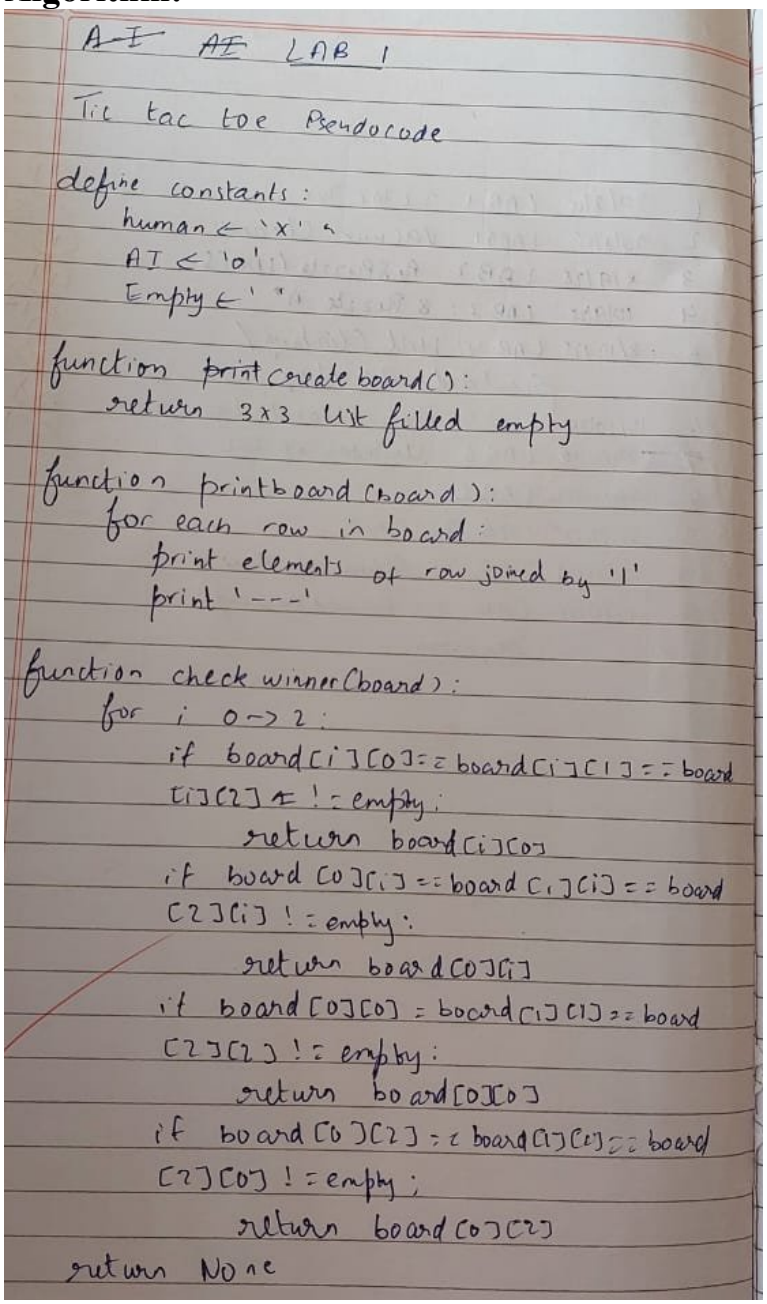
Program 1

Implement Tic –Tac –Toe Game

Implement vacuum cleaner agent

Algorithm:

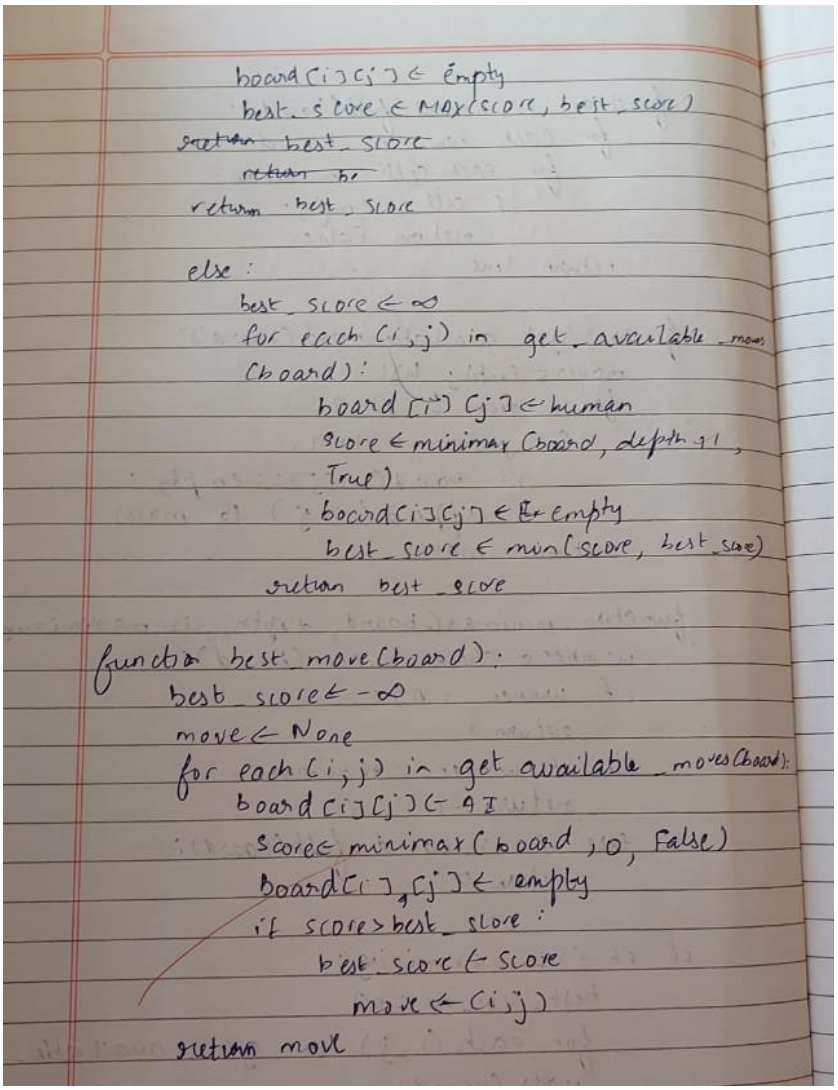


AI LAB 1

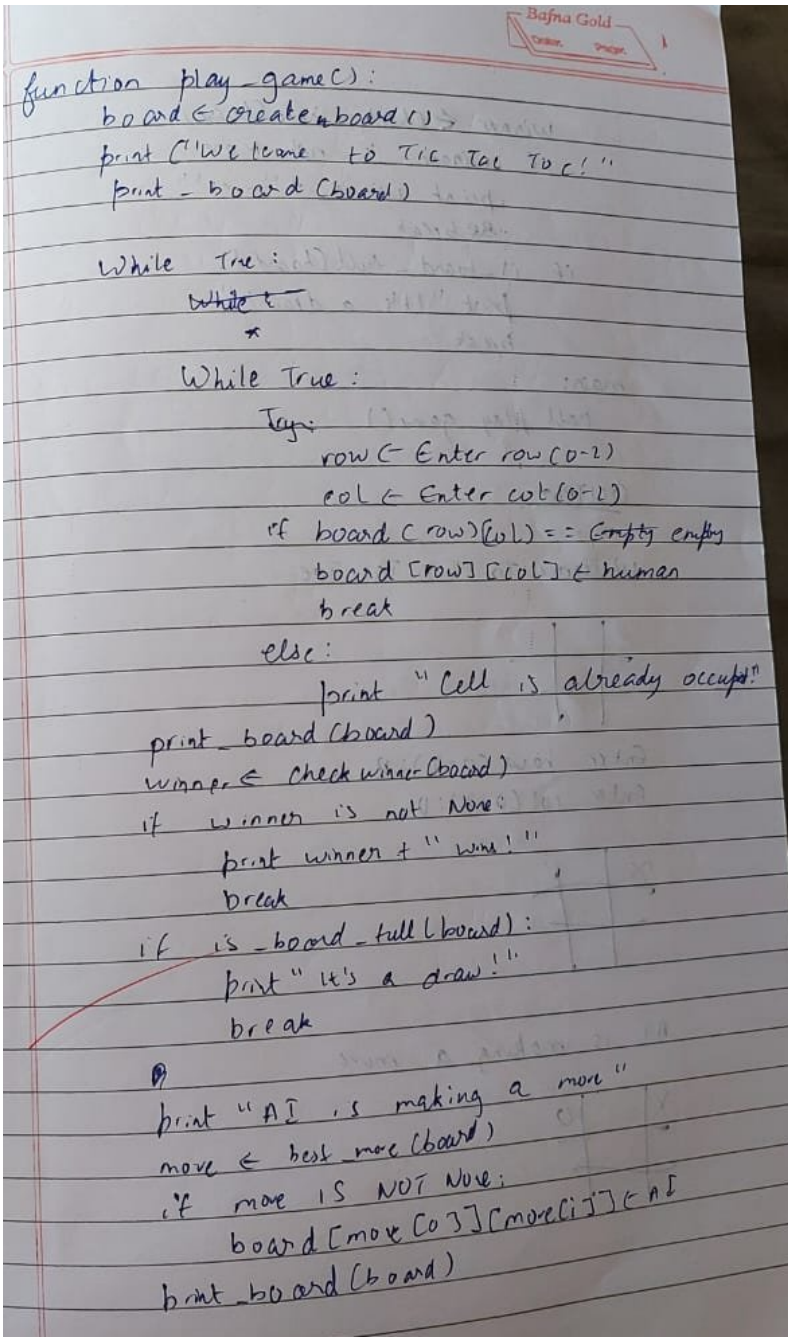
Tic tac toe Pseudocode

```
define constants:
    human ← 'x'
    AI ← 'o'
    Empty ← ' '

function print create board():
    return 3x3 list filled empty

function printboard(board):
    for each row in board:
        print elements of row joined by '|'
        print '---'

function check winner(board):
    for i 0 -> 2:
        if board[i][0] == board[i][1] == board
        [i][2] != ' ': empty:
            return board[i][0]
        if board[0][i] == board[1][i] == board
        [2][i] != empty:
            return board[0][i]
        if board[0][0] = board[1][1] == board
        [2][2] != empty:
            return board[0][0]
        if board[0][2] = board[1][1] == board
        [2][0] != empty;
            return board[0][2]
    return None
```

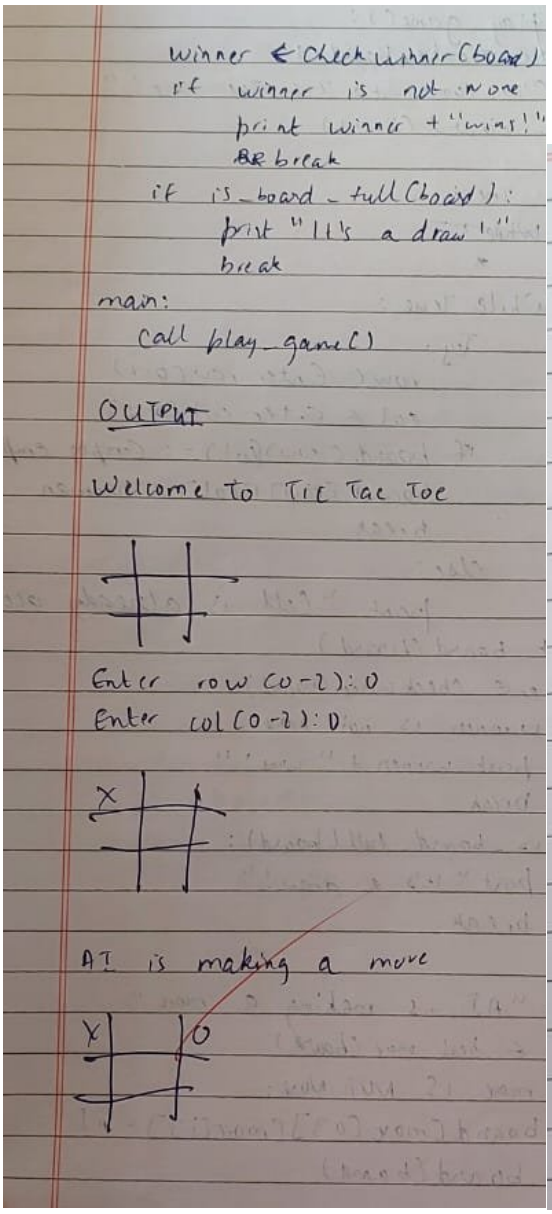
```
function is_board_full(board):
    for each row in board:
        for each cell in row:
            if cell == empty:
                return False
    return True

function get_available_moves(board):
    moves ← empty list
    for i from 0 to 2:
        for j from 0 to 2:
            if board[i][j] == empty:
                append (i, j) to moves
    return moves

function minimax(board, depth, is_maximizing):
    winner ← check_winner(board)
    if winner == AI:
        return 1
    else if winner == human:
        return -1
    else if is_board_full(board):
        return 0

if is_maximizing:
    best_score ← -∞
    for each (i, j) in get_available_
    moves(board):
        board[i][j] ← AI
        score ← minimax(board, depth+1,
        False)
```

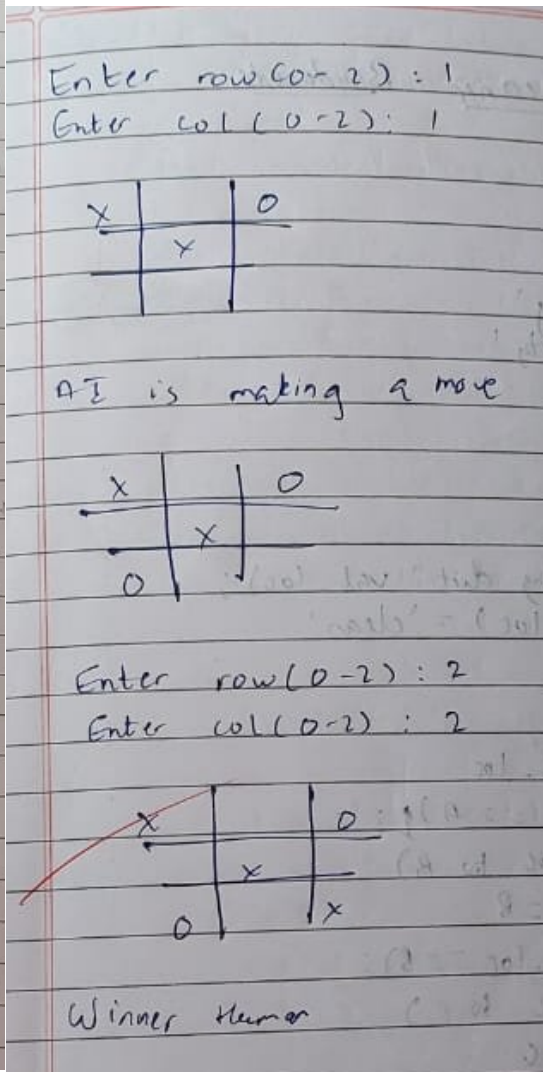


```
        board[i][j] ← Empty
        best_score ← MAX(score, best_score)
    return best_score
    return best_score

    return best_score

else:
    best_score ← ∞
    for each (i,j) in get_available_moves
    (board):
        board[i][j] ← human
        score ← minimax (board, depth+1,
        True)
        board[i][j] ← Empty
        best_score ← min(score, best_score)
    return best_score

function best_move(board):
    best_score ← -∞
    move ← None
    for each (i,j) in get available_moves(board):
        board[i][j] ← AI
        score ← minimax(board, 0, False)
        Board[i],[j] ← empty
        if score > best_score:
            best_score ← score
                move ← (i,j)
return move
```



```
function play_game():
    board ← create_board()
    print("Welcome to Tic Tac Toe!")
    print_board(board)

    While True:
        ~~While t~~
        *

    While True:
        Try:
            row ← Enter row(0-2)
            col ← Enter col(0-2)
        if board[row][col] == ~~Empty~~ empty
            board[row][col] ← human
            break
        else:
            print "Cell is already occupied"
    print_board(board)
    winner ← check_winner(board)
    if winner is not None:
        print winner + " wins!"
        break
    if is_board_full(board):
        print "It's a draw!"
        break

    print "AI is making a move"
    move ← best_move(board)
    if move IS NOT None:
        board[move[0]][move[1]] ← AI
    print_board(board)
```

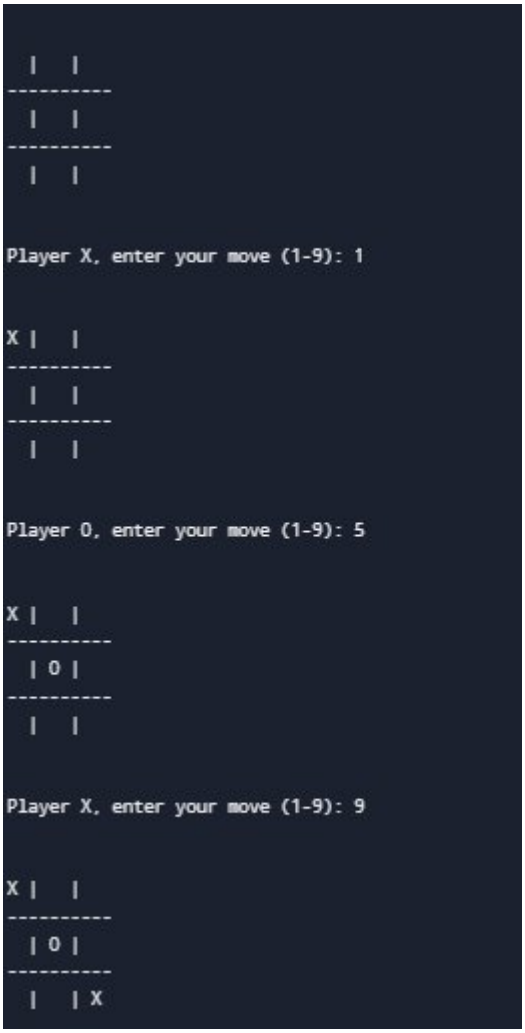




Code:

```
def print_board(board):
    print("\n")
    for i in range(3):
        print(" | ".join(board[i*3:(i+1)*3]))
        if i < 2:
            print("-" * 10)
    print("\n")

def check_winner(board, player):
    win_conditions = [
        [0, 1, 2], [3, 4, 5], [6, 7, 8],
```

```
        [0, 3, 6], [1, 4, 7], [2, 5, 8],
        [0, 4, 8], [2, 4, 6]
    ]
    for combo in win_conditions:
        count=0
        for pos in combo:
            if board[pos]==player:
                count+=1
        if count==3:
            return True
    return False

board = [" "] * 9
current_player = "X"
print_board(board)

while True:
    while True:
        pos = int(input(f"Player {current_player}, enter your move (1-9): ")) - 1
        if 0 <= pos <= 8 and board[pos] == " ":
            board[pos] = current_player
            break
        else:
            print("Invalid move. Try again.")

    print_board(board)

    if check_winner(board, current_player):
        print(f"Player {current_player} wins!")
        break
    if " " not in board:
        print("It's a draw!")
        break

    # Switch players
    current_player = "O" if current_player == "X" else "X"
```


| |

| |

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

| |

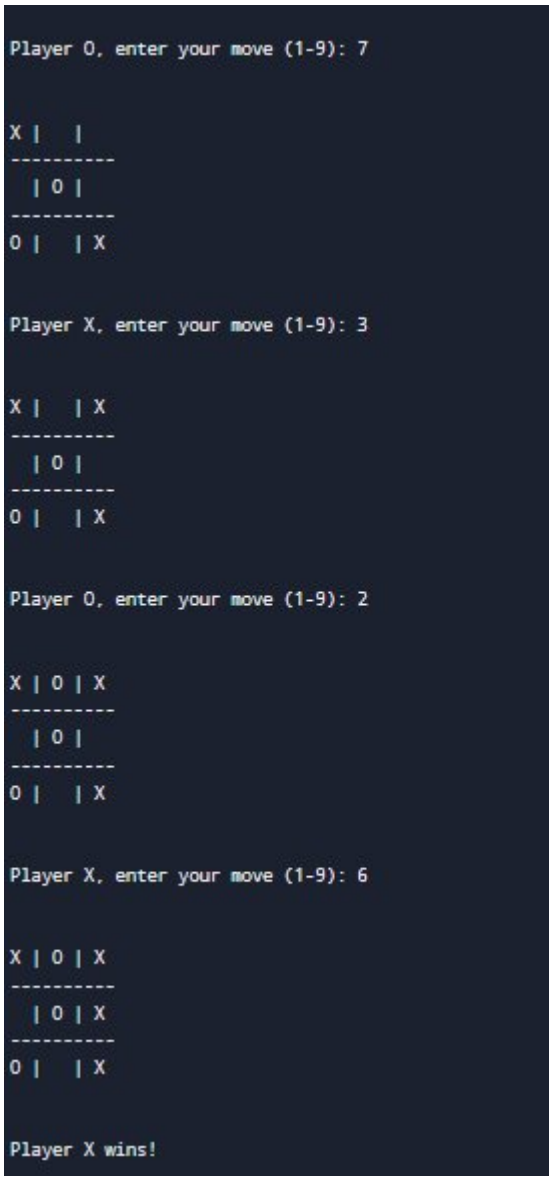
| |
Player O, enter your move (1-9): 5
X | |

| O |

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

| O |

| | X


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

| O |

O | | X
Player X, enter your move (1-9): 3
X | | X

| O |

O | | X
Player O, enter your move (1-9): 2
X | O | X

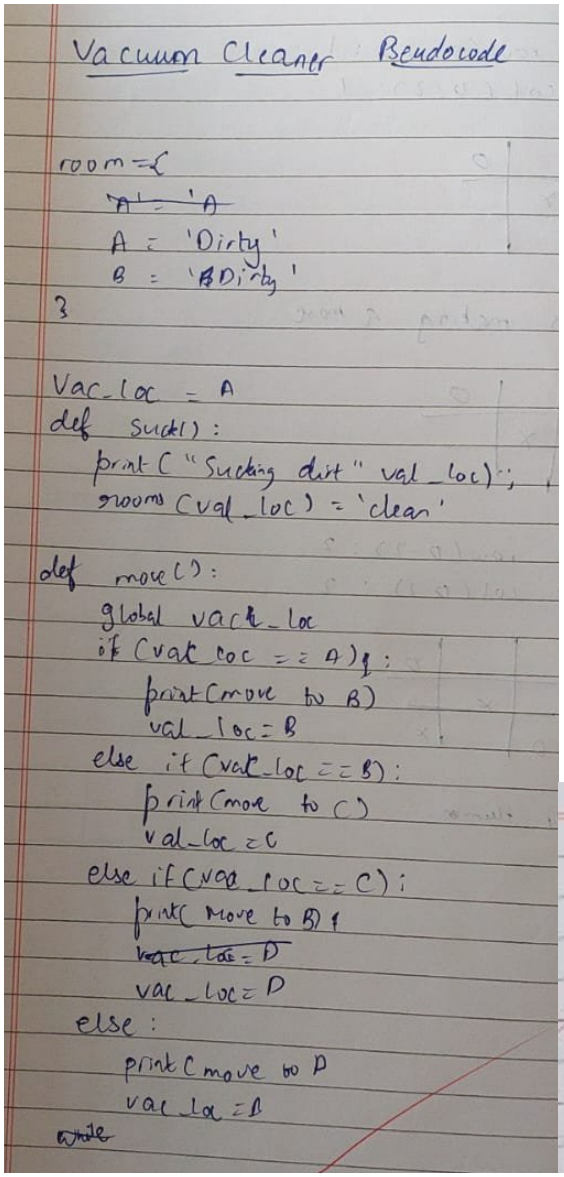
| O |

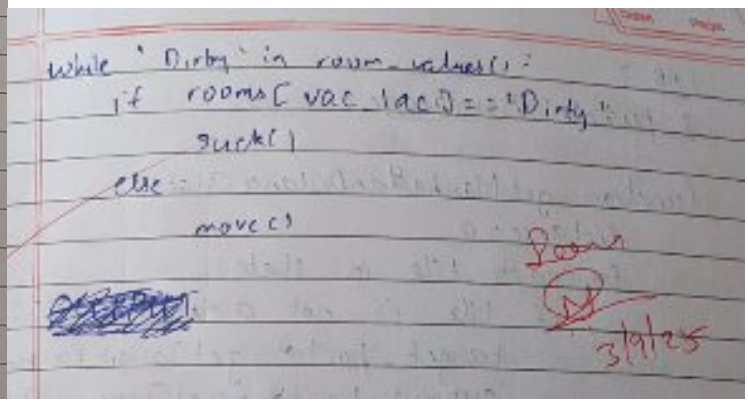
O | | X
Player X, enter your move (1-9): 6
X | O | X

| O | X

O | | X
Player X wins!

Vacuum Cleaner






```
import random
rooms=[1,1,1,1]
botpos =(int(input("Enter Initial Position"))-1)
cleanedpos=[]
cost=0

def movebot(pos):

    while True:
        n= random.randint(0,3)
        if n != pos and n not in cleanedpos:
            pos = n
            break
```

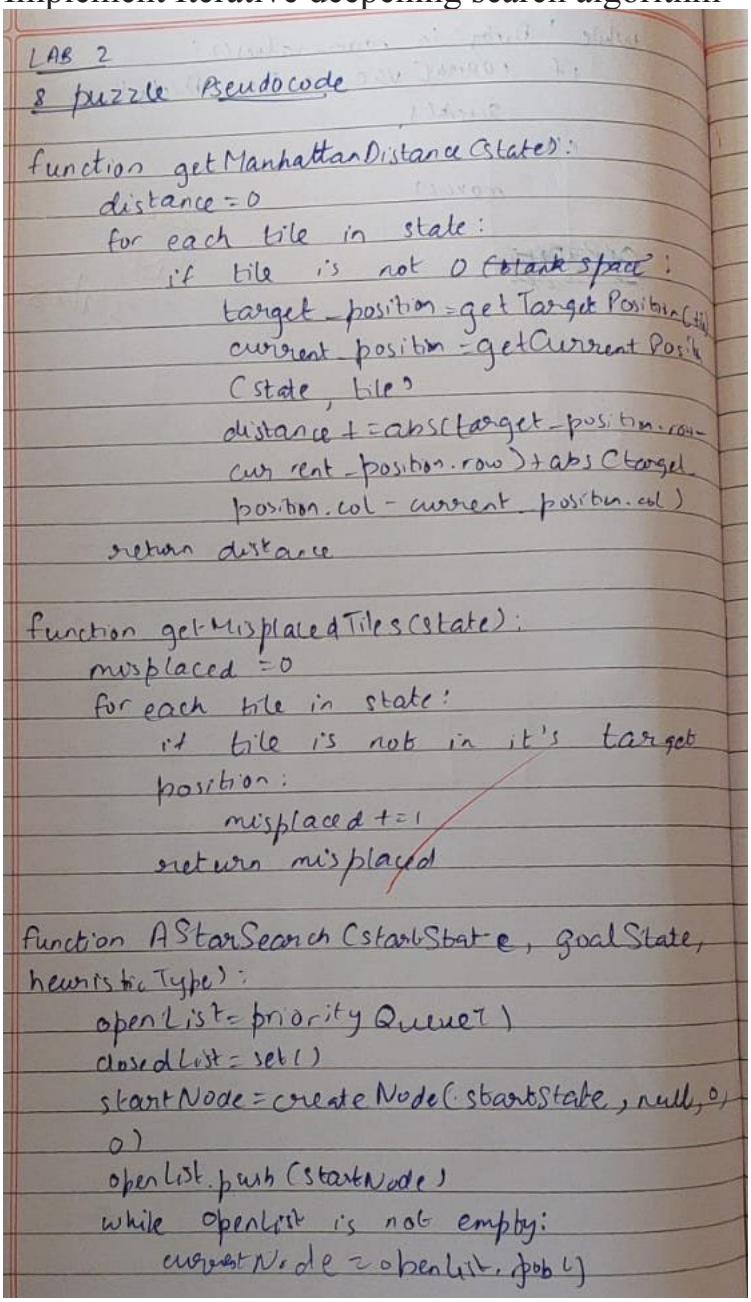
```
    return pos

while True:
    print(str(rooms))
    print(botpos+1)

    if rooms[botpos]==1:

        rooms[botpos]=0
        cleanedpos.append(botpos)
        cost+=1
        if len(cleanedpos) == 4:
            break
        botpos=movebot(botpos)

    elif rooms[botpos]==0:
        cleanedpos.append(botpos)
        if len(cleanedpos) == 4:
            break
        botpos = movebot(botpos)

print("cost="+str(cost))
```

```
Enter Initial Position2
[1, 1, 1, 1]
2
[1, 0, 1, 1]
3
[1, 0, 0, 1]
1
[0, 0, 0, 1]
4
cost=4
```

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)

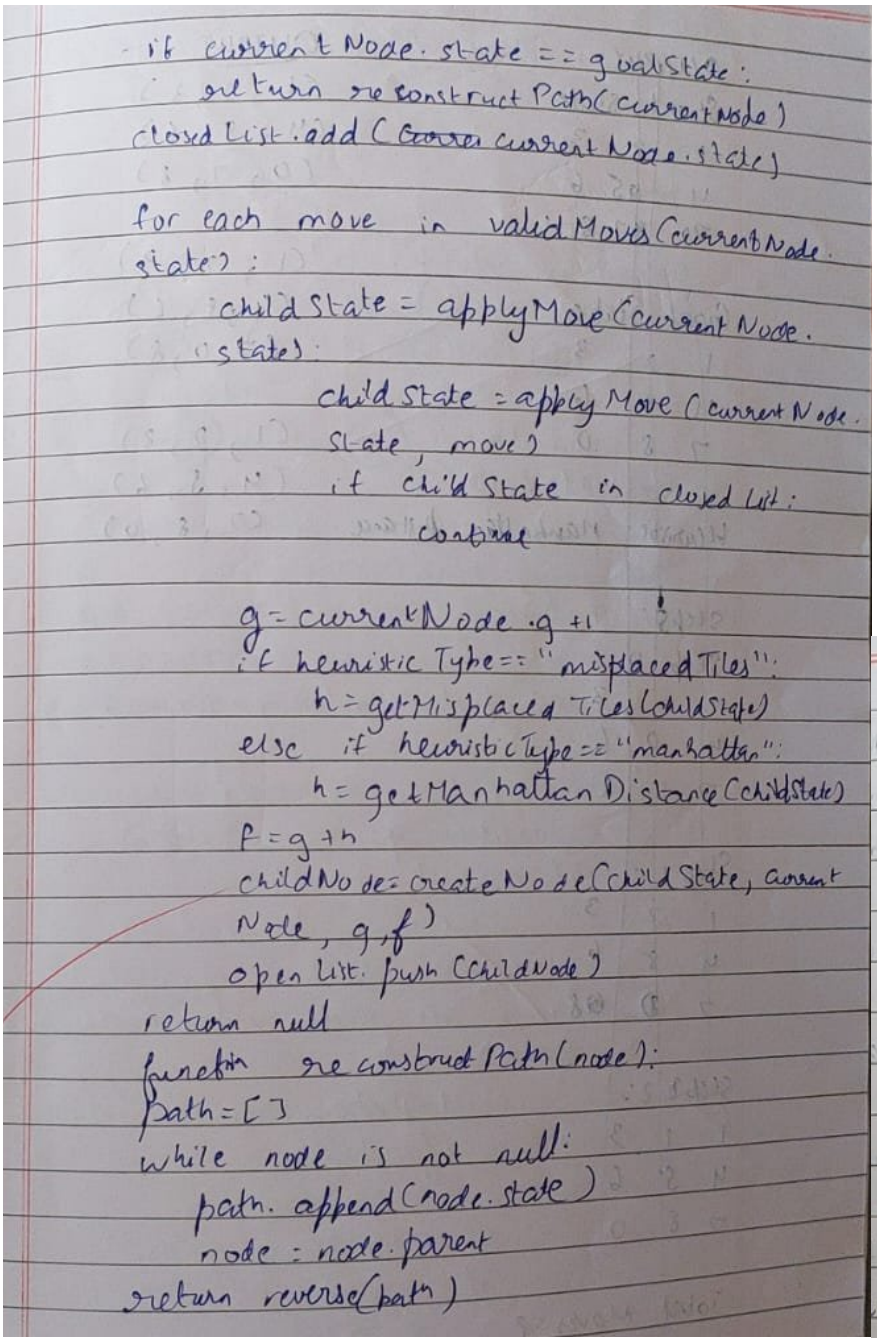
Implement Iterative deepening search algorithm



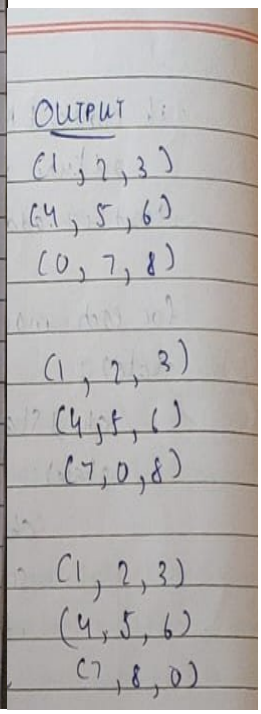
LAB 2

8 puzzle Pseudocode

```
function getManhattanDistance(state):
    distance = 0
    for each tile in state:
        if tile is not 0 (blank space):
            target_position = getTargetPosition(tile)
            current_position = getCurrentPosition(state, tile)
            distance += abs(target_position.row - current_position.row) + abs(target_position.col - current_position.col)
    return distance

function getMisplacedTiles(state):
    misplaced = 0
    for each tile in state:
        if tile is not in it's target position:
            misplaced += 1
    return misplaced

function AStarSearch(startState, goalState, heuristicType):
    openList = priorityQueue()
    closedList = set()
    startNode = createNode(startState, null, 0, 0)
    openList.push(startNode)
    while openList is not empty:
        currentNode = openList.pop()
```



```
if currentNode.state == goalState:
    return reconstructPath(currentNode)
closedList.add(currentNode.state)

for each move in validMoves(currentNode.
state):
    childState = applyMove(currentNode.
    state)
        childState = applyMove(currentNode.
        state, move)
        if childState in closedList:
            continue

    g = currentNode.g + 1
    if heuristicType == "misplacedTiles":
        h = getMisplacedTiles(childState)
    else if heuristicType == "manhattan":
        h = getManhattanDistance(childState)
    f = g + h
    childNode = createNode(childState, current
    Node, g, f)
    openList.push(childNode)
return null
function reconstructPath(node):
path = []
while node is not null:
    path.append(node.state)
    node = node.parent
return reverse(path)
```




```
import time

def find_possible_moves(state):
    index = state.index('_')
    moves = {
        0: [1, 3],
        1: [0, 2, 4],
        2: [1, 5],
        3: [0, 4, 6],
        4: [1, 3, 5, 7],
        5: [2, 4, 8],
```

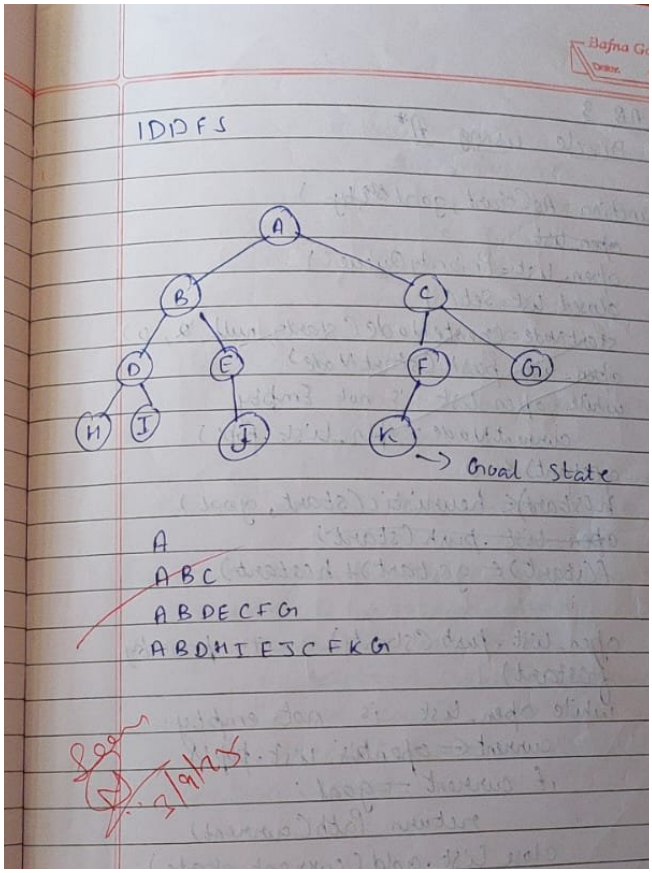
```
        6: [3, 7],
        7: [6, 8, 4],
        8: [5, 7],
    }
    return moves.get(index, [])

def dfs(initial_state, goal_state, max_depth=50):
    stack = [(initial_state, [], 0)]
    visited = {tuple(initial_state)}
    states_explored = 0
    printed_depths = set()

    while stack:
        current_state, path, depth = stack.pop()

        if depth > max_depth:
            continue

        if depth not in printed_depths:
            print(f"\n--- Depth {depth} ---")
            printed_depths.add(depth)

        states_explored += 1
        print(f"State #{states_explored}: {current_state}")

        if current_state == goal_state:
            print(f"\n Goal reached at depth {depth} after exploring {states_explored} states.\n")
            return path, states_explored

        possible_moves_indices = find_possible_moves(current_state)

        for move_index in reversed(possible_moves_indices):  # Reverse for DFS order
            next_state = list(current_state)
            blank_index = next_state.index('_')
            next_state[blank_index], next_state[move_index] = next_state[move_index],
next_state[blank_index]

            if tuple(next_state) not in visited:
                visited.add(tuple(next_state))
                stack.append((next_state, path + [next_state], depth + 1))

    print(f"\n Goal state not reachable within depth {max_depth}. Explored {states_explored}
states.\n")
    return None, states_explored


# ----------------- TEST -----------------
```

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

goal_state    = [1, 2, 3,
                 4, 5, 6,
                 7, 8, '_']

# Measure execution time
start_time = time.time()
solution_path, explored = dfs(initial_state, goal_state, max_depth=50)
end_time = time.time()

if solution_path is None:
    print("No solution found.")
else:
    print("Solution path:")
    for step, state in enumerate(solution_path, start=1):
        print(f"Step {step}: {state}")

print("\nExecution time: {:.6f} seconds".format(end_time - start_time))
print("Total states explored:", explored)
```

```
--- Depth 0 ---
State #1: [1, 2, 3, 4, 8, '_', 7, 6, 5]

--- Depth 1 ---
State #2: [1, 2, '_', 4, 8, 3, 7, 6, 5]

--- Depth 2 ---
State #3: [1, '_', 2, 4, 8, 3, 7, 6, 5]

--- Depth 3 ---
State #4: ['_', 1, 2, 4, 8, 3, 7, 6, 5]

--- Depth 4 ---
State #5: [4, 1, 2, '_', 8, 3, 7, 6, 5]

--- Depth 5 ---
State #6: [4, 1, 2, 8, '_', 3, 7, 6, 5]

--- Depth 6 ---
State #7: [4, '_', 2, 8, 1, 3, 7, 6, 5]

--- Depth 7 ---
State #8: ['_', 4, 2, 8, 1, 3, 7, 6, 5]

--- Depth 8 ---
State #9: [8, 4, 2, '_', 1, 3, 7, 6, 5]
```

```
--- Depth 9 ---
State #10: [8, 4, 2, 1, '_', 3, 7, 6, 5]

--- Depth 10 ---
State #11: [8, '_', 2, 1, 4, 3, 7, 6, 5]

--- Depth 11 ---
State #12: ['_', 8, 2, 1, 4, 3, 7, 6, 5]

--- Depth 12 ---
State #13: [1, 8, 2, '_', 4, 3, 7, 6, 5]

--- Depth 13 ---
State #14: [1, 8, 2, 7, 4, 3, '_', 6, 5]

--- Depth 14 ---
State #15: [1, 8, 2, 7, 4, 3, 6, '_', 5]

--- Depth 15 ---
State #16: [1, 8, 2, 7, 4, 3, 6, 5, '_']

--- Depth 16 ---
State #17: [1, 8, 2, 7, 4, '_', 6, 5, 3]
```

IDDFS




```
import time

# ----------------- MOVE GENERATOR -----------------
def find_possible_moves(state):
    index = state.index('_')

    if index == 0:
        return [1, 3]
    elif index == 1:
        return [0, 2, 4]
    elif index == 2:
        return [1, 5]
    elif index == 3:
        return [0, 4, 6]
    elif index == 4:
        return [1, 3, 5, 7]
    elif index == 5:
        return [2, 4, 8]
    elif index == 6:
        return [3, 7]
    elif index == 7:
        return [4, 6, 8]
```

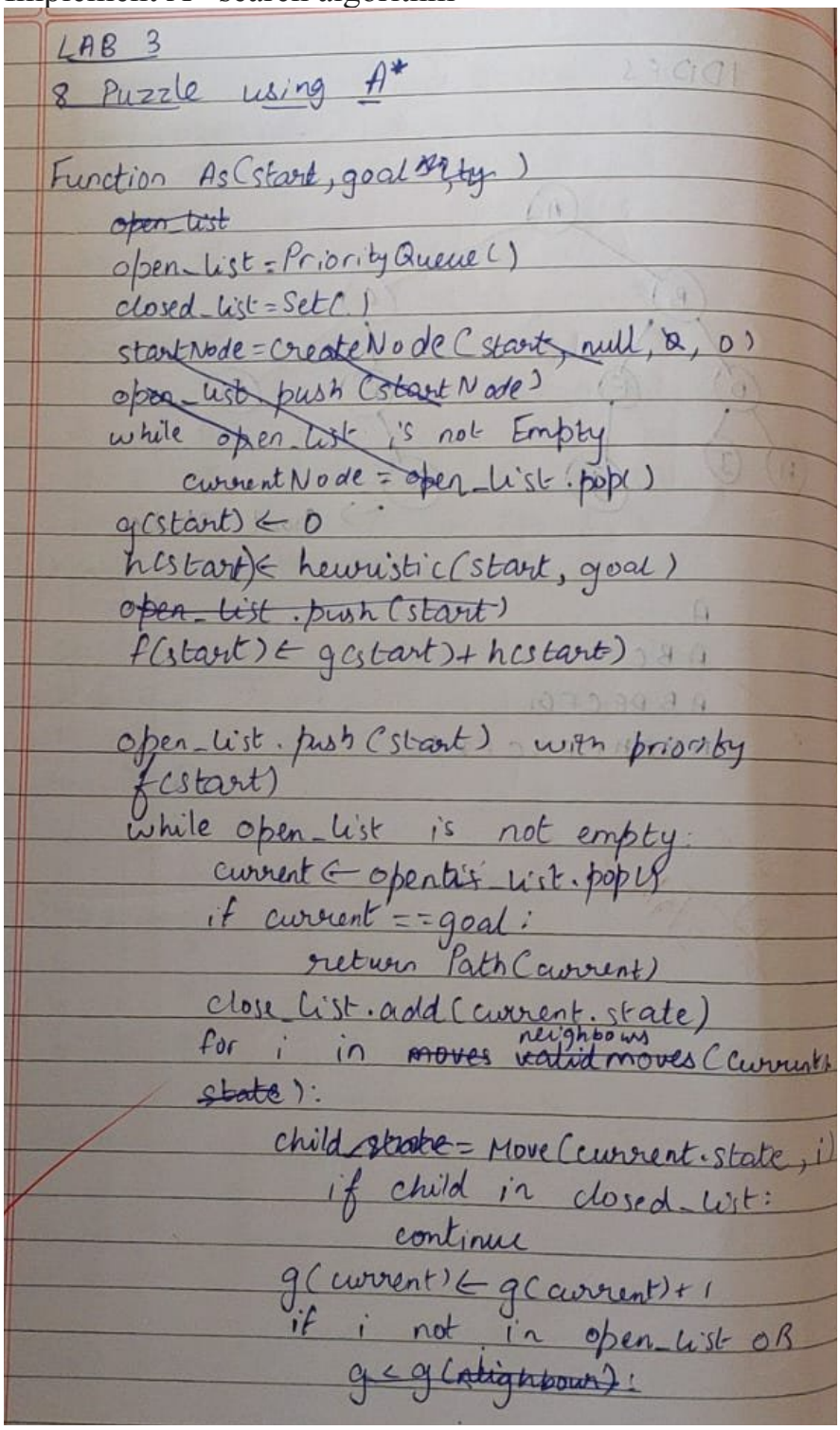
```
    elif index == 8:
        return [5, 7]
    return []

# ----------------- DEPTH LIMITED SEARCH -----------------
def depth_limited_dfs(state, goal_state, limit, path, visited):
    if state == goal_state:
        return path

    if limit <= 0:
        return None

    visited.add(tuple(state))

    for move_index in find_possible_moves(state):
        next_state = list(state)
        blank_index = next_state.index('_')
        next_state[blank_index], next_state[move_index] = next_state[move_index],
next_state[blank_index]

        if tuple(next_state) not in visited:
            result = depth_limited_dfs(next_state, goal_state, limit - 1, path + [next_state], visited)
            if result is not None:
                return result
    return None

# ----------------- ITERATIVE DEEPENING DFS -----------------
def iddfs(initial_state, goal_state, max_depth=30):
    for depth in range(max_depth):
        print(f"Searching at depth limit = {depth}")
        visited = set()
        result = depth_limited_dfs(initial_state, goal_state, depth, [initial_state], visited)
        if result is not None:
            return result, depth
    return None, max_depth

# ----------------- TEST -----------------
initial_state = [1, 2, 3,
                 4, 8, '_',
                 7, 6, 5]

goal_state    = [1, 2, 3,
                 4, 5, 6,
                 7, 8, '_']

# Measure execution time
start_time = time.time()
```

```
solution_path, depth_reached = iddfs(initial_state, goal_state, max_depth=30)
end_time = time.time()

if solution_path is None:
    print("Goal state is not reachable within given depth limit.")
else:
    print("\n\nSolution path found:")
    for step, state in enumerate(solution_path, start=0):
        print(f"Step {step}: {state}")

print("\nExecution time: {:.6f} seconds".format(end_time - start_time))
print("Depth reached:", depth_reached)
```

```
Searching at depth limit = 0
Searching at depth limit = 1
Searching at depth limit = 2
Searching at depth limit = 3
Searching at depth limit = 4
Searching at depth limit = 5


Solution path found:
Step 0: [1, 2, 3, 4, 8, '_', 7, 6, 5]
Step 1: [1, 2, 3, 4, 8, 5, 7, 6, '_']
Step 2: [1, 2, 3, 4, 8, 5, 7, '_', 6]
Step 3: [1, 2, 3, 4, '_', 5, 7, 8, 6]
Step 4: [1, 2, 3, 4, 5, '_', 7, 8, 6]
Step 5: [1, 2, 3, 4, 5, 6, 7, 8, '_']

Execution time: 0.000194 seconds
Depth reached: 5

=== Code Execution Successful ===
```

Program 3

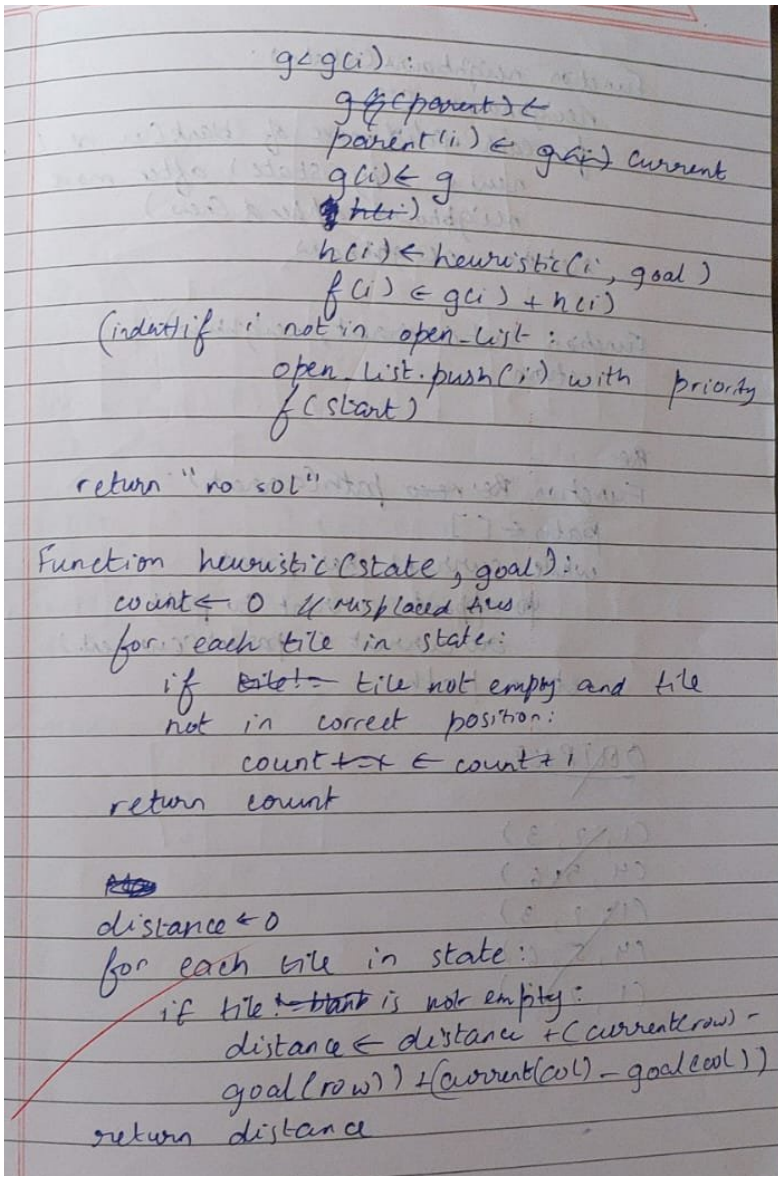
Implement A* search algorithm



LAB 3

8 Puzzle using A*

```
Function AS(start, goal)
    open_list
    open_list = PriorityQueue()
    closed_list = Set()
    startNode = CreateNode(start, null, 0, 0)
    open_list.push(startNode)
    while open_list is not Empty
        currentNode = open_list.pop()
    g(start) ← 0
    h(start) ← heuristic(start, goal)
    open_list.push(start)
    f(start) ← g(start) + h(start)

    open_list.push(start) with priority
    f(start)
    while open_list is not empty:
        current ← openlist_list.pop()
        if current == goal:
            return Path(current)
        close_list.add(current.state)
        for i in moves neighbours validmoves(Currents
        state):
            child_state = Move(current.state, i)
            if child in closed_list:
                continue
            g(current) ← g(current) + 1
            if i not in open_list OR
                g < g(neighbour):
```



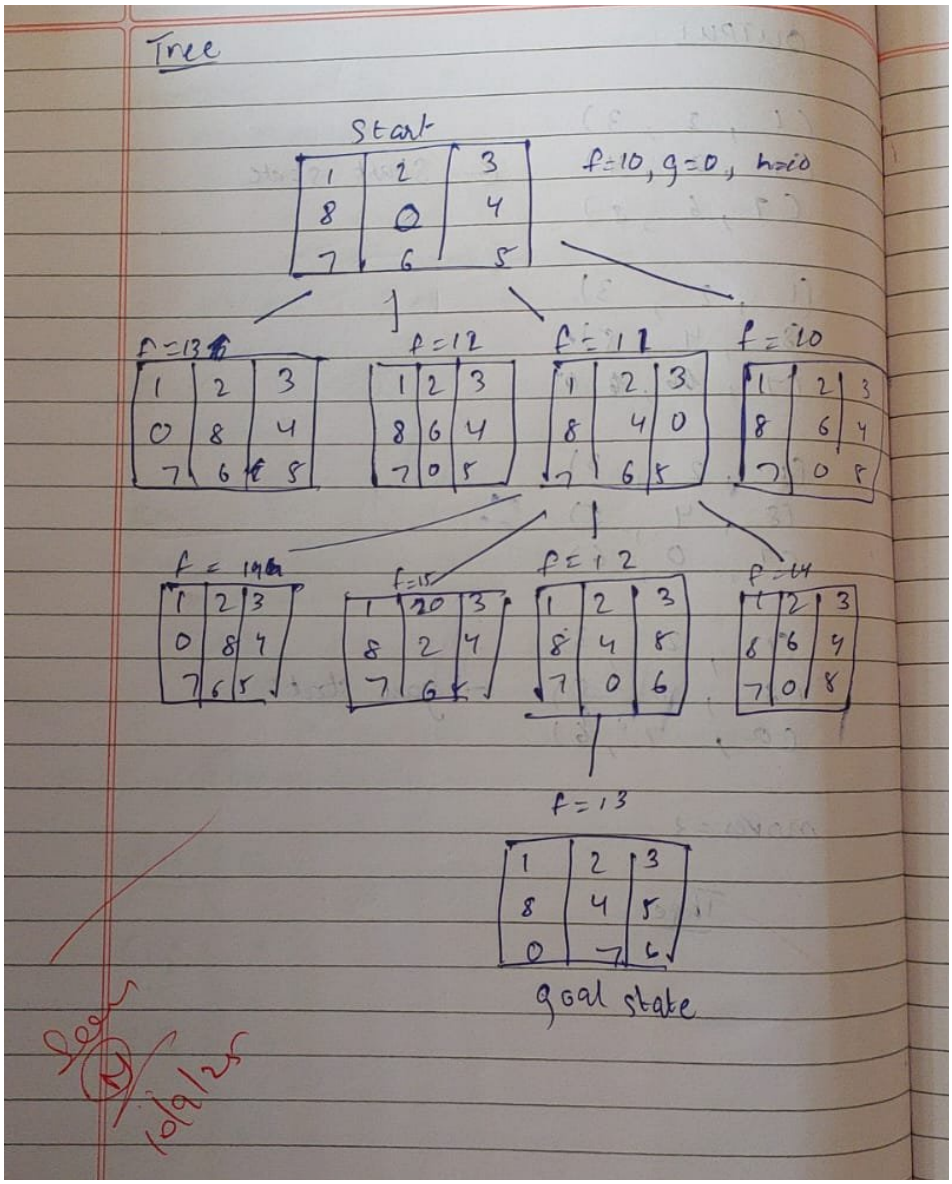
```
        g < g(i):
            g(parent) <-
            parent(i) <- current
            g(i) <- g
            h(i)
            h(i) <- heuristic(i, goal)
            f(i) <- g(i) + h(i)
    (indent)if i not in open_list:
            open_list.push(i) with priority
            f(start)

return "no sol"

Function heuristic(state, goal):
    count <- 0 // misplaced tiles
    for each tile in state:
        if tile != tile not empty and tile
        not in correct position:
            count += 1 <- count + 1
    return count

distance <- 0
for each tile in state:
    if tile != blank is not empty:
        distance <- distance + (current(row) -
        goal(row)) + (current(col) - goal(col))
return distance
```

```
Function neighbours(state):
    neighbours ← []
    for each valid move of blank (u, d, l, r):
        new ← copy(state) after move
        neighbours.append(new)
    return neighbours

Function cost(current, neighbour):
    return 1

Re
Function Re~~reco~~ path(current):
    path ← []
    while current has parent:
        ~~ap~~ append current to path
        ~~cu~~ current ← parent(current)
    return path
```

OUTPUT

```
(1, 2, 3)
(8, 0, 4)   ← start state
(7, 6, 5)

(1, 2, 3)
(8, 4, 5)
(7, 6, 0)

(1, 2, 3)
(8, 4, 5)
(7, 0, 6)

(1, 2, 3)
(8, 4, 5)   ← goal state
(0, 7, 6)

moves = 3
```

Time




```
import heapq
import time

# Heuristic: Manhattan Distance
def heuristic(state, goal):
    distance = 0
    for i in range(1, 9):  # tile numbers 1 to 8
        x1, y1 = divmod(state.index(i), 3)
        x2, y2 = divmod(goal.index(i), 3)
        distance += abs(x1 - x2) + abs(y1 - y2)
    return distance

# Get neighbors by sliding blank (0) up/down/left/right
def get_neighbors(state):
    neighbors = []
```

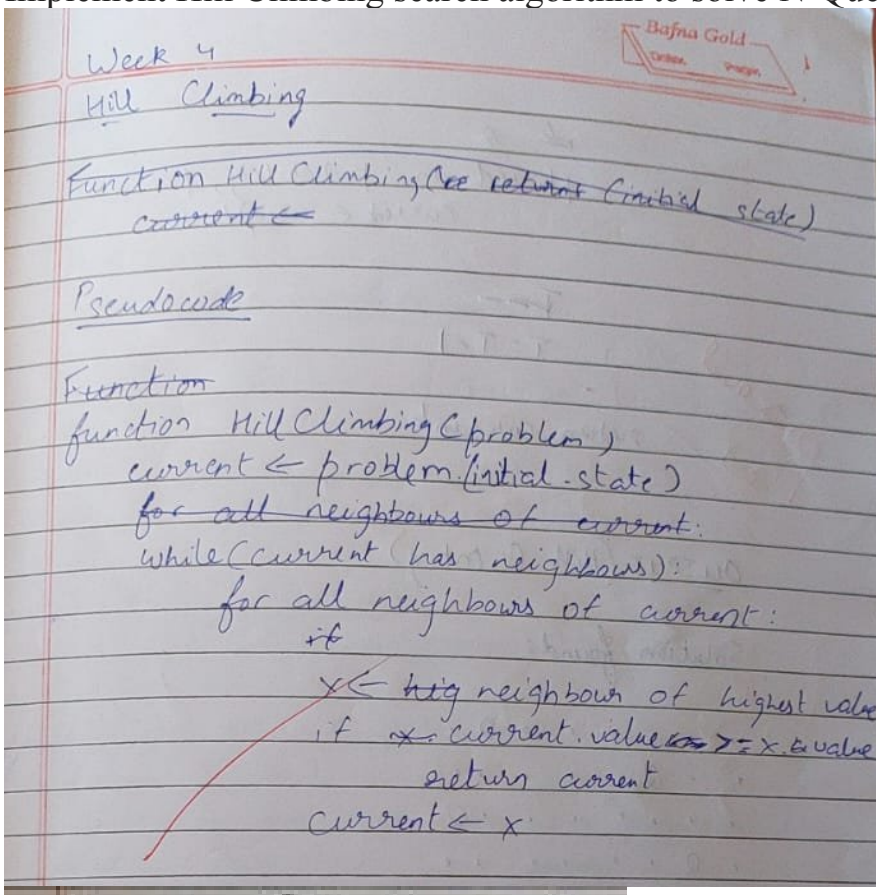
```
    i = state.index(0)  # position of blank
    x, y = divmod(i, 3)
    moves = [(-1,0), (1,0), (0,-1), (0,1)]

    for dx, dy in moves:
        new_x, new_y = x + dx, y + dy
        if 0 <= new_x < 3 and 0 <= new_y < 3:
            j = new_x * 3 + new_y
            new_state = list(state)
            new_state[i], new_state[j] = new_state[j], new_state[i]
            neighbors.append(tuple(new_state))
    return neighbors

# A* Search for 8-puzzle
def astar(start, goal):
    open_set = []
    heapq.heappush(open_set, (heuristic(start, goal), 0, start))

    came_from = {}
    g_score = {start: 0}

    while open_set:
        _, cost, current = heapq.heappop(open_set)

        if current == goal:
            # Reconstruct path
            path = []
            while current in came_from:
                path.append(current)
                current = came_from[current]
            path.append(start)
            return path[::-1]

        for neighbor in get_neighbors(current):
            tentative_g = g_score[current] + 1
            if neighbor not in g_score or tentative_g < g_score[neighbor]:
                came_from[neighbor] = current
                g_score[neighbor] = tentative_g
                f_score = tentative_g + heuristic(neighbor, goal)
                heapq.heappush(open_set, (f_score, tentative_g, neighbor))

    return None  # no solution

# ----------------- TEST -----------------
start = (1, 2, 3,
         4, 8, 0,
         7, 6, 5)
```

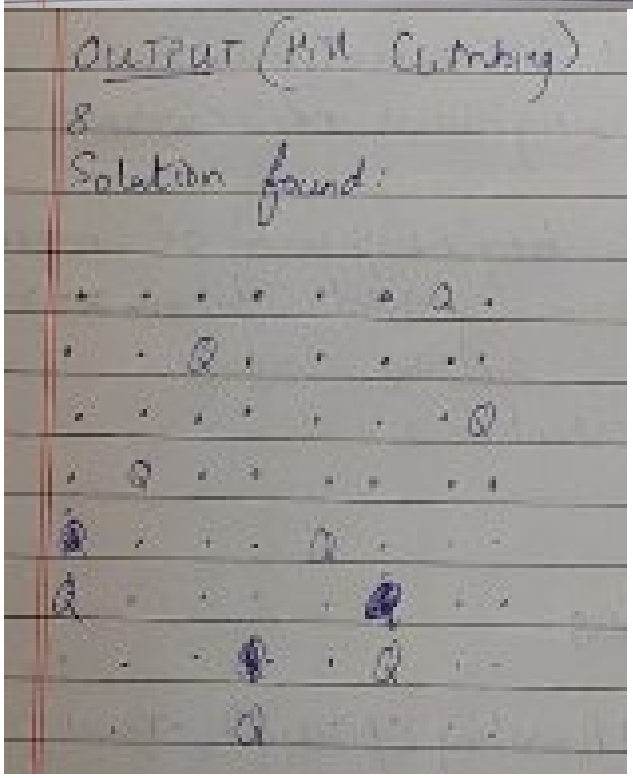
```
goal = (1, 2, 3,
        4, 5, 6,
        7, 8, 0)

# Measure execution time
start_time = time.time()
path = astar(start, goal)
end_time = time.time()

if path:
    print("Steps to solve ({} moves):".format(len(path)-1))
    for state in path:
        for i in range(0, 9, 3):
            print(state[i:i+3])
        print()
else:
    print("No solution found")

print("Execution time: {:.6f} seconds".format(end_time - start_time))
```

```
Steps to solve (5 moves):
(1, 2, 3)
(4, 8, 0)
(7, 6, 5)

(1, 2, 3)
(4, 8, 5)
(7, 6, 0)

(1, 2, 3)
(4, 8, 5)
(7, 0, 6)

(1, 2, 3)
(4, 0, 5)
(7, 8, 6)

(1, 2, 3)
(4, 5, 0)
(7, 8, 6)

(1, 2, 3)
(4, 5, 6)
(7, 8, 0)

Execution time: 0.000111 seconds
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem





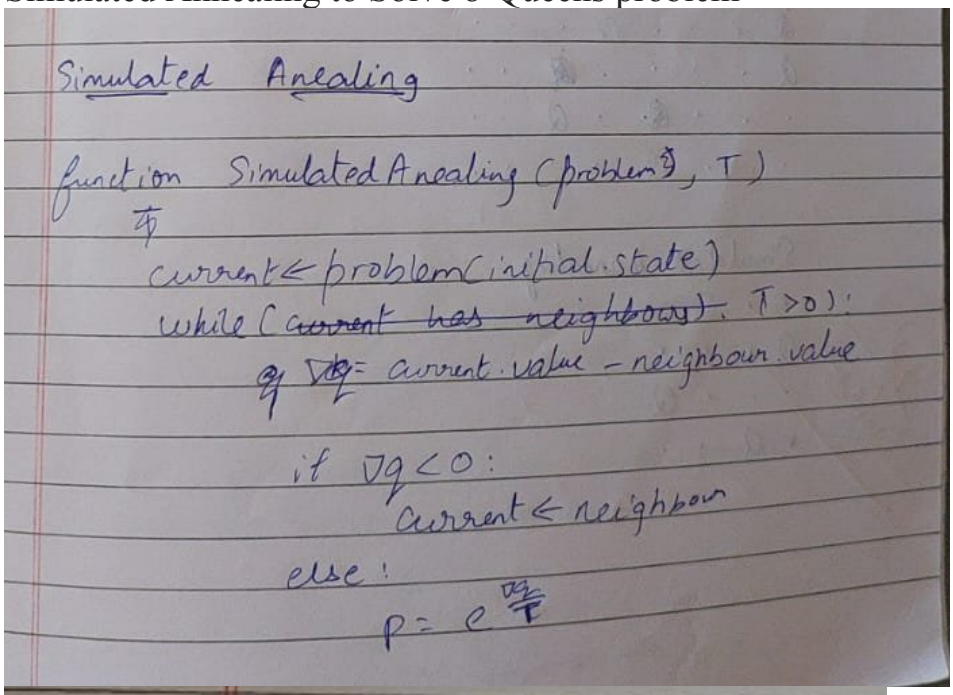
```
import random
import math

def compute_cost(state):
    """Count diagonal conflicts for a permutation-state (one queen per row & column)."""
    conflicts = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            if abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts

def random_permutation(n):
    arr = list(range(n))
    random.shuffle(arr)
    return arr

def neighbors_by_swaps(state):
    """All neighbors obtained by swapping two columns (keeps permutation property)."""
    n = len(state)
    for i in range(n - 1):
        for j in range(i + 1, n):
            nb = state.copy()
            nb[i], nb[j] = nb[j], nb[i]
            yield nb

def hill_climb_with_restarts(n, max_restarts=None):
    """Hill climbing on permutations with random restart on plateau (no revisits)."""
    visited = set()
    total_states = math.factorial(n)
    restarts = 0

    while True:
        # pick a random unvisited start permutation
        if len(visited) >= total_states:
            raise RuntimeError("All states visited — giving up (no solution found).")

        state = random_permutation(n)
        while tuple(state) in visited:
            state = random_permutation(n)
        visited.add(tuple(state))

        # climb from this start
        while True:
            cost = compute_cost(state)
            if cost == 0:
```

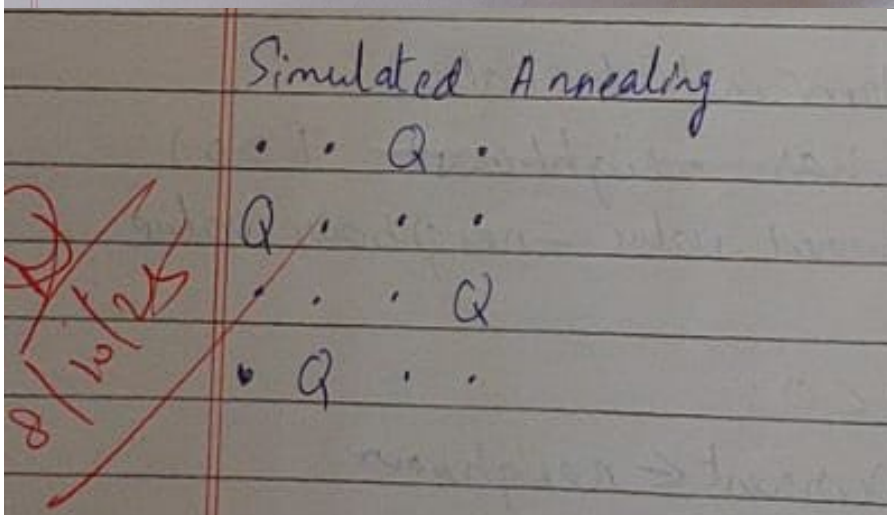
```
            return state, restarts

        # find best neighbor (swap-based neighbors)
        best_neighbor = None
        best_cost = float("inf")
        for nb in neighbors_by_swaps(state):
            c = compute_cost(nb)
            if c < best_cost:
                best_cost = c
                best_neighbor = nb

        # if strictly better, move; otherwise it's a plateau/local optimum -> restart
        if best_cost < cost:
            state = best_neighbor
            visited.add(tuple(state))
        else:
            # plateau or local optimum -> restart
            restarts += 1
            if max_restarts is not None and restarts >= max_restarts:
                raise RuntimeError(f"Stopped after {restarts} restarts (no solution found).")
            break  # go pick a new unvisited start

def format_board(state):
    n = len(state)
    lines = []
    for r in range(n):
        lines.append(" ".join("Q" if state[c] == r else "-" for c in range(n)))
    return "\n".join(lines)

if __name__ == "__main__":
    n = 4
    solution, restarts = hill_climb_with_restarts(n)
    print("Found solution:", solution)
    print(format_board(solution))
```

```
Found solution: [2, 0, 3, 1]
- Q - -
- - - Q
Q - - -
- - Q -
```

Program 5

Simulated Annealing to Solve 8-Queens problem






```
import random
import math

def cost(state):

    attacks = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                attacks += 1
    return attacks
```

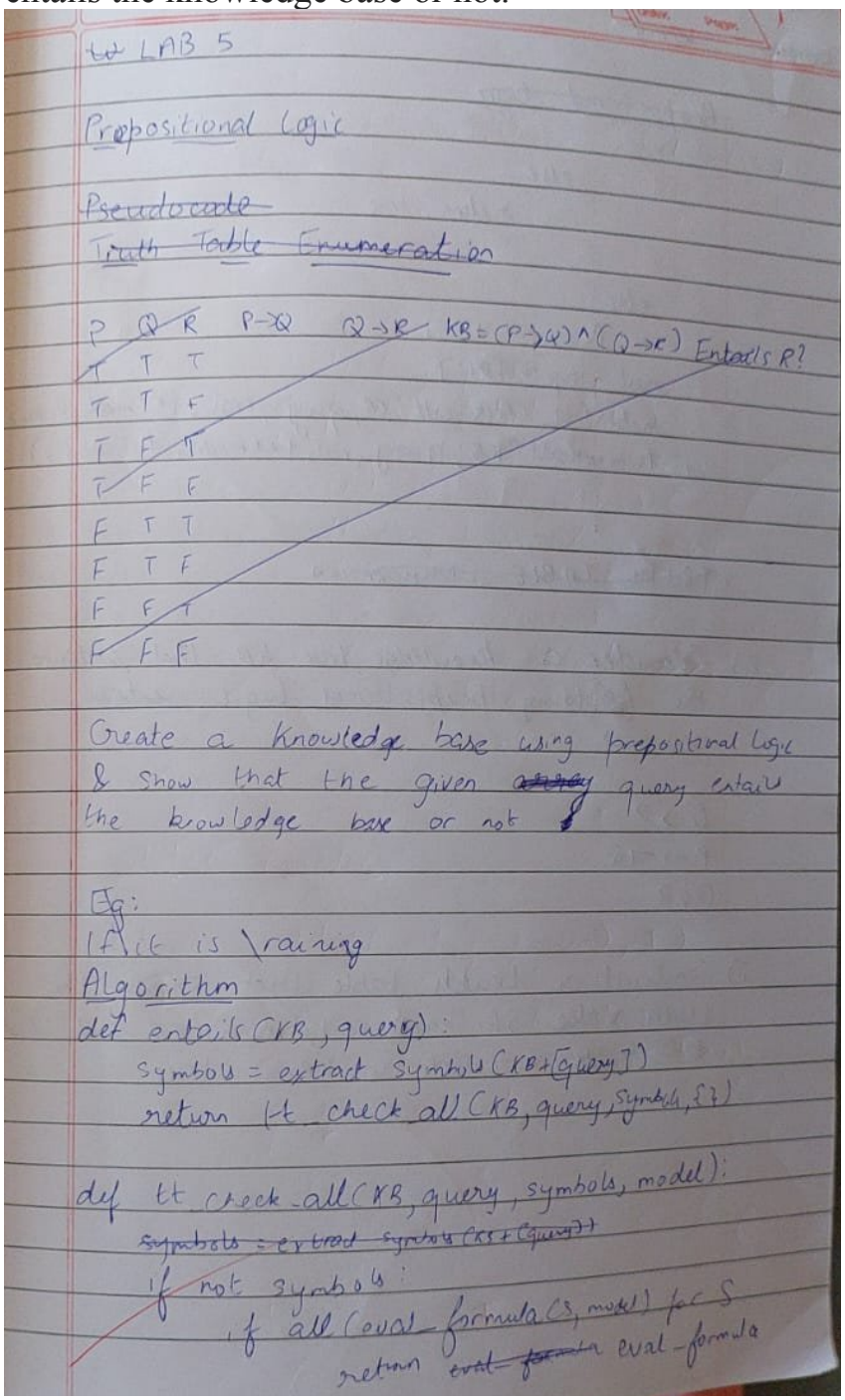
```
def get_neighbor(state):

    neighbor = state[:]
    i, j = random.sample(range(len(state)), 2)
    neighbor[i], neighbor[j] = neighbor[j], neighbor[i]
    return neighbor

def simulated_annealing(n=8, max_iter=10000, temp=100.0, cooling=0.95):

    current = list(range(n))
    random.shuffle(current)
    current_cost = cost(current)

    temperature = temp
    cooling_rate = cooling

    best = current[:]
    best_cost = current_cost

    for _ in range(max_iter):
        if temperature <= 0 or best_cost == 0:
            break

        neighbor = get_neighbor(current)
        neighbor_cost = cost(neighbor)
        delta = current_cost - neighbor_cost

        if delta > 0 or random.random() < math.exp(delta / temperature):
            current, current_cost = neighbor, neighbor_cost
            if neighbor_cost < best_cost:
                best, best_cost = neighbor[:], neighbor_cost

        temperature *= cooling_rate

    return best, best_cost

def print_board(state):

    n = len(state)
    for row in range(n):
        line = " ".join("Q" if state[col] == row else "." for col in range(n))
        print(line)
    print()


n = 8
solution, cost_val = simulated_annealing(n, max_iter=20000)
```

```
print("Best position found:", solution)
print(f"Number of non-attacking pairs: {n*(n-1)//2 - cost_val}")
print("\nBoard:")
print_board(solution)
```

```
Best position found: [6, 3, 1, 7, 5, 0, 2, 4]
Number of non-attacking pairs: 28

Board:
. . . . . Q . .
. . Q . . . . .
. . . . . . Q .
. Q . . . . . .
. . . . . . . Q
. . . . Q . . .
Q . . . . . . .
. . . Q . . . .


=== Code Execution Successful ===
```

Program 6

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



LAB 5

Propositional Logic

~~Pseudocode~~

~~Truth Table Enumeration~~

P	Q	R	P→Q	Q→R	KB = (P→Q) ∧ (Q→R)	Entails R?
T	T	T				
T	T	F				
T	F	T				
T	F	F				
F	T	T				
F	T	F				
F	F	T				
F	F	F				

Create a knowledge base using propositional logic & show that the given ~~query~~ query entails the knowledge base or not

Eg:

If it is raining

Algorithm

```
def entails(KB, query):
    symbols = extract symbols(KB+[query])
    return tt_check_all(KB, query, symbols, {})

def tt_check_all(KB, query, symbols, model):
    ~~symbols = extract symbols(KB+[query])~~
    if not symbols:
        if all(eval_formula(S, model) for S
        return eval_formula
```

else:
return true

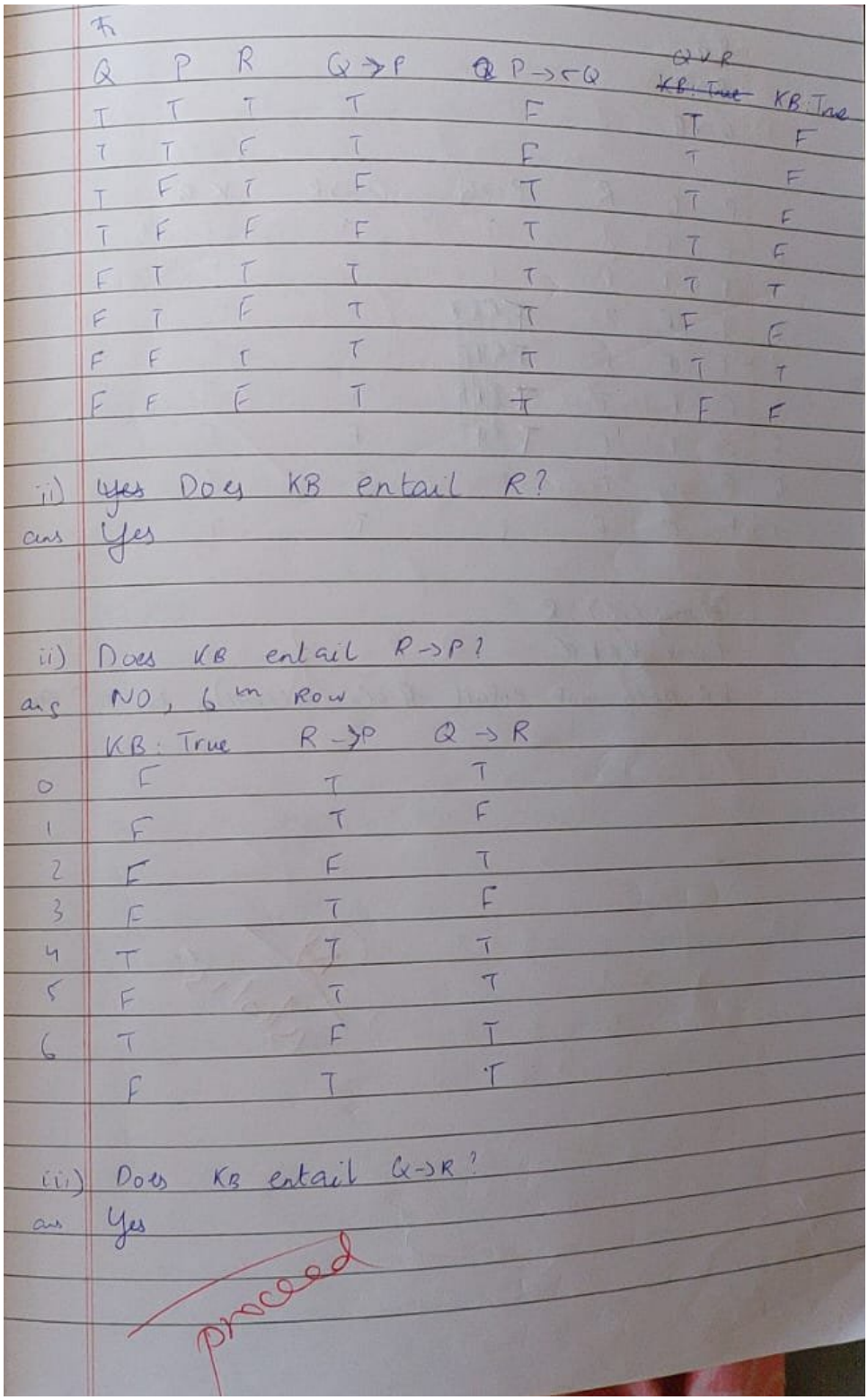
else:
P = symbols[0]
rest = symbols[1:]
return (tt_check_all(KB, query, rest, {**model, P: True})
and tt_check_all(KB, query, rest, {**model, P: False}))

~~TRUTH TABLE ENUMERATION~~

2) Consider a knowledge base KB that contains the following propositional logic ~~sentence~~ sentences

$Q \rightarrow P$
$P \rightarrow \neg Q$
$Q \vee R$

i) Construct a truth table that shows the truth value of each sentence in KB and indicate the models in which the KB is true



Q	P	R	Q→P	P→¬Q	Q∨R	KB: True
T	T	T	T	F	T	F
T	T	F	T	F	T	F
T	F	T	F	T	T	F
T	F	F	F	T	T	F
F	T	T	T	T	T	T
F	T	F	T	T	F	F
F	F	T	T	T	T	T
F	F	F	T	T	F	F

ii) ~~yes~~ Does KB entail R?

ans Yes

ii) Does KB entail R→P?

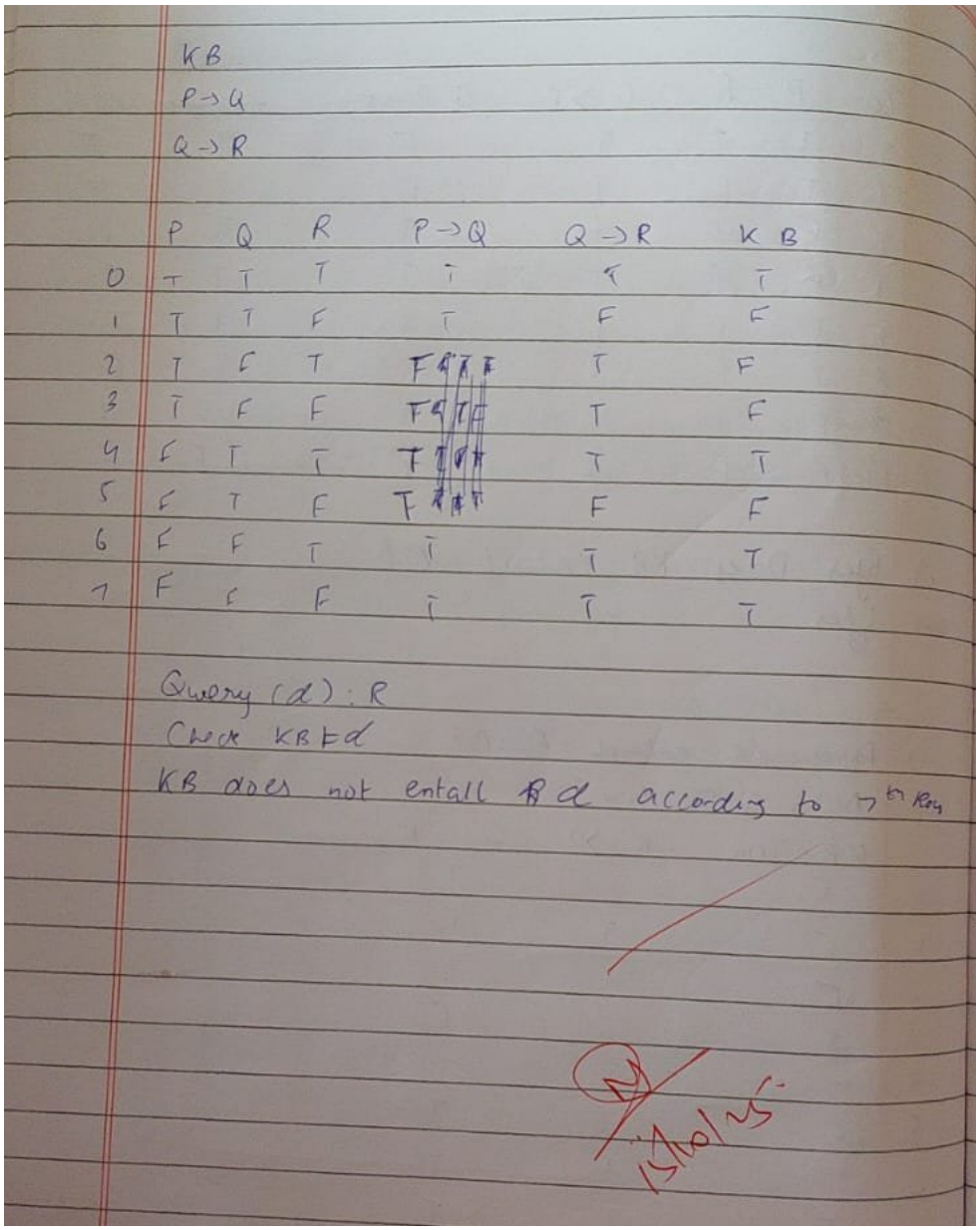
ans NO, 6th Row

	KB: True	R→P	Q→R
0	F	T	T
1	F	T	F
2	F	F	T
3	F	T	F
4	T	T	T
5	F	T	T
6	T	F	T
	F	T	T

(ii) Does KB entail Q→R?

ans Yes

proceed



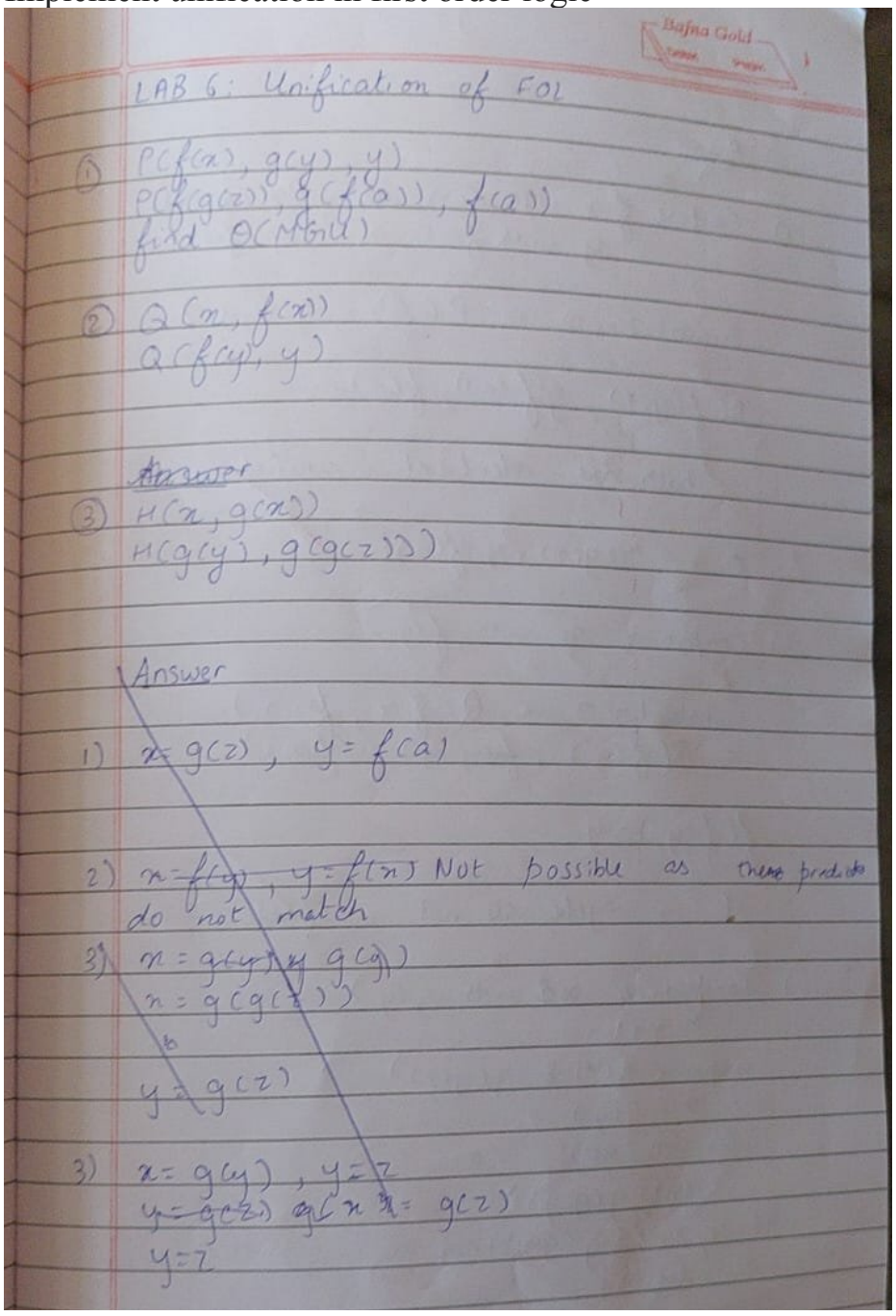

```
import itertools
def evaluate_formula(formula, truth_assignment):
    eval_formula = formula
    for symbol, value in truth_assignment.items():
        eval_formula = eval_formula.replace(symbol, str(value))
    return eval(eval_formula)

def generate_truth_table(variables):
    return list(itertools.product([False, True], repeat=len(variables)))

def is_entailed(KB_formula, alpha_formula, variables):
    truth_combinations = generate_truth_table(variables)
    print(f"{' '.join(variables)} | KB Result | Alpha Result")
    print("-" * (len(variables) * 2 + 15))
```

```
    for combination in truth_combinations:
        truth_assignment = dict(zip(variables, combination))
        KB_value = evaluate_formula(KB_formula, truth_assignment)
        alpha_value = evaluate_formula(alpha_formula, truth_assignment)
        result_str = " ".join(["T" if value else "F" for value in combination])
        print(f"{result_str} | {'T' if KB_value else 'F'}         | {'T' if alpha_value else 'F'}")
        if KB_value and not alpha_value:
            return False
    return True

KB = "(A or C) and (B or not C)"
alpha = "A or B"
variables = ['A', 'B', 'C']

if is_entailed(KB, alpha, variables):
    print("\nThe knowledge base entails alpha.")
else:
    print("\nThe knowledge base does not entail alpha.")
```

```
A B C | KB Result | Alpha Result
--------------------
F F F | F         | F
F F T | F         | F
F T F | F         | T
F T T | T         | T
T F F | T         | T
T F T | F         | T
T T F | T         | T
T T T | T         | T

The knowledge base entails alpha.
```

Program 7

Implement unification in first order logic



LAB 6: Unification of FOL

① P(f(x), g(y), y)
P(f(g(z)), g(f(a)), f(a))
find MGU

② Q(x, f(x))
Q(f(y), y)

Answer

③ H(x, g(x))
H(g(y), g(g(z)))

Answer

1) x = g(z), y = f(a)

2) x = f(y), y = f(x) Not possible as these predicate do not match

3) x = g(y) g(g)
x = g(g(z))
y = g(z)

3) x = g(y), y = z
y = g(z) x = g(z)
y = z

Answer

1) Compare of x with $g(z)$, $\theta_1 = \{x / g(z)\}$
y with $f(a)$, $\theta_2 = \{y / f(a)\}$

Substituting θ in $P(f(x), g(y), y)$
=
$P(f(g(z)), g(f(a)), f(a))$

∴ both are identical ∴ unified

$\theta = \{x / g(z), y / f(a)\}$

2) Comparing x with $f(y)$

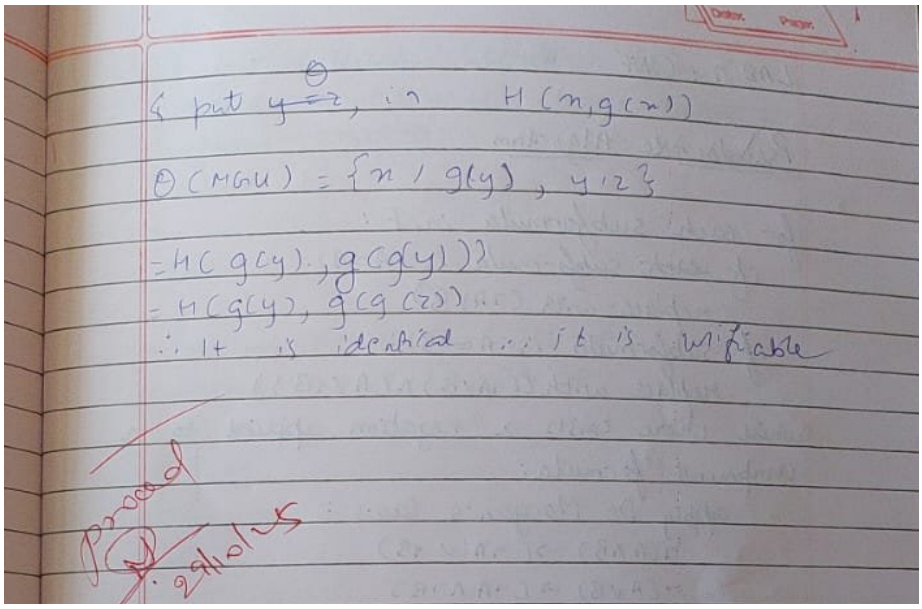
substituting θ in $P(f(x), f(x))$
$= P(f(f(y)), f(f(y)))$

$f(f(y)) = y$

it is cycle so not unifiable

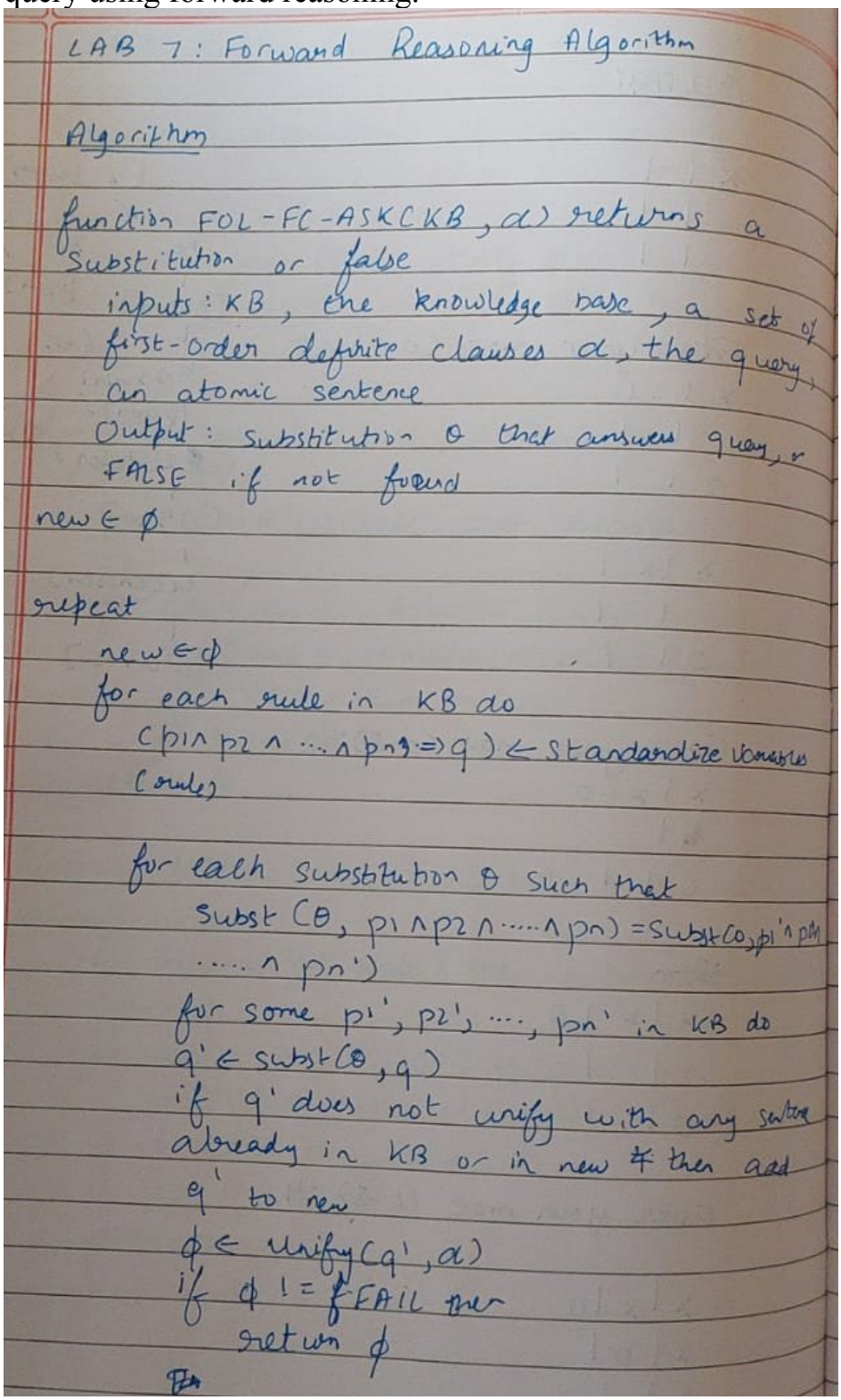
3) Comparing x with $g(y)$
$x = g(y)$

comparing $g(x)$ & $g(g(z))$
$x = g(y)$
$\theta_1 = \{x / g(y)\}$
$g(x) = g(g(y))$
if $y = z$, $g(g(y))$ can be unified with $g(g(z))$
$\theta_2 = \{y, z\}$


put y=z, in H(x, g(x))
θ(MGU) = {x / g(y), y/z}
= H(g(y), g(g(y)))
= H(g(y), g(g(z)))
∴ It is identical ∴ it is unifiable
Proved
Solution

Program 8

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



LAB 7: 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

Output: substitution θ that answers query, or FALSE if not found

new ← ϕ

repeat

new ← ϕ

for each rule in KB do

(p1 ∧ p2 ∧ ... ∧ pn ⇒ q) ← Standardize Variables (rule)

for each substitution θ such that

Subst(θ, p1 ∧ p2 ∧ ... ∧ pn) = Subst(θ, p1' ∧ p2' ∧ ... ∧ pn')

for some p1', p2', ..., pn' in KB do

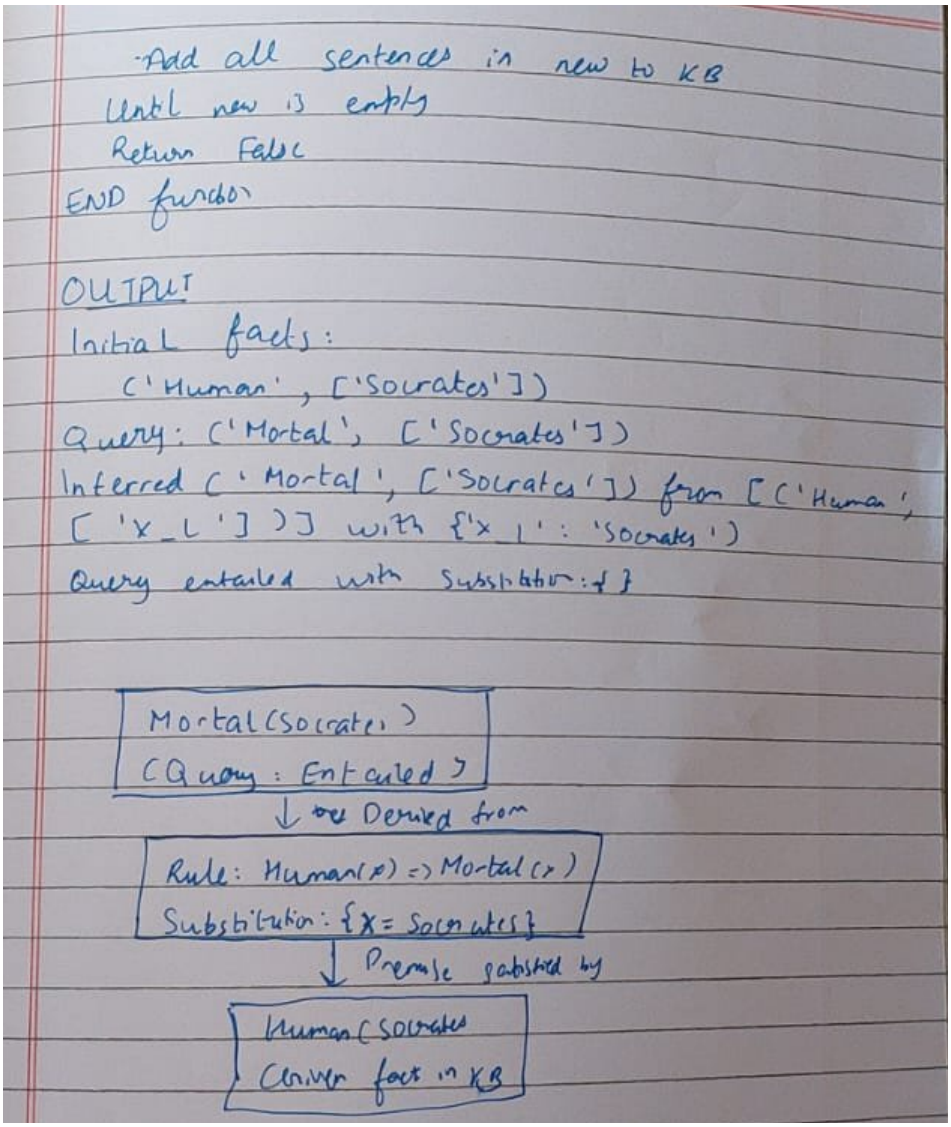
q' ← Subst(θ, q)

if q' does not unify with any sentence already in KB or in new then add q' to new

ϕ ← Unify(q', α)

if ϕ != fail then

return ϕ




```
import re

def match_pattern(pattern, fact):
    """
    Checks if a fact matches a rule pattern using regex-style variable substitution.
    Variables are lowercase words like p, q, x, r etc.
    Returns a dict of substitutions or None if not matched.
    """
    # Extract predicate name and arguments
    pattern_pred, pattern_args = re.match(r'(\w+)
', pattern).groups()
    fact_pred, fact_args = re.match(r'(\w+)
', fact).groups()

    if pattern_pred != fact_pred:
        return None  # predicate mismatch
```

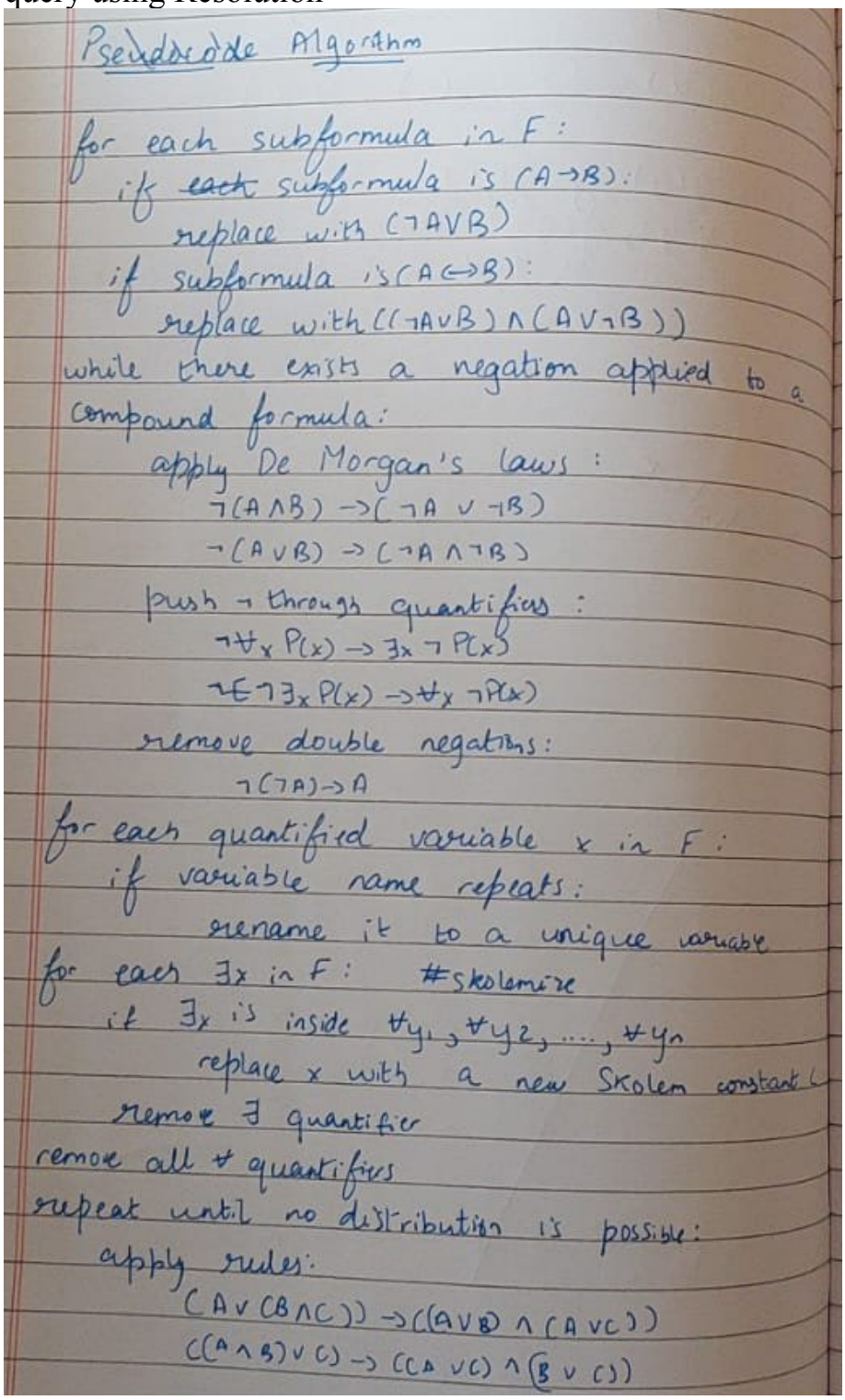
```
    pattern_args = [a.strip() for a in pattern_args.split(",")]
    fact_args = [a.strip() for a in fact_args.split(",")]

    if len(pattern_args) != len(fact_args):
        return None

    subst = {}
    for p_arg, f_arg in zip(pattern_args, fact_args):
        if re.fullmatch(r'[a-z]\w*', p_arg):  # variable
            subst[p_arg] = f_arg
        elif p_arg != f_arg:  # constants mismatch
            return None
    return subst


def apply_substitution(expr, subst):
    """Replaces all variable names in expr using the given substitution dict."""
    for var, val in subst.items():
        expr = re.sub(rf'\b{var}\b', val, expr)
    return expr


# ---------- Knowledge Base ----------

rules = [
    (["American(p)", "Weapon(q)", "Sells(p,q,r)", "Hostile(r)"], "Criminal(p)"),
    (["Missile(x)"], "Weapon(x)"),
    (["Enemy(x, America)"], "Hostile(x)"),
    (["Missile(x)", "Owns(A, x)"], "Sells(Robert, x, A)")
]

facts = {
    "American(Robert)",
    "Enemy(A, America)",
    "Owns(A, T1)",
    "Missile(T1)"
}

goal = "Criminal(Robert)"

def forward_chain(rules, facts, goal):
    added = True
    while added:
        added = False
        for premises, conclusion in rules:
```

```
            possible_substs = []
            for p in premises:
                for f in facts:
                    subst = match_pattern(p, f)
                    if subst:
                        possible_substs.append(subst)
                        break
                else:

                    break
            else:

                combined = {}
                for s in possible_substs:
                    combined.update(s)

                new_fact = apply_substitution(conclusion, combined)

                if new_fact not in facts:
                    facts.add(new_fact)
                    print(f"Inferred: {new_fact}")
                    added = True
                    if new_fact == goal:
                        return True
    return goal in facts


print("Goal achieved:", forward_chain(rules, facts, goal))
```

```
Inferred: Weapon(T1)
Inferred: Hostile(A)
Inferred: Sells(Robert, T1, A)
Inferred: Criminal(Robert)
Goal achieved: True
```

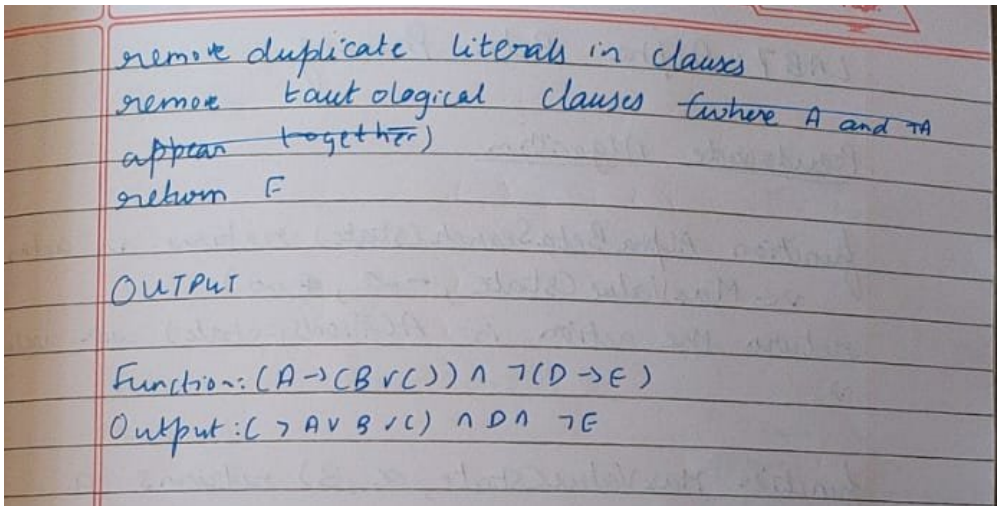
Program 9

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



Pseudocode Algorithm

for each subformula in F:
  if ~~each~~ subformula is (A→B):
    replace with (¬A∨B)
  if subformula is (A↔B):
    replace with ((¬A∨B)∧(A∨¬B))
while there exists a negation applied to a compound formula:
  apply De Morgan's laws:
    ¬(A∧B) → (¬A ∨ ¬B)
    ¬(A∨B) → (¬A ∧ ¬B)
  push ¬ through quantifiers:
    ¬∀x P(x) → ∃x ¬P(x)
    ¬∃x P(x) → ∀x ¬P(x)
  remove double negations:
    ¬(¬A) → A
for each quantified variable x in F:
  if variable name repeats:
    rename it to a unique variable
for each ∃x in F: #skolemize
  if ∃x is inside ∀y1, ∀y2, ..., ∀yn
    replace x with a new Skolem constant
  remove ∃ quantifier
remove all ∀ quantifiers
repeat until no distribution is possible:
  apply rules:
    (A∨(B∧C)) → ((A∨B)∧(A∨C))
    ((A∧B)∨C) → ((A∨C)∧(B∨C))




```
from copy import deepcopy

def print_step(title, content):
    print(f"\n{'='*45}\n{title}\n{'='*45}")
    if isinstance(content, list):
        for i, c in enumerate(content, 1):
            print(f"{i}. {c}")
    else:
        print(content)

KB = [
    ["¬Food(x)", "Likes(John,x)"],
    ["Food(Apple)"],
    ["Food(Vegetable)"],
    ["¬Eats(x,y)", "Killed(x)", "Food(y)"],
    ["Eats(Anil,Peanuts)"],
    ["Alive(Anil)"],
    ["¬Alive(x)", "¬Killed(x)"],
    ["Killed(x)", "Alive(x)"]
]

QUERY = ["Likes(John,Peanuts)"]

def negate(literal):
    if literal.startswith("¬"):
        return literal[1:]
    return "¬" + literal

def substitute(clause, subs):
    new_clause = []
    for lit in clause:
        for var, val in subs.items():
            lit = lit.replace(var, val)
        new_clause.append(lit)
```

```
    return new_clause

def unify(lit1, lit2):
    """Small unifier for patterns like Food(x) and Food(Apple)."""
    if "(" not in lit1 or "(" not in lit2:
        return None
    pred1, args1 = lit1.split("(")
    pred2, args2 = lit2.split("(")
    args1 = args1[:-1].split(",")
    args2 = args2[:-1].split(",")
    if pred1 != pred2 or len(args1) != len(args2):
        return None
    subs = {}
    for a, b in zip(args1, args2):
        if a == b:
            continue
        if a.islower():
            subs[a] = b
        elif b.islower():
            subs[b] = a
        else:
            return None
    return subs

def resolve(ci, cj):
    """Return list of (resolvent, substitution, pair)."""
    resolvents = []
    for li in ci:
        for lj in cj:
            if li == negate(lj):
                new_clause = [x for x in ci if x != li] + [x for x in cj if x != lj]
                resolvents.append((list(set(new_clause)), {}, (li, lj)))
            else:
                # same predicate, opposite sign
                if li.startswith("¬") and not lj.startswith("¬") and li[1:].split("(")[0] == lj.split("(")[0]:
                    subs = unify(li[1:], lj)
                    if subs:
                        new_clause = substitute([x for x in ci if x != li] + [x for x in cj if x != lj], subs)
                        resolvents.append((list(set(new_clause)), subs, (li, lj)))
                elif lj.startswith("¬") and not li.startswith("¬") and lj[1:].split("(")[0] == li.split("(")[0]:
                    subs = unify(lj[1:], li)
                    if subs:
                        new_clause = substitute([x for x in ci if x != li] + [x for x in cj if x != lj], subs)
                        resolvents.append((list(set(new_clause)), subs, (li, lj)))
    return resolvents

def resolution(kb, query):
```

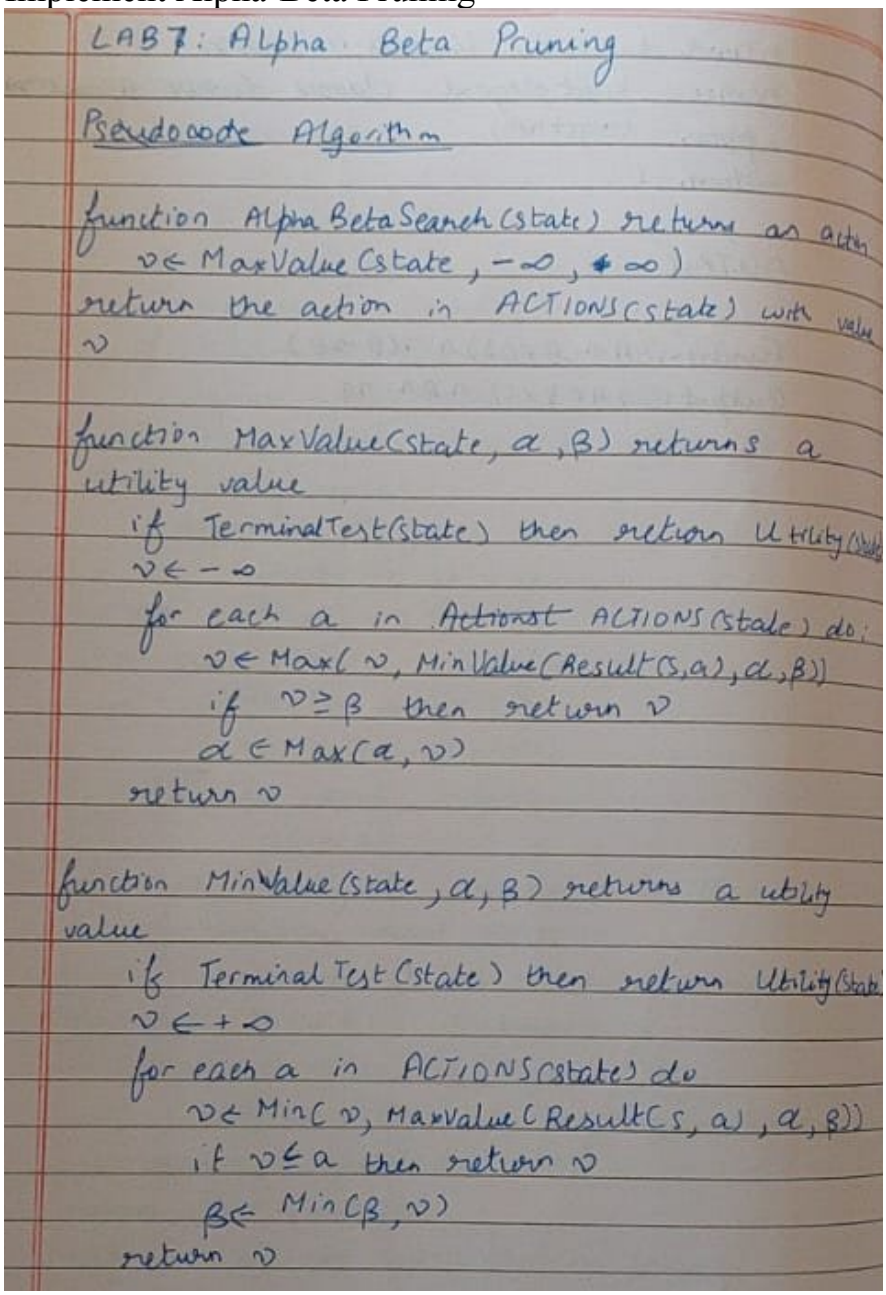
```
    clauses = deepcopy(kb)
    negated_query = [negate(q) for q in query]
    clauses.append(negated_query)
    print_step("Initial Clauses", clauses)

    steps = []
    new = []
    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:
            for r, subs, pair in resolve(ci, cj):
                if not r:
                    steps.append({
                        "parents": (ci, cj),
                        "resolvent": r,
                        "subs": subs
                    })
                    print_tree(steps)
                    print("\n✓ Empty clause derived — query proven.")
                    return True
                if r not in clauses and r not in new:
                    new.append(r)
                    steps.append({
                        "parents": (ci, cj),
                        "resolvent": r,
                        "subs": subs
                    })
        if all(r in clauses for r in new):
            print_step("No New Clauses", "Query cannot be proven ✗")
            print_tree(steps)
            return False
        clauses.extend(new)

def print_tree(steps):
    print("\n" + "="*45)
    print("Resolution Proof Trace")
    print("="*45)
    for i, s in enumerate(steps, 1):
        p1, p2 = s["parents"]
        r = s["resolvent"]
        subs = s["subs"]
        subs_text = f"  Substitution: {subs}" if subs else ""

        print(f"  Resolve {p1} and {p2}")
        if subs_text:
            print(subs_text)
```

```
        if r:
            print(f"  ⇒ {r}")
        else:
            print("  ⇒ {} (empty clause)")
        print("-"*45)

def main():
    print_step("Knowledge Base in CNF", KB)
    print_step("Negated Query", [negate(q) for q in QUERY])
    proven = resolution(KB, QUERY)
    if proven:
        print("\n✓ Query Proven by Resolution: John likes peanuts.")
    else:
        print("\n✗ Query cannot be proven from KB.")

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

```
Unifying: P(f(x),g(y),y)  and  P(f(g(z)),g(f(a)),f(a
    ))
=> Substitution: x : g(z), y : f(a)

Unifying: Q(x,f(x))  and  Q(f(y),y)
=> Not unifiable.

Unifying: H(x,g(x))  and  H(g(y),g(g(z)))
=> Substitution: x : g(y), y : z

=== Code Execution Successful ===
```

Program 10

Implement Alpha-Beta Pruning



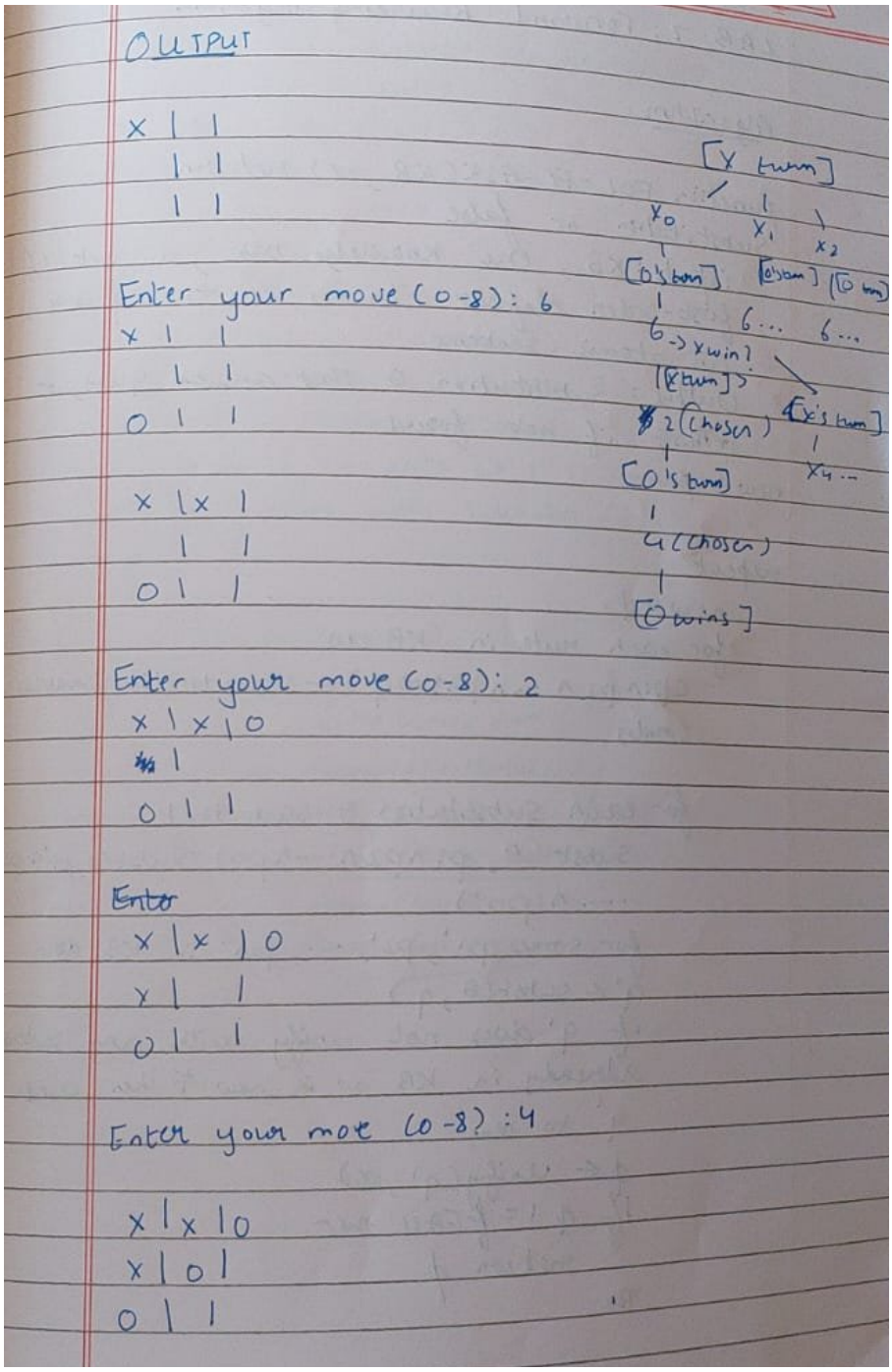
LAB 7: Alpha Beta Pruning

Pseudocode Algorithm

function AlphaBetaSearch(state) returns an action
  $v \leftarrow$ MaxValue(state, $-\infty$, $+\infty$)
return the action in ACTIONS(state) with value v

function MaxValue(state, α, β) returns a utility value
  if TerminalTest(state) then return Utility(state)
  $v \leftarrow -\infty$
  for each a in Actions(state) do:
    $v \leftarrow$ Max(v, MinValue(Result(s,a), α, β))
    if $v \geq \beta$ then return v
    $\alpha \leftarrow$ Max(α, v)
  return v

function MinValue(state, α, β) returns a utility value
  if TerminalTest(state) then return Utility(state)
  $v \leftarrow +\infty$
  for each a in ACTIONS(state) do
    $v \leftarrow$ Min(v, MaxValue(Result(s, a), α, β))
    if $v \leq a$ then return v
    $\beta \leftarrow$ Min(β, v)
  return v




```
# Simplified Tic-Tac-Toe with Unification + Alpha-Beta
# No parsing layer, direct symbolic unification and minimax

def unify(a, b):
    """Very simple unification for small terms like ('line', [X,O,X])"""
    if a == b:
        return {}
    if isinstance(a, str) and a.islower():  # variable
        return {a: b}
```

```
    if isinstance(b, str) and b.islower():
        return {b: a}
    if isinstance(a, tuple) and isinstance(b, tuple):
        if a[0] != b[0] or len(a[1]) != len(b[1]):
            return None
        subs = {}
        for x, y in zip(a[1], b[1]):
            s = unify(x, y)
            if s is None:
                return None
            subs.update(s)
        return subs
    return None


# Winning triples (rows, cols, diagonals)
WIN_TRIPLES = [(0,1,2),(3,4,5),(6,7,8),(0,3,6),(1,4,7),(2,5,8),(0,4,8),(2,4,6)]

def winner(board):
    pattern = ('line', ['X','X','X'])
    for i,j,k in WIN_TRIPLES:
        term = ('line', [board[i], board[j], board[k]])
        if unify(term, pattern):
            return 'X'
        if unify(term, ('line',['O','O','O'])):
            return 'O'
    return None

def is_full(board): return all(c != '_' for c in board)

def evaluate(board):
    w = winner(board)
    if w == 'X': return 1
    if w == 'O': return -1
    if is_full(board): return 0
    return None

def alpha_beta(board, player, alpha=-float('inf'), beta=float('inf')):
    val = evaluate(board)
    if val is not None:
        return val, None

    moves = [i for i,c in enumerate(board) if c == '_']
    best_move = None
    if player == 'X':
        max_eval = -float('inf')
        for m in moves:
```

```
            new_board = board[:]
            new_board[m] = 'X'
            eval_, _ = alpha_beta(new_board, 'O', alpha, beta)
            if eval_ > max_eval:
                max_eval, best_move = eval_, m
            alpha = max(alpha, eval_)
            if beta <= alpha: break
        return max_eval, best_move
    else:
        min_eval = float('inf')
        for m in moves:
            new_board = board[:]
            new_board[m] = 'O'
            eval_, _ = alpha_beta(new_board, 'X', alpha, beta)
            if eval_ < min_eval:
                min_eval, best_move = eval_, m
            beta = min(beta, eval_)
            if beta <= alpha: break
        return min_eval, best_move

def print_board(b):
    for i in range(0,9,3):
        print(' '.join(b[i:i+3]))
    print()

# --- Example usage ---
board = ['_']*9
score, move = alpha_beta(board, 'X')
print("Best first move for X:", move)
board[move] = 'X'
print_board(board)
```

```
Best first move for X: 0
X _ _
_ _ _
_ _ _
```