VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

SIRIPURAPU MANASWI (1BM23CS331)

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 **Siripurapu Manaswi (1BM23CS331),** 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.

Sonika Sharma D Assistant Professor Department of CSE, BMSCE	Dr. Kavitha Sooda Professor & HOD Department of CSE, BMSCE

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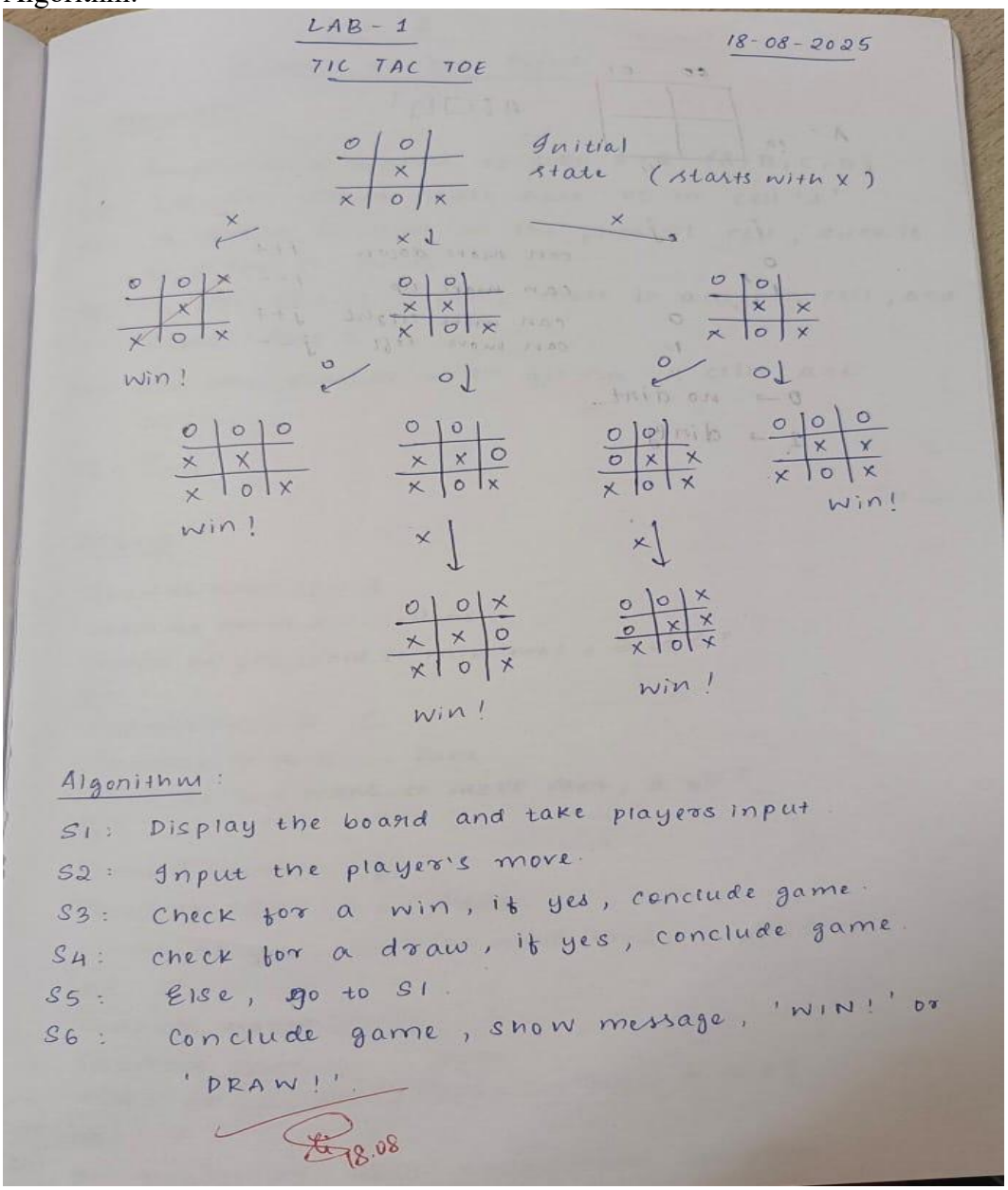
Github Link:
https://github.com/s-manaswi/AI_LAB_1BM23CS331

LAB - 1
Implement Tic –Tac –Toe Game

Algorithm:



Code:

```
board = [['-', '-', '-'],
         ['-', '-', '-'],
         ['-', '-', '-']]

def print_board():
    for row in board:
        print(row)

def check_winner(player):
    for row in board:
        if all(cell == player for cell in row):
            return True

    for col in range(3):
        if all(board[row][col] == player for row in range(3)):
            return True

    if all(board[i][i] == player for i in range(3)):
        return True
    if all(board[i][2 - i] == player for i in range(3)):
        return True

    return False

def play_game():
    print_board()
    for turn in range(9):
        if turn % 2 == 0:
            player = 'X'
        else:
            player = 'O'

        print(f"Enter position to place {player}: ")
        row = int(input("Row (1-3): ")) - 1
        col = int(input("Column (1-3): ")) - 1

        if board[row][col] == '-':
            board[row][col] = player
        else:
            print("Cell already taken, try again!")
            continue

        print_board()

        if check_winner(player):
            print(f"{player} wins")
```

```
        print("Game Over")
        return

    print("It's a Draw!")
    print("Game Over")

play_game()
```

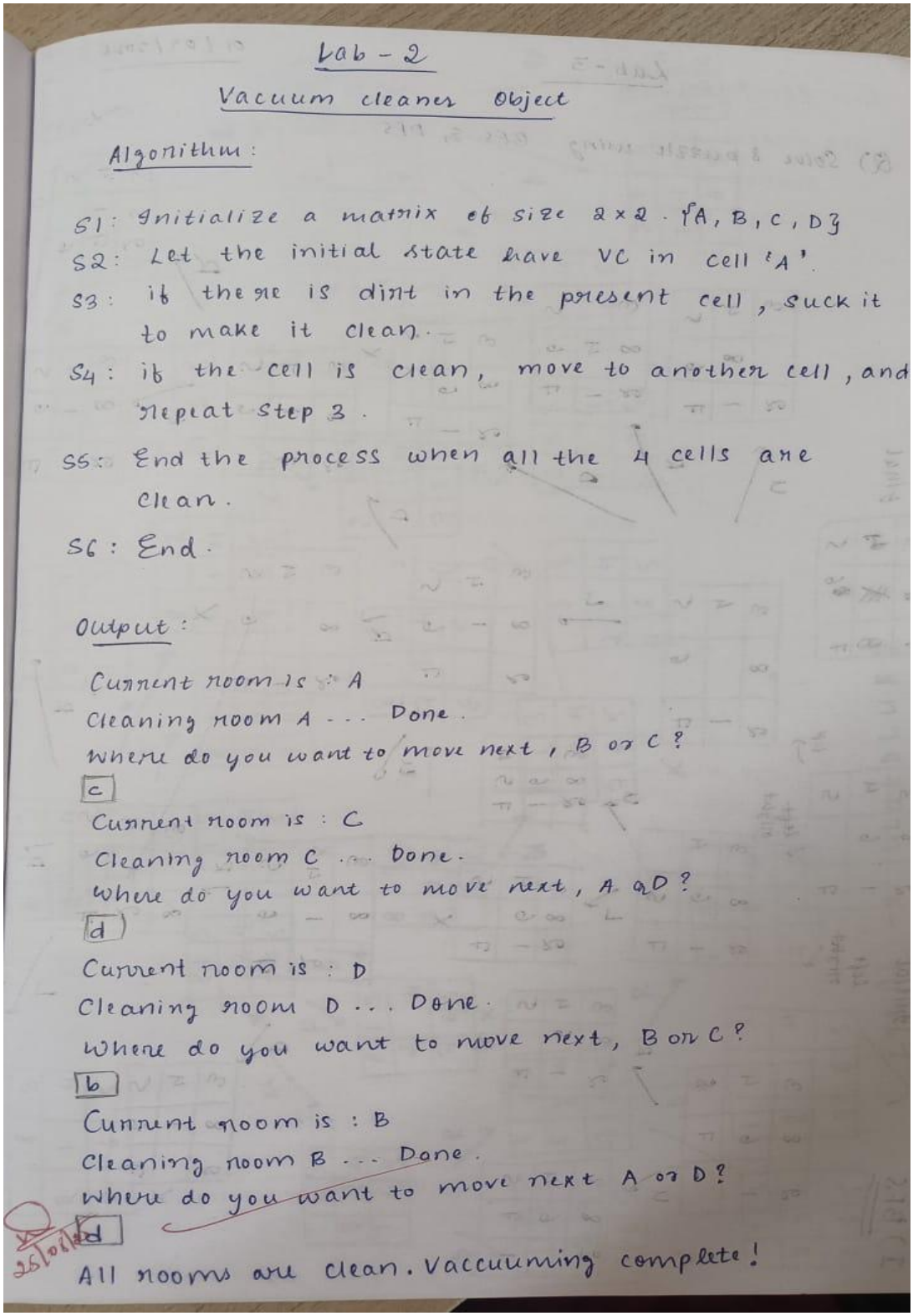
Output:

```
Enter position to place X:
Row (1-3): 1
Column (1-3): 3
['-', '-', 'X']
['-', '-', '-']
['-', '-', '-']
Enter position to place O:
Row (1-3): 2
Column (1-3): 2
['-', '-', 'X']
['-', 'O', '-']
['-', '-', '-']
Enter position to place X:
Row (1-3): 2
Column (1-3): 3
['-', '-', 'X']
['-', 'O', 'X']
['-', '-', '-']
Enter position to place O:
Row (1-3): 1
Column (1-3): 1
['O', '-', 'X']
['-', 'O', 'X']
['-', '-', '-']
Enter position to place X:
Row (1-3): 1
Column (1-3): 2
['O', 'X', 'X']
['-', 'O', 'X']
['-', '-', '-']
Enter position to place O:
Row (1-3): 3
Column (1-3): 3
['O', 'X', 'X']
['-', 'O', 'X']
['-', '-', 'O']
O wins
Game Over
```

```
['-', '-', '-']
['-', '-', '-']
['-', '-', '-']
Enter position to place X:
Row (1-3): 1
Column (1-3): 1
['X', '-', '-']
['-', '-', '-']
['-', '-', '-']
Enter position to place O:
Row (1-3): 2
Column (1-3): 1
['X', '-', '-']
['O', '-', '-']
['-', '-', '-']
Enter position to place X:
Row (1-3): 1
Column (1-3): 2
['X', 'X', '-']
['O', '-', '-']
['-', '-', '-']
Enter position to place O:
Row (1-3): 2
Column (1-3): 2
['X', 'X', '-']
['O', 'O', '-']
['-', '-', '-']
Enter position to place X:
Row (1-3): 1
Column (1-3): 3
['X', 'X', 'X']
['O', 'O', '-']
['-', '-', '-']
X wins
Game Over
```

```
Enter position to place X:
Row (1-3): 1
Column (1-3): 1
['X', '-', '-']
['-', '-', '-']
['-', '-', '-']
Enter position to place O:
Row (1-3): 2
Column (1-3): 2
['X', '-', '-']
['-', 'O', '-']
['-', '-', '-']
Enter position to place X:
Row (1-3): 1
Column (1-3): 2
['X', 'X', '-']
['-', 'O', '-']
['-', '-', '-']
Enter position to place O:
Row (1-3): 1
Column (1-3): 3
['X', 'X', 'O']
['-', 'O', '-']
['-', '-', '-']
Enter position to place X:
Row (1-3): 3
Column (1-3): 1
['X', 'X', 'O']
['-', 'O', '-']
['X', '-', '-']
Enter position to place O:
Row (1-3): 2
Column (1-3): 1
['X', 'X', 'O']
['O', 'O', '-']
['X', '-', '-']
Enter position to place X:
Row (1-3): 2
Column (1-3): 3
['X', 'X', 'O']
['O', 'O', 'X']
['X', '-', '-']
Enter position to place O:
Row (1-3): 3
Column (1-3): 2
['X', 'X', 'O']
['O', 'O', 'X']
['X', 'O', '-']
Enter position to place X:
Row (1-3): 3
Column (1-3): 3
['X', 'X', 'O']
['O', 'O', 'X']
['X', 'O', 'X']
It's a Draw!
Game Over
```

LAB - 2
Implement vacuum cleaner agent



Lab - 2

Vacuum cleaner Object

Algorithm:

S1: Initialize a matrix of size 2 x 2. {A, B, C, D}
S2: Let the initial state have VC in cell 'A'.
S3: if there is dirt in the present cell, suck it to make it clean.
S4: if the cell is clean, move to another cell, and repeat step 3.
S5: End the process when all the 4 cells are clean.
S6: End.

Output:

Current room is : A
Cleaning room A ... Done.
Where do you want to move next, B or C?
c
Current room is : C
Cleaning room C ... Done.
Where do you want to move next, A or D?
d
Current room is : D
Cleaning room D ... Done.
Where do you want to move next, B or C?
b
Current room is : B
Cleaning room B ... Done.
Where do you want to move next A or D?
d
All rooms are clean. Vaccuuming complete!

Code:

```
def vacuum_agent_2x2():
    state = {
        'A1': int(input("Enter state of A1 (0 for clean, 1 for dirty): ")),
        'A2': int(input("Enter state of A2 (0 for clean, 1 for dirty): ")),
        'B1': int(input("Enter state of B1 (0 for clean, 1 for dirty): ")),
        'B2': int(input("Enter state of B2 (0 for clean, 1 for dirty): "))
    }

    location = input("Enter starting location (A1, A2, B1, B2): ").upper()
    cost = 0

    if all(state[loc] == 0 for loc in state):
        print("All rooms clean. Turning vacuum off.")
        print(f"Cost: {cost}")
        print(state)
        return

    traversal_order = ['A1', 'A2', 'B2', 'B1']

    while traversal_order[0] != location:
        traversal_order.append(traversal_order.pop(0))

    print(f"Starting cleaning at {location}")

    for idx, loc in enumerate(traversal_order):
        if idx == 0:
            pass
        else:
            print(f"Moving vacuum to {loc}")
            cost += 1

        if state[loc] == 1:
            print(f"Cleaned {loc}.")
            state[loc] = 0
            cost += 1  # cost for cleaning

        print(f"Is {loc} clean now? (0 if clean, 1 if dirty): {state[loc]}")

    print("Finished cleaning all rooms.")
    print(f"Total cost: {cost}")
    print(state)


vacuum_agent_2x2()
```

Output:

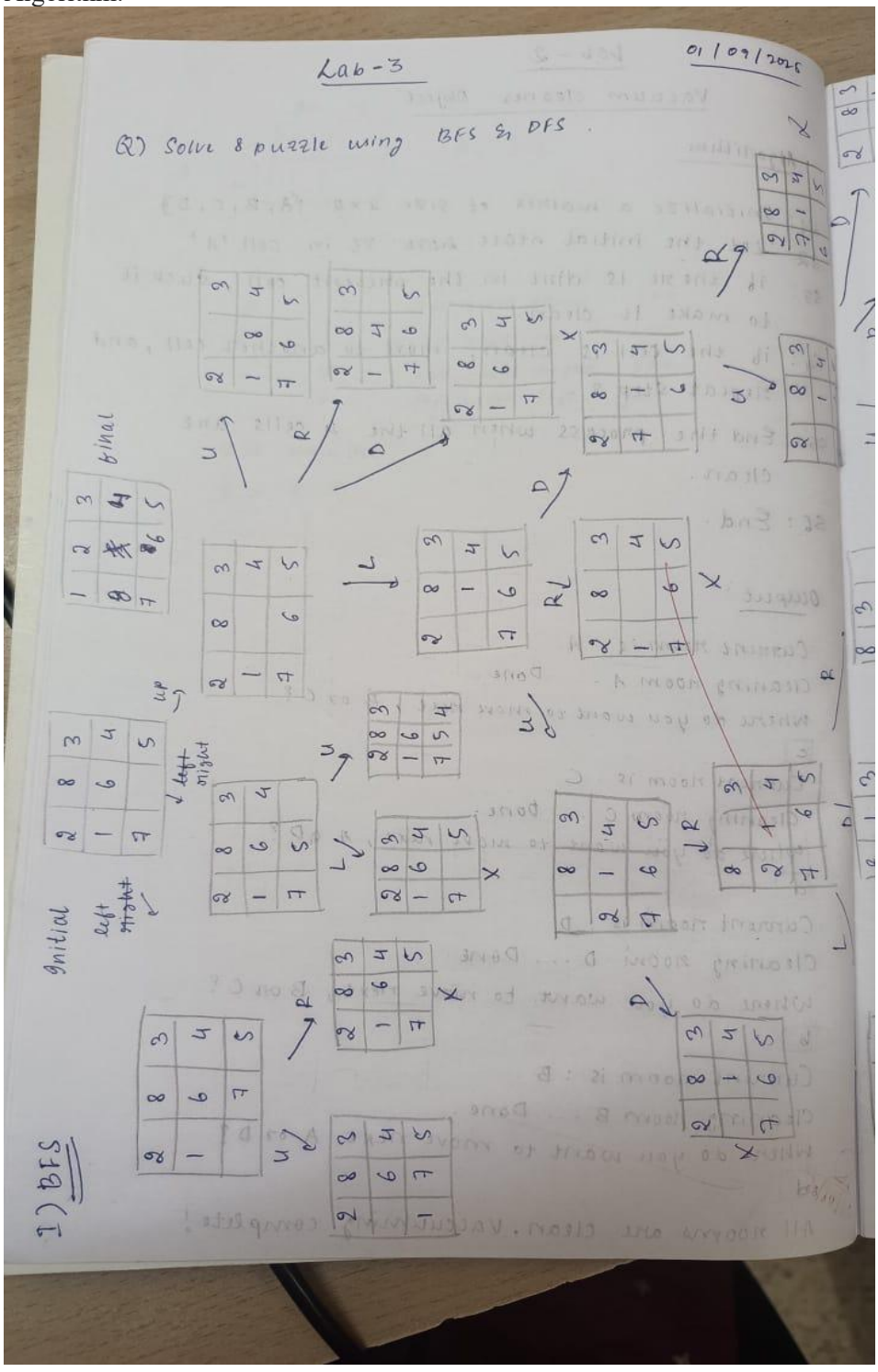
```
Enter state of A1 (0 for clean, 1 for dirty): 1
Enter state of A2 (0 for clean, 1 for dirty): 1
Enter state of B1 (0 for clean, 1 for dirty): 1
Enter state of B2 (0 for clean, 1 for dirty): 1
Enter starting location (A1, A2, B1, B2): a1
Starting cleaning at A1
Cleaned A1.
Is A1 clean now? (0 if clean, 1 if dirty): 0
Moving vacuum to A2
Cleaned A2.
Is A2 clean now? (0 if clean, 1 if dirty): 0
Moving vacuum to B2
Cleaned B2.
Is B2 clean now? (0 if clean, 1 if dirty): 0
Moving vacuum to B1
Cleaned B1.
Is B1 clean now? (0 if clean, 1 if dirty): 0
Finished cleaning all rooms.
Total cost: 7
{'A1': 0, 'A2': 0, 'B1': 0, 'B2': 0}
```

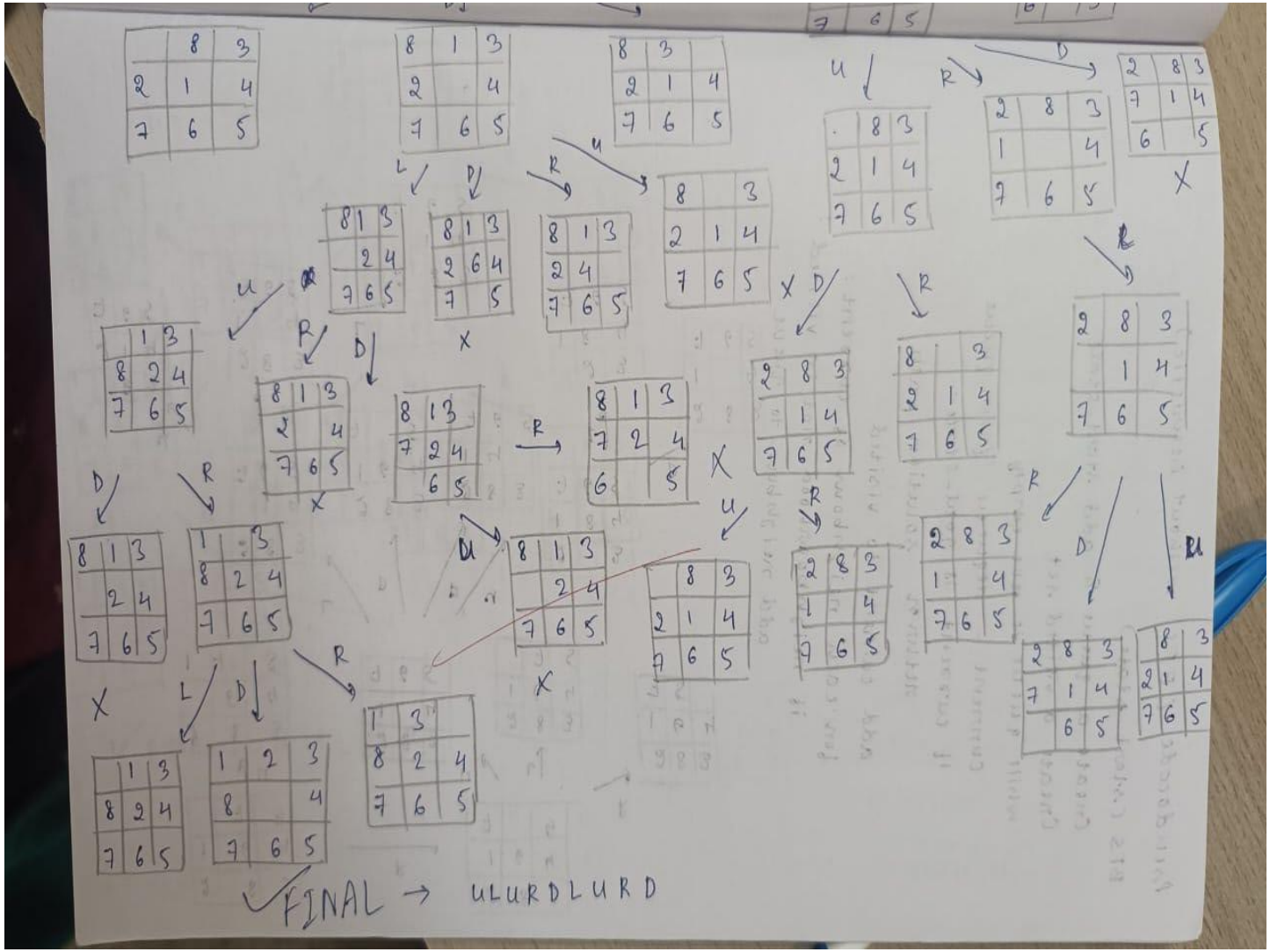
Siripurapu Manaswi

LAB - 3

Implement 8 puzzle problems using Depth First Search (DFS)

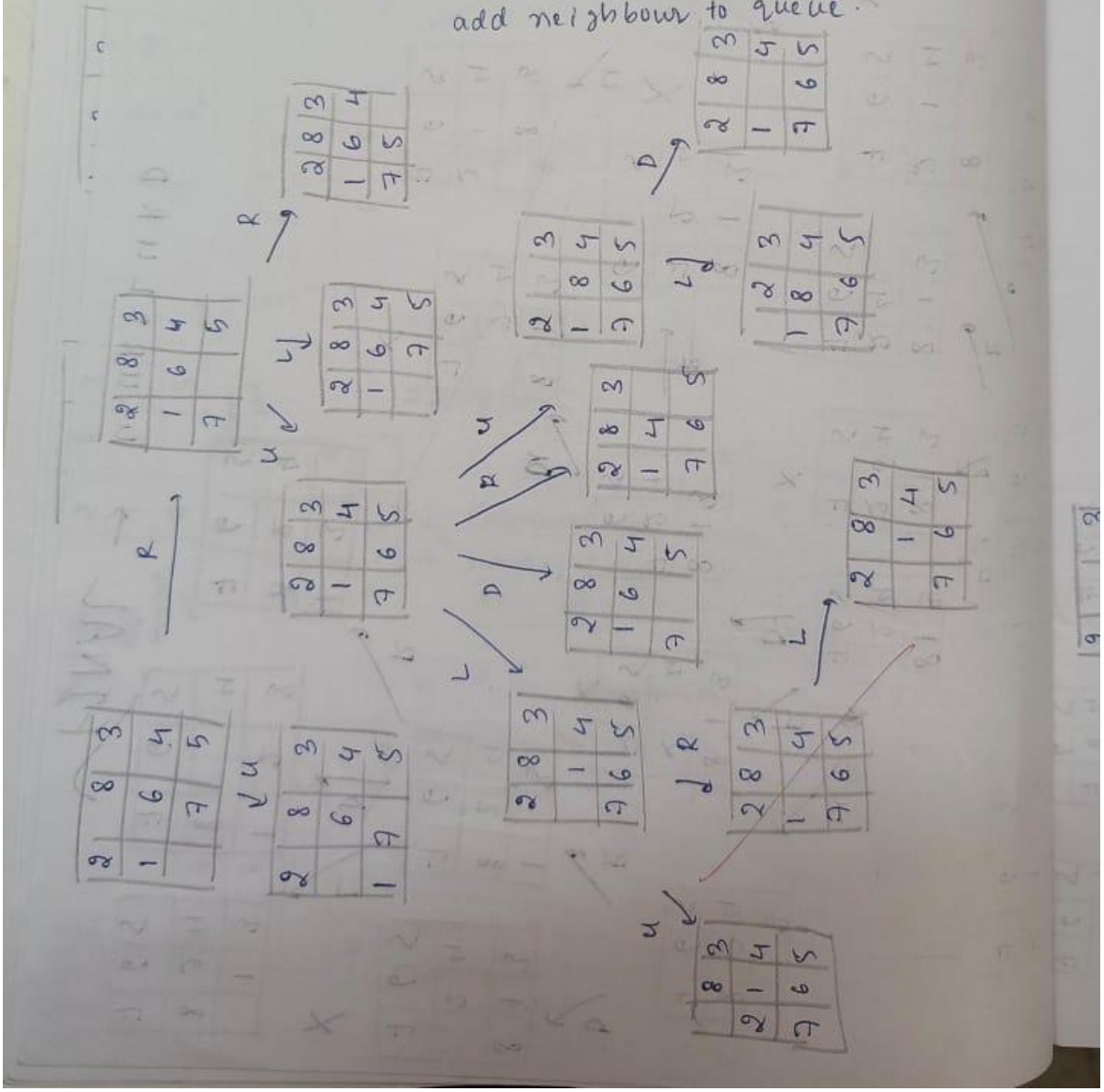
Algorithm:

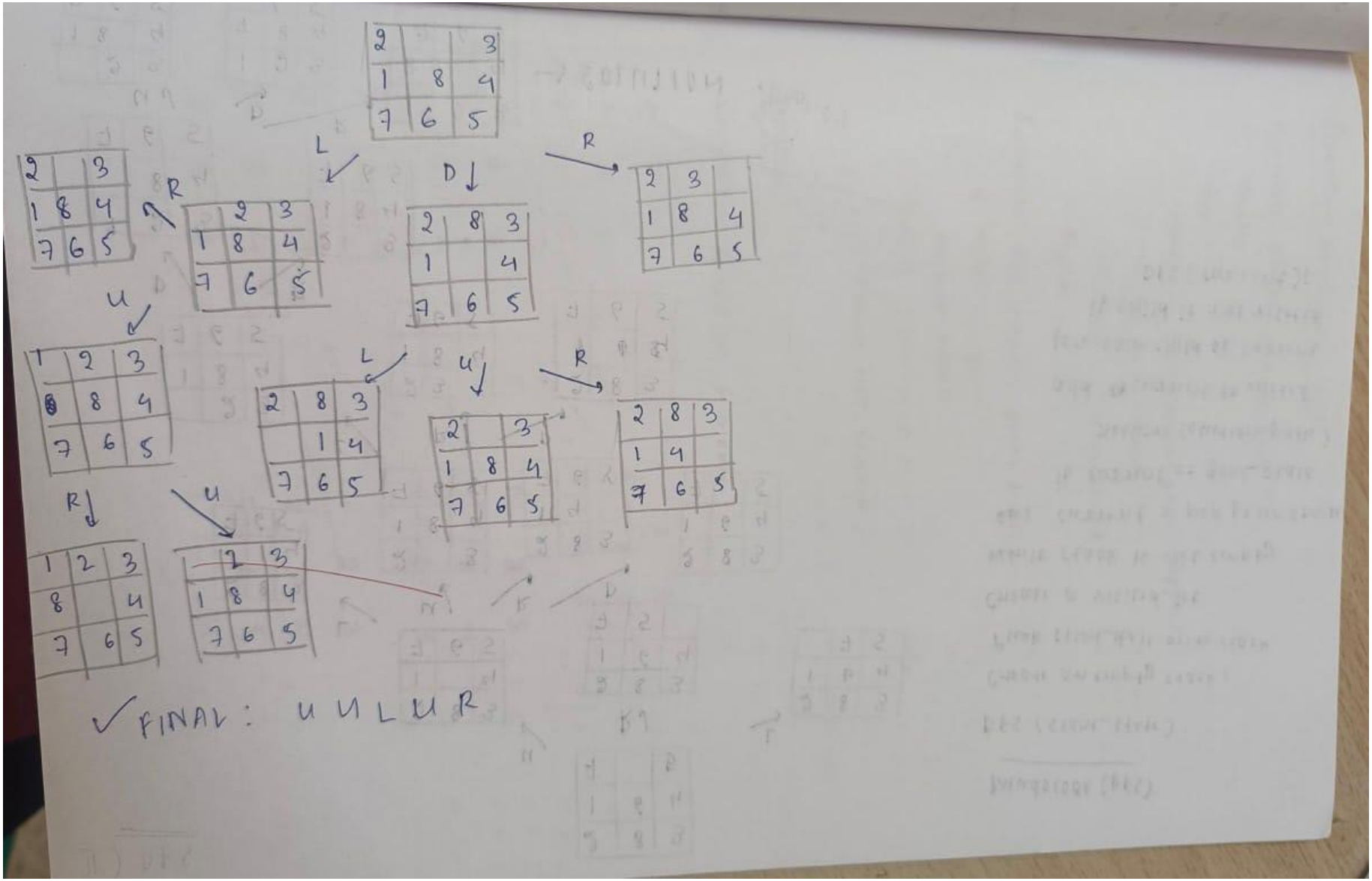



FINAL → ULURDLURD

Pseudocode (BFS without heuristic)

```
BFS (start_state)
    Create a queue & add start_state
    Create a visited set
    while queue is not empty:
        current = dequeue from queue
        if current is goal_state:
            return solution path
        add current to visited
        for each neighbour of current:
            if neighbourhood not in visited:
                add neighbour to queue.
```

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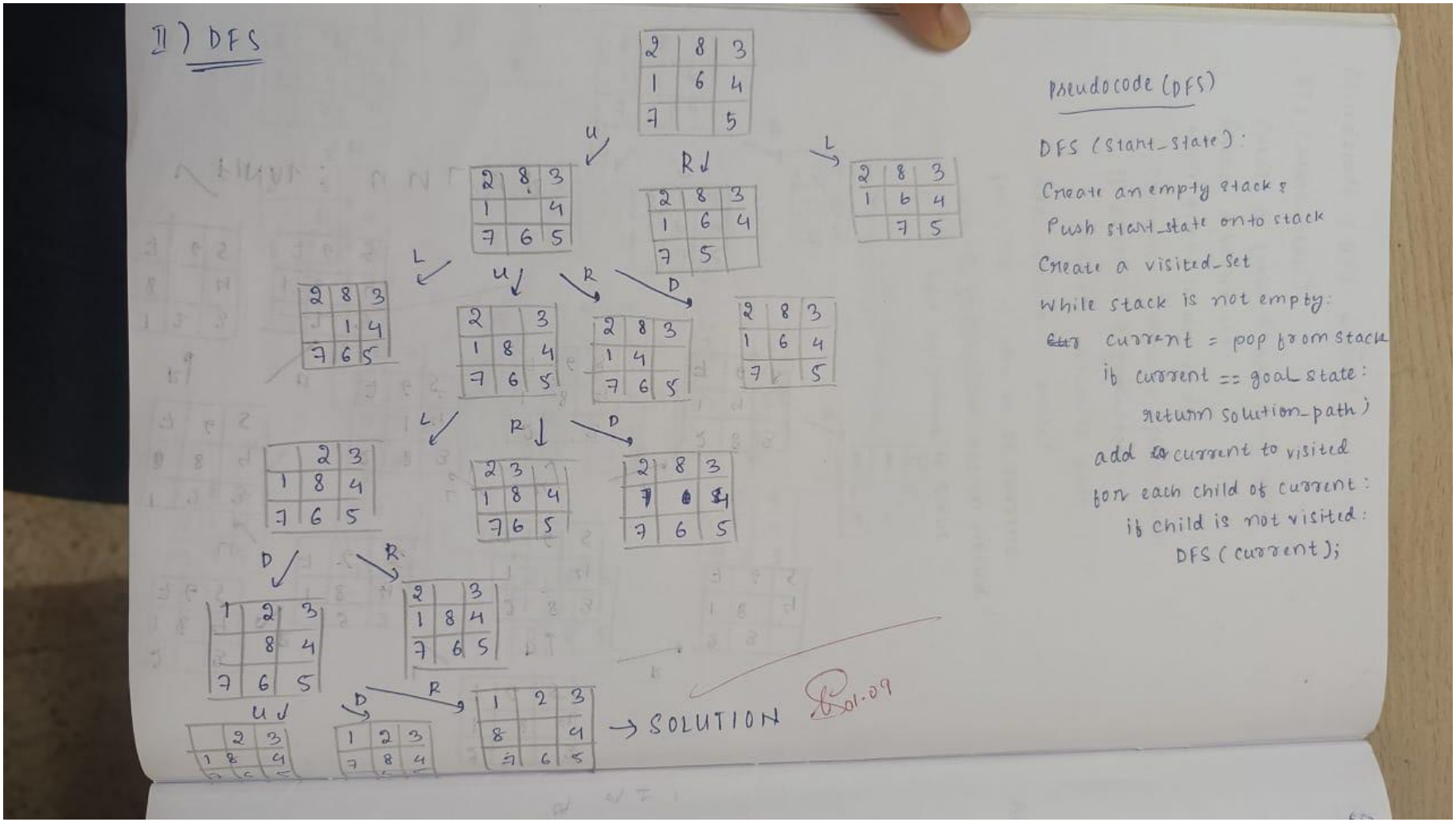
✓ FINAL: U U L U R


II) DFS
pseudocode (DFS)
DFS (start_state):
Create an empty stack
Push start_state onto stack
Create a visited_set
while stack is not empty:
current = pop from stack
if current == goal_state:
return solution_path
add current to visited
for each child of current:
if child is not visited:
DFS (current);
SOLUTION

Code:

```
def print_state(state):
    for i in range(0, 9, 3):
        print(" ".join(state[i:i+3]))
    print()

def is_goal(state):
    return state == "123804765"

def get_neighbors(state):
    neighbors = []
    moves = {'Up': -3, 'Down': 3, 'Left': -1, 'Right': 1}
    zero_index = state.index('0')

    for move, pos_change in moves.items():
        new_index = zero_index + pos_change

        if move == 'Left' and zero_index % 3 == 0:
            continue
        if move == 'Right' and zero_index % 3 == 2:
            continue
        if move == 'Up' and zero_index < 3:
            continue
        if move == 'Down' and zero_index > 5:
            continue

        state_list = list(state)
        state_list[zero_index], state_list[new_index] = state_list[new_index], state_list[zero_index]
        neighbors.append(("".join(state_list), move))

    return neighbors

def dfs(start_state, max_depth=20):
    visited = set()
    stack = [(start_state, [], [], 0)]  # (state, path, moves, depth)

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

        if current_state in visited:
            continue

        visited.add(current_state)

        if is_goal(current_state):
            steps = path + [current_state]
            print("\nGoal reached (DFS)!\n")
```

```
            for i, step in enumerate(steps):
                print(f"Step {i}:")
                print_state(step)
            print("Moves:", " -> ".join(moves))
            print("Total steps to goal:", len(steps) - 1)
            print("Total unique states visited:", len(visited))
            return

        if depth < max_depth:
            for neighbor, move in reversed(get_neighbors(current_state)):
                if neighbor not in visited:
                    stack.append((neighbor, path + [current_state], moves + [move], depth + 1))

    print(f"No solution found within depth limit of {max_depth}!")
start = "283164705"
dfs(start, max_depth=20)
```

Output:
Goal reached (DFS)!

Step 0:
2 8 3
1 6 4
7 0 5

Step 1:
2 8 3
1 0 4
7 6 5

Step 2:
2 0 3
1 8 4
7 6 5

Step 3:
0 2 3
1 8 4
7 6 5

Step 4:
1 2 3
0 8 4
7 6 5

Step 5:

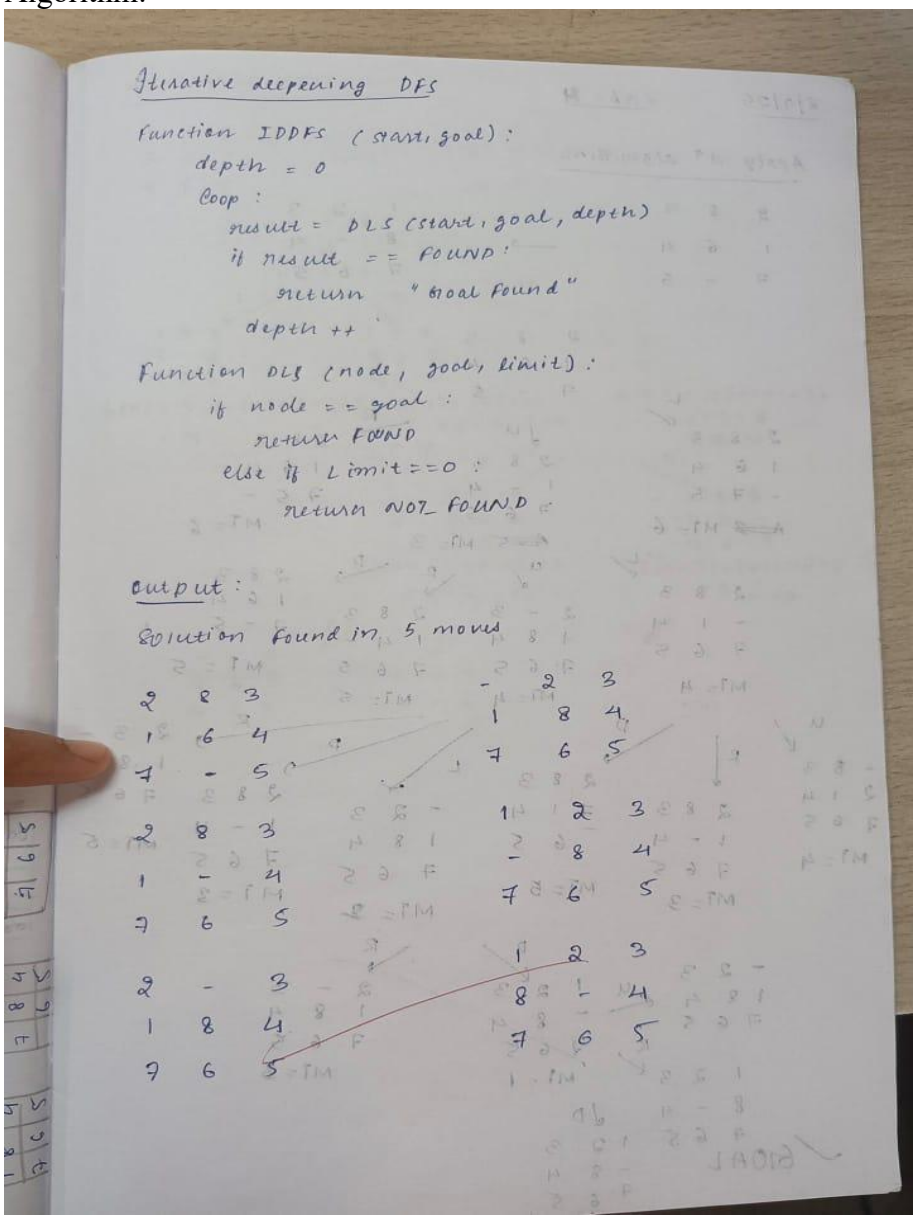
1 2 3
8 0 4
7 6 5

Moves: Up -> Up -> Left -> Down -> Right
Total steps to goal: 5
Total unique states visited: 1167

Siripurapu Manaswi – 1BM23CS331

Implement Iterative deepening search algorithm

Algorithm:



Code:

```
from collections import deque

# Board size (3x3 puzzle)
N = 3

# Moves: Up, Down, Left, Right
moves = [(-1,0),(1,0),(0,-1),(0,1)]

# Helper: Find position of blank tile
def find_blank(state):
    idx = state.index("_")
    return divmod(idx, N)

# Helper: Swap tiles
def swap(state, i1, j1, i2, j2):
    s = list(state)
    idx1, idx2 = i1*N+j1, i2*N+j2
    s[idx1], s[idx2] = s[idx2], s[idx1]
    return tuple(s)

# Expand node: Generate next states
def expand(state):
    x, y = find_blank(state)
    children = []
    for dx, dy in moves:
        nx, ny = x+dx, y+dy
        if 0 <= nx < N and 0 <= ny < N:
            children.append(swap(state, x, y, nx, ny))
    return children

# Depth Limited Search
def dls(state, goal, limit, path, visited):
    if state == goal:
        return path

    if limit == 0:
        return None

    visited.add(state)
    for child in expand(state):
        if child not in visited:
            result = dls(child, goal, limit-1, path+[child], visited)
            if result is not None:
                return result
    visited.remove(state)
    return None
```

```
def iddfs(start, goal, max_depth=20):
    for depth in range(max_depth):
        visited = set()
        result = dls(start, goal, depth, [start], visited)
        if result is not None:
            return result
    return None


initial = (2,8,3,1,6,4,7,"_",5)
goal = (1,2,3,8,"_",4,7,6,5)

solution = iddfs(initial, goal, max_depth=30)

if solution:
    print("Solution found in", len(solution)-1, "moves:\n")
    for step in solution:
        for i in range(0, 9, 3):
            print(step[i:i+3])
        print()
else:
    print("No solution found within depth limit")
```

Output:
Solution found in 5 moves:

(2, 8, 3)
(1, 6, 4)
(7, '_', 5)

(2, 8, 3)
(1, '_', 4)
(7, 6, 5)

(2, '_', 3)
(1, 8, 4)
(7, 6, 5)

('_', 2, 3)
(1, 8, 4)
(7, 6, 5)

(1, 2, 3)
('_', 8, 4)
(7, 6, 5)

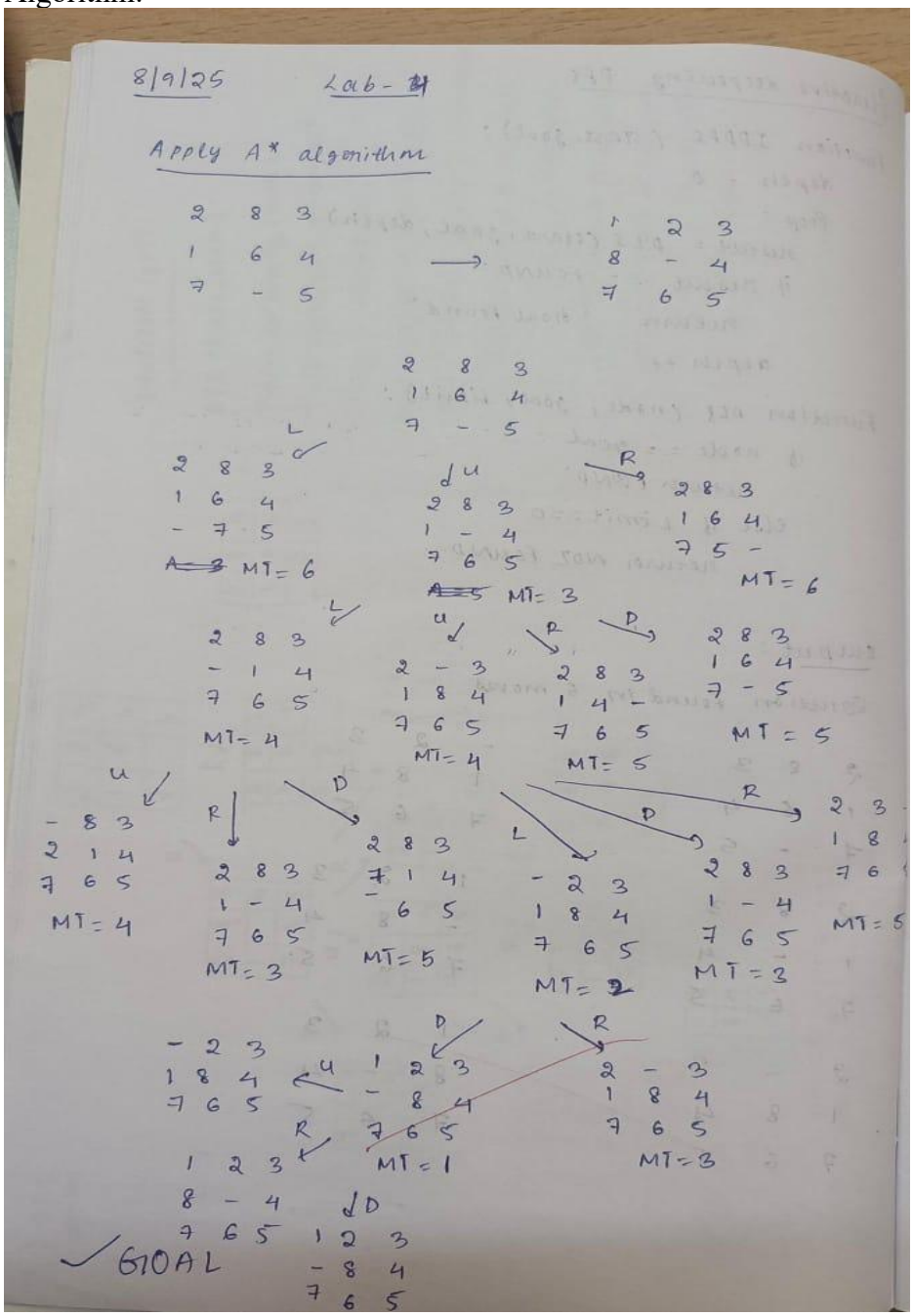
(1, 2, 3)
(8, '_', 4)
(7, 6, 5)

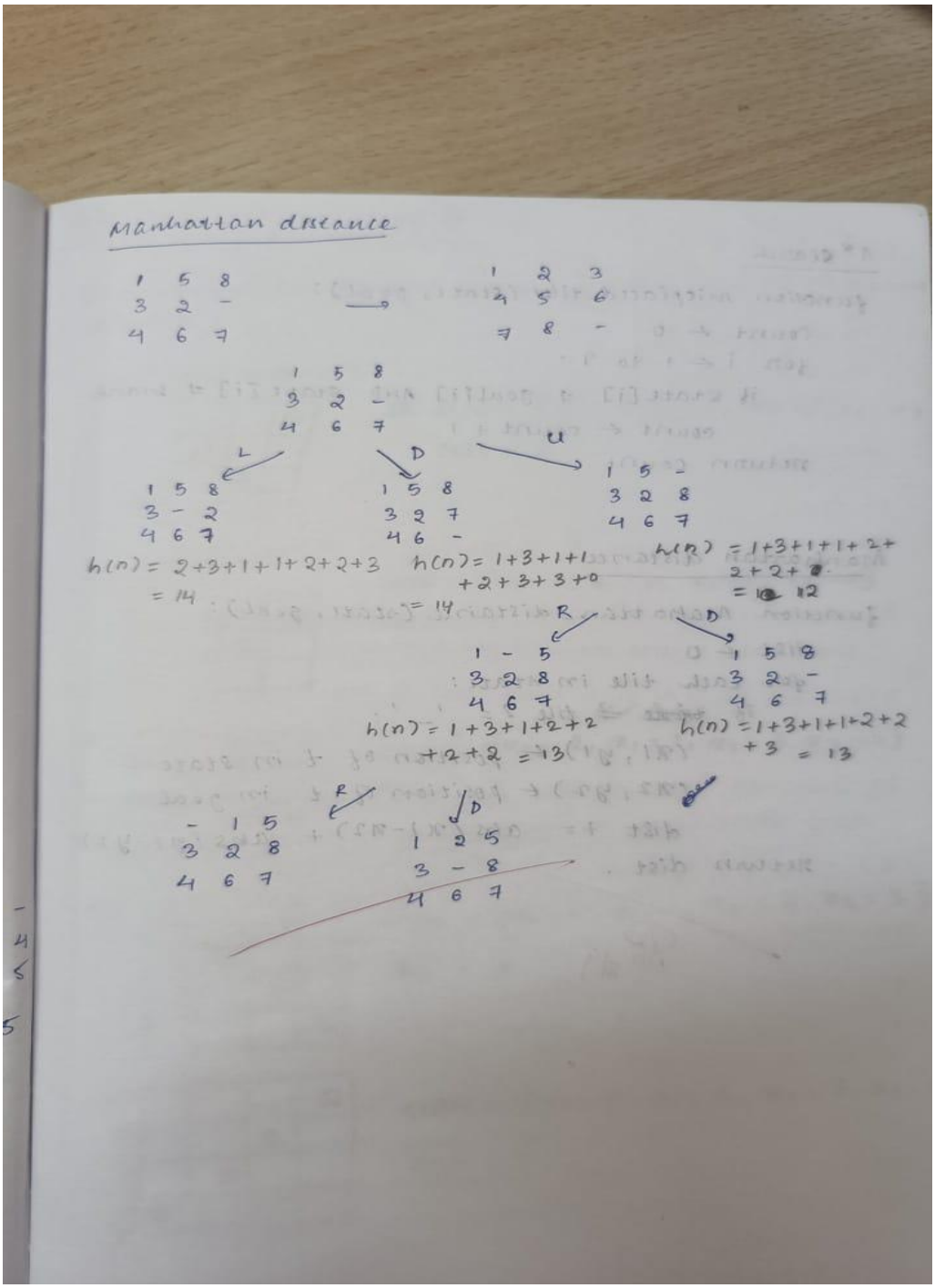
LAB - 4

Implement A* search algorithm

a) Misplaced Tiles

Algorithm:





Code: from collections import deque

```
def solve_puzzle_all_paths(initial, goal, max_depth=50):
    visited = set()
    initial_t = tuple(map(tuple, initial))
    visited.add(initial_t)

    queue = deque()
```

```
    queue.append((initial, [initial]))

    while queue:
        current, path = queue.popleft()

        if current == goal:
            return path

        if len(path) > max_depth:
            continue

        neighbors_states = neighbors(current)
        misplaced_list = [(state, misplaced_tiles(state, goal)) for state in neighbors_states]

        if not misplaced_list:
            continue

        min_misplaced = min(m for _, m in misplaced_list)

        for state, m in misplaced_list:
            state_t = tuple(map(tuple, state))
            if m == min_misplaced and state_t not in visited:
                visited.add(state_t)
                queue.append((state, path + [state]))

    return None

def main():
    initial_state = input_puzzle("initial")
    goal_state = input_puzzle("goal")

    print("\nInitial State:")
    print_state(initial_state)
    print("Goal State:")
    print_state(goal_state)

    misplaced = misplaced_tiles(initial_state, goal_state)
    print(f"Initial misplaced tiles count: {misplaced}\n")

    max_depth = int(input("Enter maximum search depth (e.g., 50): "))

    solution_path = solve_puzzle_all_paths(initial_state, goal_state, max_depth=max_depth)

    if solution_path is None:
        print("Could not solve the puzzle within the depth limit.")
    else:
        for step, state in enumerate(solution_path):
```

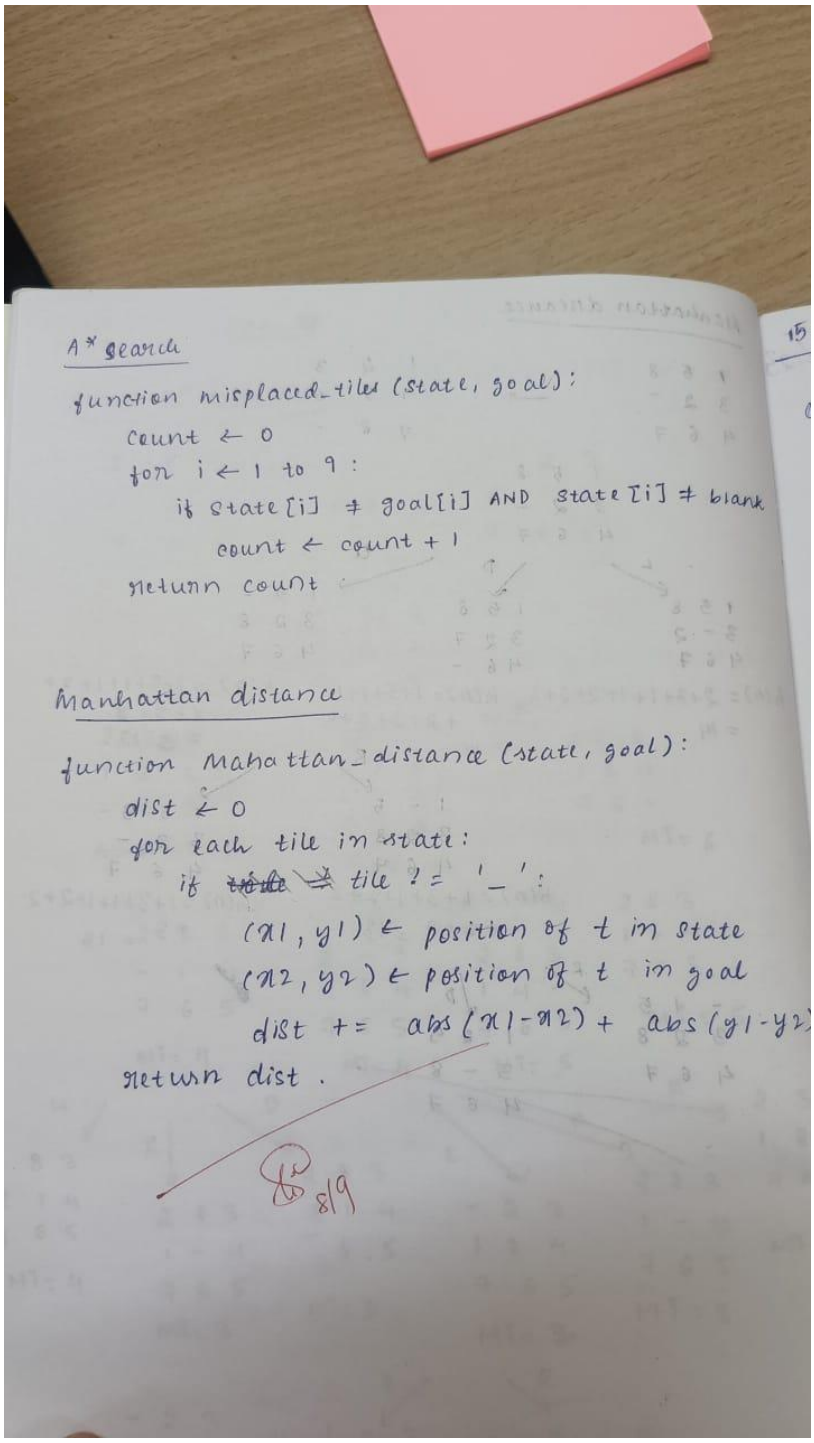
```
        print(f"Step {step}:")
        print_state(state)

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

Output:

```
Enter the initial puzzle state (use 0 for the blank):
Row 1: 1 2 3
Row 2: 4 0 6
Row 3: 7 5 8
Enter the goal puzzle state (use 0 for the blank):
Row 1: 1 2 3
Row 2: 4 5 6
Row 3: 7 8 0

Initial State:
1 2 3
4 0 6
7 5 8

Goal State:
1 2 3
4 5 6
7 8 0

Initial misplaced tiles count: 3

Enter maximum search depth: 20
```

b) Manhattan Distance

Algorithm:



A* search

```
function misplaced_tiles (state, goal):
    count ← 0
    for i ← 1 to 9 :
        if state[i] ≠ goal[i] AND state[i] ≠ blank
            count ← count + 1
    return count
```

Manhattan distance

```
function Manhattan_distance (state, goal):
    dist ← 0
    for each tile in state:
        if tile ?= '_':
            (x1, y1) ← position of t in state
            (x2, y2) ← position of t in goal
            dist += abs(x1-x2) + abs(y1-y2)
    return dist .
```

8|9

Code:

```
from heapq import heappush, heappop

class PuzzleState:
    def __init__(self, board, parent=None, move=None, depth=0):
        self.board = board
        self.parent = parent
        self.move = move
        self.depth = depth
        self.zero_pos = self.board.index(0)

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

    def get_moves(self):
        moves = []
        zero = self.zero_pos
        row, col = zero // 3, zero % 3

        directions = {
            'Up': (row - 1, col),
            'Down': (row + 1, col),
            'Left': (row, col - 1),
            'Right': (row, col + 1)
        }

        for move, (r, c) in directions.items():
            if 0 <= r < 3 and 0 <= c < 3:
                new_zero = r * 3 + c
                new_board = list(self.board)
                new_board[zero], new_board[new_zero] = new_board[new_zero], new_board[zero]
                moves.append(PuzzleState(tuple(new_board), self, move, self.depth + 1))
        return moves

    def manhattan_distance(self, goal):
        distance = 0
        for i, tile in enumerate(self.board):
            if tile != 0:
                goal_index = goal.index(tile)
                current_row, current_col = i // 3, i % 3
                goal_row, goal_col = goal_index // 3, goal_index % 3
                distance += abs(current_row - goal_row) + abs(current_col - goal_col)
        return distance

    def __lt__(self, other):
        return True
```

```
def a_star(start, goal):
    open_list = []
    closed_set = set()
    start_state = PuzzleState(start)
    heappush(open_list, (start_state.manhattan_distance(goal), start_state))

    while open_list:
        _, current = heappop(open_list)
        if current.is_goal(goal):
            return reconstruct_path(current)
        closed_set.add(current.board)
        for neighbor in current.get_moves():
            if neighbor.board in closed_set:
                continue
            cost = neighbor.depth + neighbor.manhattan_distance(goal)
            heappush(open_list, (cost, neighbor))

    return None

def reconstruct_path(state):
    path = []
    while state.parent is not None:
        path.append(state.move)
        state = state.parent
    path.reverse()
    return path

if __name__ == "__main__":
    start = (2, 8, 3,
             1, 6, 4,
             7, 0, 5)

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

    print("SIRIPURAPU MANASWI (1BM23CS331)")
    solution = a_star(start, goal)
    if solution:
        print(f"Solution found in {len(solution)} moves: {solution}")
    else:
        print("No solution found.")
```

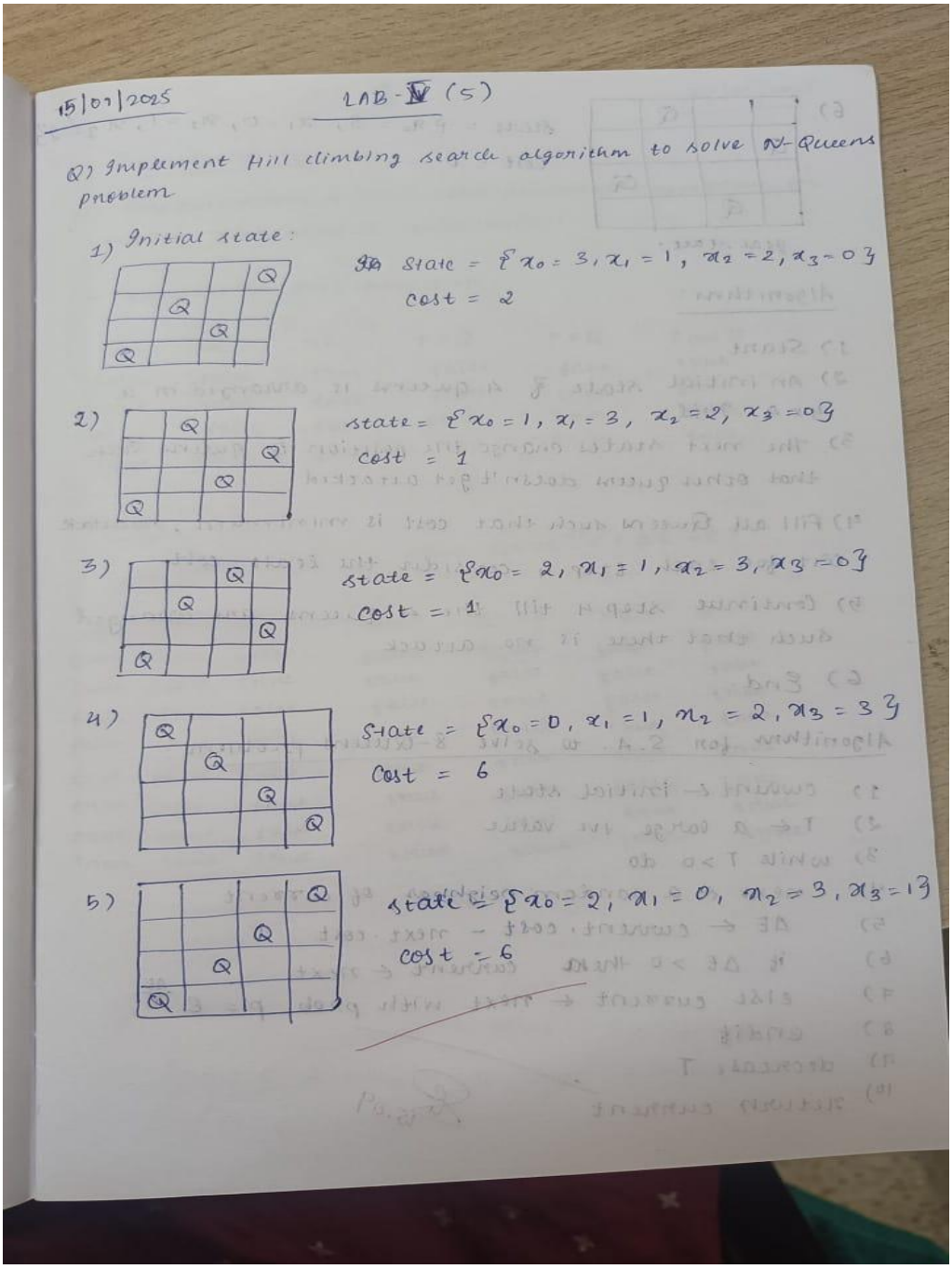
Output:

```
Solution found in 5 moves: ['Up', 'Up', 'Left', 'Down', 'Right']
```

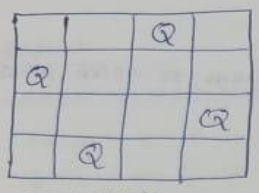
LAB - 5

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:



6)



goal state :

state = $\{x_0 = 3, x_1 = 0, x_2 = 1, x_3$

cost = 0

Algorithm :

1) Start
2) An initial state of 4 queens is arranged in a 4 * 4 grid.
3) The next states change the position of queens such that other queens doesn't get attacked
4) Fill all Queens such that cost is minimum, calculate cost for each step & consider the least cost.
5) Continue step 4 till the 4 queens are arranged such that there is no attack.
6) End.

Algorithm for S.A. to solve 8-Queens problem :

1) current ← initial state
2) T ← a large +ve value
3) while T > 0 do
4) next ← a random neighbor of current
5) ΔE ← current.cost − next.cost
6) if ΔE > 0 then current ← next
7) else current ← next with prob. $p = e^{\frac{\Delta E}{T}}$
8) endif
9) decrease T
10) return current

15.09

Code:

```
from itertools import permutations

def compute_cost(state):
    cost = 0
    for i in range(4):
        for j in range(i+1, 4):
            if abs(state[i] - state[j]) == abs(i - j):
                cost += 1
    return cost

def print_board(state):
    board = ""
    for row in range(4):
        for col in range(4):
            board += " Q " if state[col] == row else " . "
        board += "\n"
    return board

def is_valid_permutation(state):
    return sorted(state) == [0, 1, 2, 3]

def main():
    all_perms = list(permutations(range(4)))
    print(f"Total permutations: {len(all_perms)}\n")

    while True:
        user_input = input("Enter initial state as 4 comma-separated integers from 0 to 3 (e.g. 1,3,0,2):
")
        try:
            user_state = tuple(int(x.strip()) for x in user_input.split(','))
            if len(user_state) != 4 or not is_valid_permutation(user_state):
                print("Invalid input! Please enter a permutation of 0,1,2,3 (each number exactly once).")
                continue
            break
        except ValueError:
            print("Invalid input! Please enter integers separated by commas.")

    cost = compute_cost(user_state)
    print(f"\nYour input state: {user_state} | Diagonal Conflicts Cost: {cost}")
    print(print_board(user_state))
    print("-" * 30)

    print("Showing first 16 permutations with their costs:\n")
    for idx, perm in enumerate(all_perms[:16], 1):
        cost = compute_cost(perm)
        print(f"Case {idx}: {perm} | Diagonal Conflicts Cost: {cost}")
```

```
        print(print_board(perm))
        print("-" * 30)

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

Output:

```
Total permutations: 24

Enter initial state as 4 comma-separated integers from 0 to 3 (e.g. 1,3,0,2): 3,1,2,0

Your input state: (3, 1, 2, 0) | Diagonal Conflicts Cost: 2
 .  .  .  Q
 .  Q  .  .
 .  .  Q  .
 Q  .  .  .

None
------------------------------
Showing first 16 permutations with their costs:

Case 1: (0, 1, 2, 3) | Diagonal Conflicts Cost: 6
 Q  .  .  .
 .  Q  .  .
 .  .  Q  .
 .  .  .  Q

None
------------------------------
Case 2: (0, 1, 3, 2) | Diagonal Conflicts Cost: 2
 Q  .  .  .
 .  Q  .  .
 .  .  .  Q
 .  .  Q  .

None
------------------------------
Case 3: (0, 2, 1, 3) | Diagonal Conflicts Cost: 2
 Q  .  .  .
 .  .  Q  .
 .  Q  .  .
 .  .  .  Q

None
------------------------------
Case 4: (0, 2, 3, 1) | Diagonal Conflicts Cost: 1
 Q  .  .  .
 .  .  .  Q
 .  Q  .  .
 .  .  Q  .

None
------------------------------
Case 5: (0, 3, 1, 2) | Diagonal Conflicts Cost: 1
 Q  .  .  .
 .  .  Q  .
 .  .  .  Q
 .  Q  .  .

None
```

Simulated Annealing to Solve 8-Queens problem

Code:

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

    temperature = 100.0
    cooling_rate = 0.95

    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:
            current, current_cost = neighbor, neighbor_cost
            if neighbor_cost < best_cost:
                best, best_cost = neighbor, neighbor_cost
        else:
            probability = math.exp(delta / temperature)
            if random.random() < probability:
                current, current_cost = neighbor, neighbor_cost

        temperature *= cooling_rate

    return best, best_cost

def print_board(state):
    n = len(state)
    for row in range(n):
        line = ""
        for col in range(n):
            if state[col] == row:
                line += " Q "
```

```
            else:
                line += " . "
        print(line)
    print()

if __name__ == "__main__":
    n = 8
    solution, cost_val = simulated_annealing(n)

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

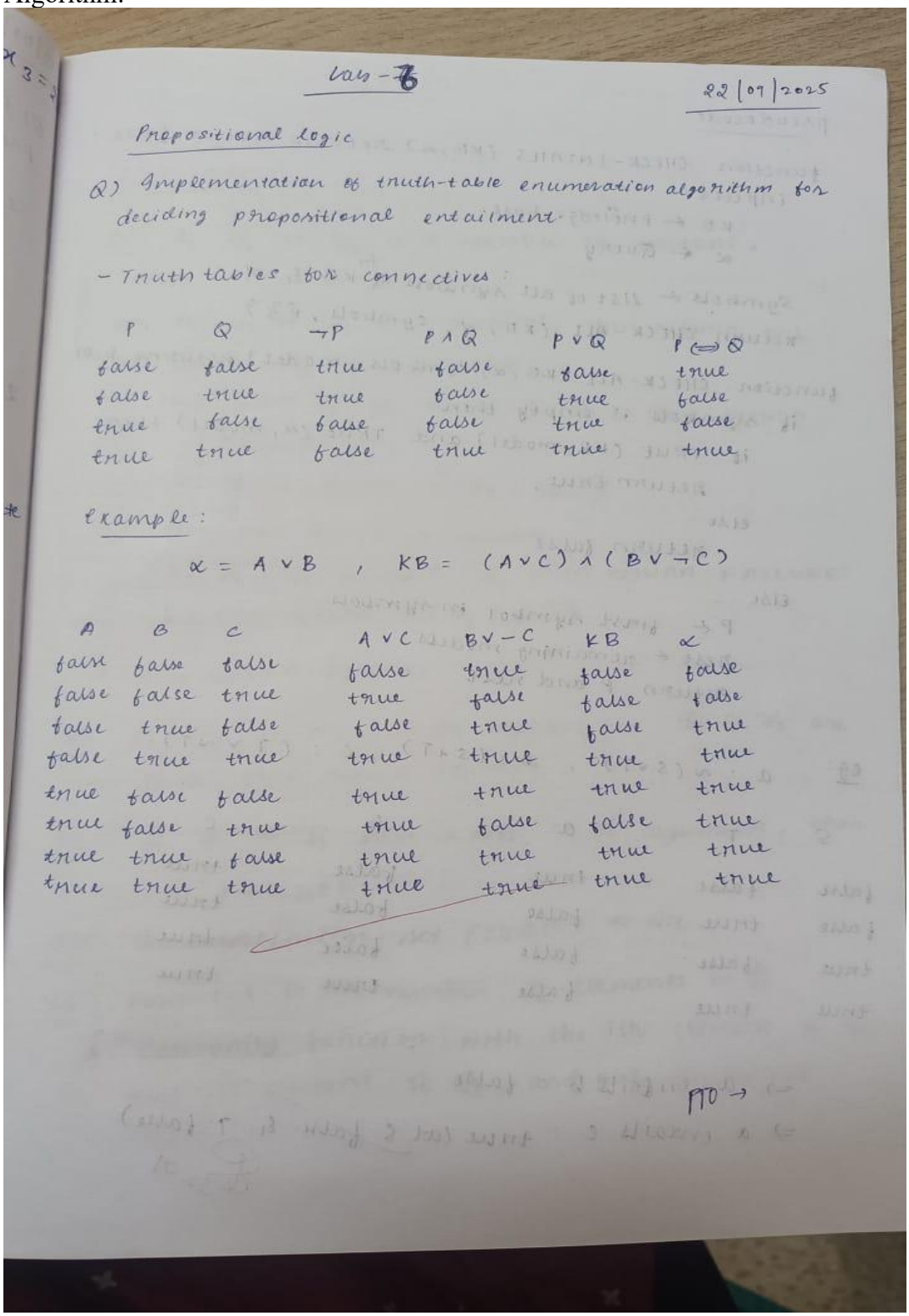
Output:

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

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

LAB - 6

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

Algorithm:



Lab - 6

22/07/2025

Propositional logic

Q) Implementation of truth-table enumeration algorithm for deciding propositional entailment

- Truth tables for connectives

P	Q	$\neg P$	$P \wedge Q$	$P \vee Q$	$P \Leftrightarrow Q$
false	false	true	false	false	true
false	true	true	false	true	false
true	false	false	false	true	false
true	true	false	true	true	true

Example:

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

A	B	C	$A \vee C$	$B \vee \neg C$	KB	α
false	false	false	false	true	false	false
false	false	true	true	false	false	false
false	true	false	false	true	false	true
false	true	true	true	true	true	true
true	false	false	true	true	true	true
true	false	true	true	false	false	true
true	true	false	true	true	true	true
true	true	true	true	true	true	true

PTO →

pseudocode:

function CHECK-ENTAILS (KB, α) returns true or false
  inputs:
    KB ← knowledge base
    α ← Query

  symbols ← list of all symbols in KB & α
  return CHECK-ALL (KB, α, symbols, {})

function CHECK-ALL (KB, α, symbols, model) returns bool
  if symbols is empty then
    if TRUE (KB, model) and TRUE (α, model) then
      return true
    else
      return false
  else
    P ← first symbol in symbols
    rest ← remaining models
    return P and rest

eg: a : $\sim(S \vee T)$, b : $(S \wedge T)$, c : $(T \vee \sim T)$

S	T	a	b	c
false	false	true	false	true
false	true	false	false	true
true	false	false	false	true
true	true	false	true	true

⇒ a entails b : false

⇒ a entails c : true (at S = false & T = false)

22.09

Code:

```
def pl_true(sentence, model):
    if isinstance(sentence, str):
        return model.get(sentence, False)
    elif isinstance(sentence, tuple):
        operator = sentence[0]
        if operator == 'not':
            return not pl_true(sentence[1], model)
        elif operator == 'and':
            return all(pl_true(arg, model) for arg in sentence[1:])
        elif operator == 'or':
            return any(pl_true(arg, model) for arg in sentence[1:])
        elif operator == '=>':
            return (not pl_true(sentence[1], model)) or pl_true(sentence[2], model)
        elif operator == '<=>':
            return pl_true(sentence[1], model) == pl_true(sentence[2], model)
    return False


def tt_check_all(kb, alpha, symbols, model, true_models, all_symbols, col_widths):
    if not symbols:
        kb_true = pl_true(kb, model)
        alpha_true = pl_true(alpha, model)
        row_values = [str(model.get(s, False)) for s in all_symbols] + [str(kb_true), str(alpha_true),
str(kb_true and alpha_true)]
        formatted_row = "│ " + " │ ".join(f"{val:^{col_widths[i]}}" for i, val in
enumerate(row_values)) + " │"

        if kb_true and alpha_true:
            print(f"\033[92m{formatted_row}\033[0m")  # green for satisfying rows
            true_models.append(model.copy())
        else:
            print(formatted_row)
        return (not kb_true) or alpha_true
    else:
        P = symbols[0]
        rest = symbols[1:]
        model_true = model.copy()
        model_true[P] = True
        model_false = model.copy()
        model_false[P] = False
        return (tt_check_all(kb, alpha, rest, model_true, true_models, all_symbols, col_widths) and
                tt_check_all(kb, alpha, rest, model_false, true_models, all_symbols, col_widths))


def tt_entails(KB, alpha):
    symbols = set()
```

```
    def extract_symbols(sentence):
        if isinstance(sentence, str):
            symbols.add(sentence)
        elif isinstance(sentence, tuple):
            for arg in sentence[1:]:
                extract_symbols(arg)

    extract_symbols(KB)
    extract_symbols(alpha)
    symbols = list(sorted(symbols))  # sorted for consistent order

    header_values = symbols + ["KB", "alpha", "KB ∧ α"]
    col_widths = [max(len(str(s)), 5) for s in header_values]

    total_width = sum(col_widths) + 3 * len(col_widths) + 1
    border = "═" * total_width

    print("\nTruth Table:")
    print(" ┌" + "┬".join("─" * (col_widths[i] + 2) for i in range(len(header_values))) + "┐ ")
    header_string = " │ " + " │ ".join(f"{val:^{col_widths[i]}}" for i, val in enumerate(header_values))
+ " │"
    print(header_string)
    print(" ├" + "┼".join("─" * (col_widths[i] + 2) for i in range(len(header_values))) + "┤ ")

    true_models = []
    result = tt_check_all(KB, alpha, list(symbols), {}, true_models, all_symbols=symbols,
col_widths=col_widths)

    print(" └" + "┴".join("─" * (col_widths[i] + 2) for i in range(len(header_values))) + "┘ ")

    print("\nModels where KB and alpha are true:")
    if true_models:
        for model in true_models:
            print(model)
    else:
        print("None")

    return result


# Example
kb2 = ('and', ('or', 'A', 'B'), ('=>', 'B', 'C'))
alpha2 = ('or', 'A', 'C')
print(f"\nDoes KB entail alpha? {tt_entails(kb2, alpha2)}")
```

Output:

Truth Table:

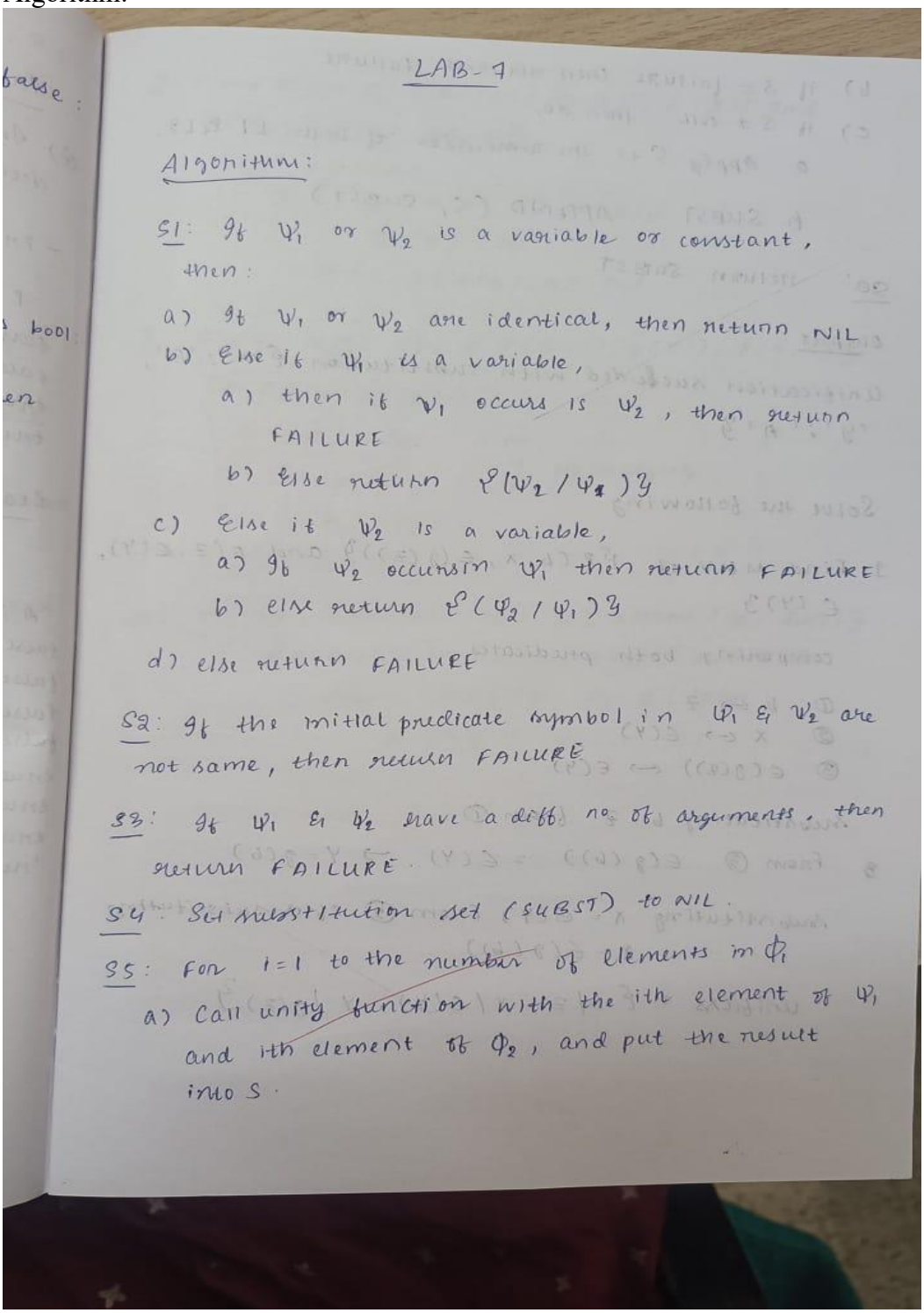
A	B	C	KB	alpha	KB ∧ α
True	True	True	True	True	True
True	True	False	False	True	False
True	False	True	True	True	True
True	False	False	True	True	True
False	True	True	True	True	True
False	True	False	False	False	False
False	False	True	False	True	False
False	False	False	False	False	False

Models where KB and alpha are true:
{'A': True, 'B': True, 'C': True}
{'A': True, 'B': False, 'C': True}
{'A': True, 'B': False, 'C': False}
{'A': False, 'B': True, 'C': True}

Does KB entail alpha? True

LAB - 7
Implement unification in first order logic

Algorithm:



LAB - 7

Algorithm:

S1: If Ψ_1 or Ψ_2 is a variable or constant, then:

a) If Ψ_1 or Ψ_2 are identical, then return NIL

b) Else if Ψ_1 is a variable,

a) then if Ψ_1 occurs is Ψ_2, then return FAILURE

b) Else return $\{(\Psi_2 / \Psi_1)\}$

c) Else if Ψ_2 is a variable,

a) If Ψ_2 occurs in Ψ_1 then return FAILURE

b) else return $\{(\Psi_2 / \Psi_1)\}$

d) else return FAILURE

S2: If the initial predicate symbol in Ψ_1 & Ψ_2 are not same, then return FAILURE

S3: If Ψ_1 & Ψ_2 have a diff no of arguments, then return FAILURE.

S4: Set substitution set (SUBST) to NIL.

S5: For i=1 to the number of elements in Φ_1

a) Call unify function with the ith element of Ψ_1 and ith element of Φ_2, and put the result into S.

b) if S = failure then returns failure

c) if S ≠ NIL then do,

a. Apply S to the remainder of both L1 & L2.

b. SUBST = APPEND (S, SUBST)

ge: return SUBST

output:

Unification succeeded with substitution {'x': 'B', 'y': 'A'}

Solve the following

1. Find MGU of {P(b, x, E(g(z)))} and P(z, E(y), E(y))}

comparing both predicates

① $b \leftrightarrow z$

② $x \leftrightarrow E(y)$

③ $E(g(z)) \leftrightarrow E(y)$

Substituting $b = z$ from ①

From ③ $E(g(b)) = E(y) \rightarrow y = g(b)$

Substituting $x = E(y)$ From ② after substituting

$x = E(g(b))$

unifiers = $\{b/z, x/E(y), y/g(z)\}$

2. Find MGU of {Q(a, g(x, a)), f(y))} and
Q(a, g(f(b), a), x)}

x / f(b)

Q(a, g(f(b), a), f(y))

f(y) / x

Q(a, g(f(b), a), x)

3. Find MGU of. {P(f(a), g(y)), P(x, x)}

P(f(a), g(y))

x / f(a)

P(x, g(y))

} no unifier

x / g(y)

P(x, x)

unify {knows(John, x), knows(y, Bill)}

{knows(John, x), knows(y, Bill)}

sub: John / y or y / John

x / Bill

Code:

```
print(SIRIPURAPU MANASWI  1BM23CS331')
def unify(x, y, subst=None):
    if subst is None:
        subst = {}

    # If x or y is a variable or constant
    if is_variable(x) or is_constant(x):
        if x == y:
            return subst
        elif is_variable(x):
            return unify_var(x, y, subst)
        elif is_variable(y):
            return unify_var(y, x, subst)
        else:
            return None

    # If both x and y are compound expressions
    if 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]):
            subst = unify(xi, yi, subst)
            if subst is None:
                return None
        return subst
    return None


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


def is_constant(x):
    return isinstance(x, str) and x.isupper() and x.isalpha()


def is_compound(x):
    return isinstance(x, tuple) and len(x) == 2 and isinstance(x[0], str) and isinstance(x[1], list)


def unify_var(var, x, subst):
    if var in subst:
        return unify(subst[var], x, subst)
    elif x in subst:
        return unify(var, subst[x], subst)
    elif occurs_check(var, x, subst):
```

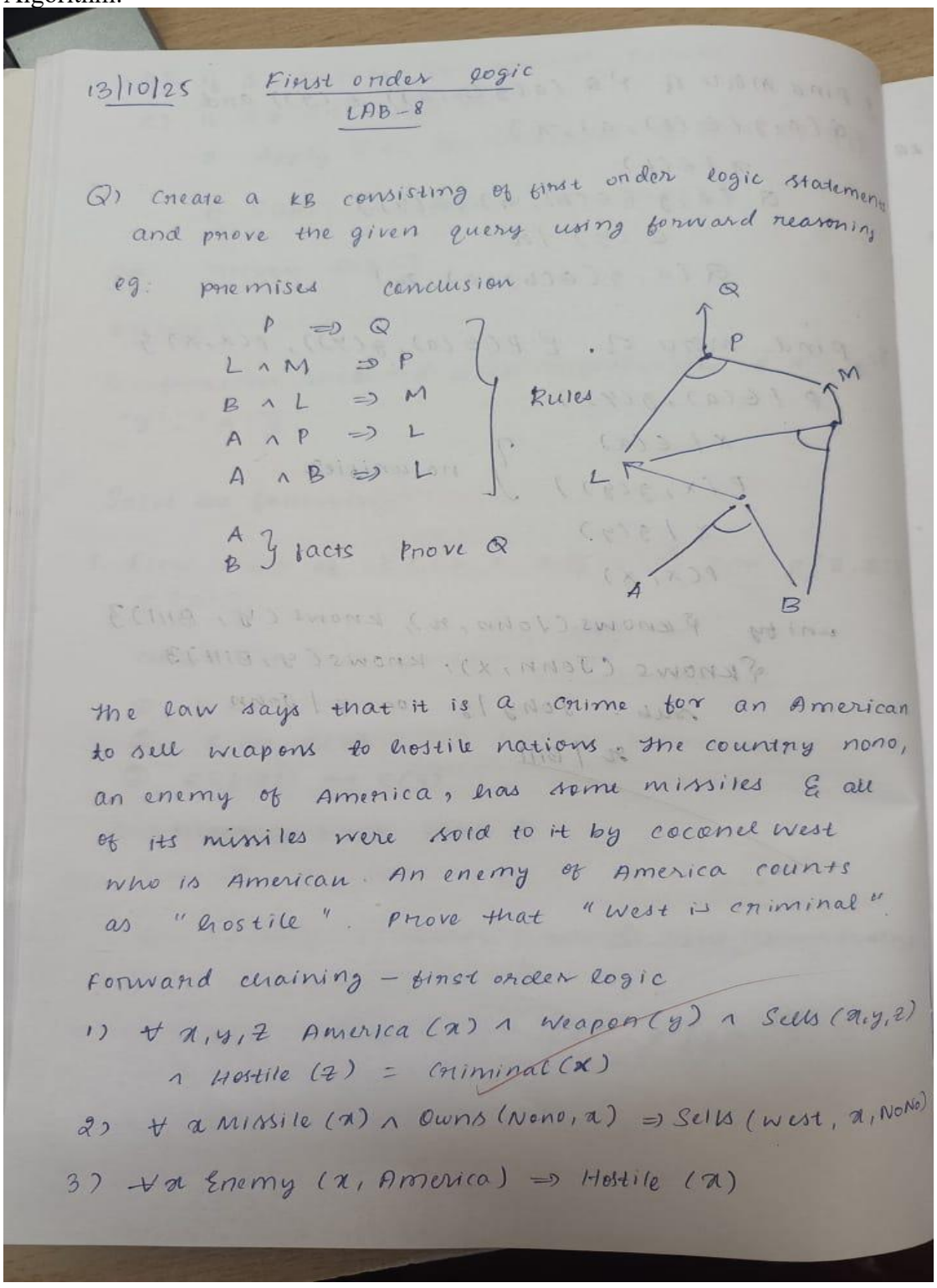
```
        return None
    else:
        subst[var] = x
        return subst


def occurs_check(var, x, subst):
    if var == x:
        return True
    elif is_variable(x) and x in subst:
        return occurs_check(var, subst[x], subst)
    elif is_compound(x):
        return any(occurs_check(var, arg, subst) for arg in x[1])
    else:
        return False


# Example usage:
# Let's say we want to unify P(x, A) and P(B, y)
x = ("P", ["x", "A"])
y = ("P", ["B", "y"])

result = unify(x, y)
if result is not None:
    print("Unification succeeded with substitution:", result)
else:
    print("Unification failed.")
```

Output:
SIRIPURAPU MANASWI 1BM23CS331
Unification succeeded with substitution: {'x': 'B', 'y': 'A'}

LAB - 8

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

Algorithm:



13/10/25 First order logic

LAB-8

Q) Create a KB consisting of first order logic statements and prove the given query using forward reasoning

eg: premises conclusion

$P \Rightarrow Q$

$L \wedge M \Rightarrow P$

$B \wedge L \Rightarrow M$

$A \wedge P \Rightarrow L$

$A \wedge B \Rightarrow L$

} Rules

A, B } facts Prove Q

The law says that it is a crime for an American to sell weapons to hostile nations. The country nono, an enemy of America, has some missiles & all of its missiles were sold to it by coconel west who is American. An enemy of America counts as "hostile". Prove that "west is criminal".

Forward chaining – first order logic

1) $\forall x,y,z$ America $(x) \wedge$ Weapon $(y) \wedge$ Sells $(x,y,z) \wedge$ Hostile $(z) \Rightarrow$ Criminal (x)

2) $\forall x$ Missile $(x) \wedge$ Owns (Nono, x) $\Rightarrow$ Sells (west, x, Nono)

3) $\forall x$ Enemy $(x$, America) $\Rightarrow$ Hostile (x)

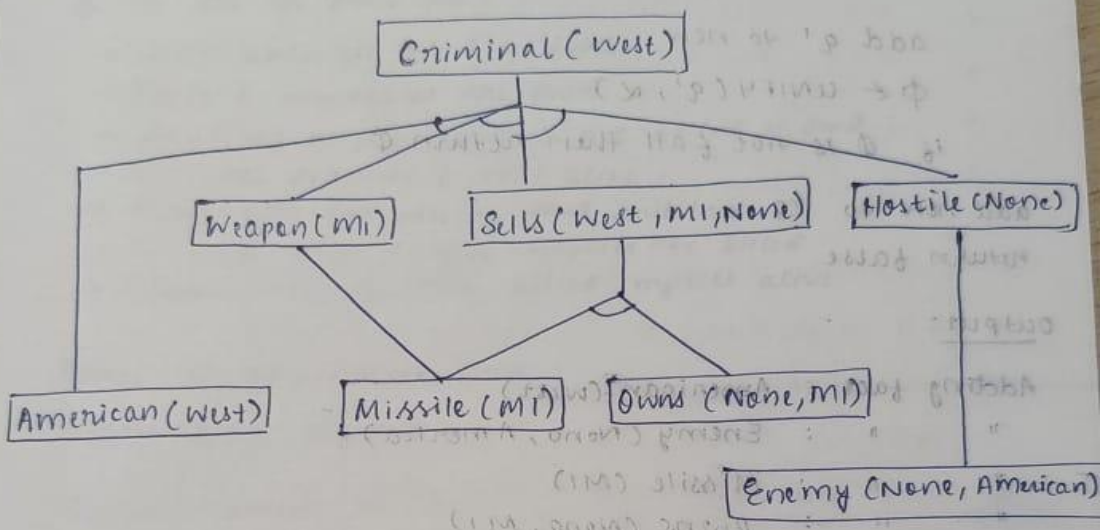
4) $\forall x$ Missile $(x) \Rightarrow$ Weapon (x)

5) American (west)

6) Enemy (Nono, America)

7) Owns (Nono, M1) and

8) Missile (M1)



Forward Reasoning Algorithm :

Function FOL-FC-ASK (KB, α) returns substitution or False.

inputs : KB, knowledge base, a set of first-order definite courses α, the query, atomic sentence.

local variables : new, the new sentences inferred on each iteration

repeat until new is empty

new $\leftarrow$ { }

for each rule in KB do

$(p_1 \wedge \dots \wedge p_n) \leftarrow$ standardize-variables (rule)

For each θ such that SUBST(θ, p1 ∧ ... ∧ pn) = SUBST(θ, p1' ∧ ... ∧ pn') for some p_1' ... p_n' in KB

q' ← SUBST(θ, q)

if q' does not unify with some sentences already in KB or new then

add q' to new

ϕ ← UNIFY(q', α)

if ϕ is not fail then return ϕ

add new to KB

return false

Output:

Adding fact : American(West)

" " : Enemy(Nono, America)

" " : Missile(M1)

" " : Owns(Nono, M1)

Inferred new fact : Weapon(M1) from ['Missile(M1)'] ⇒ Weapon(M1)

Inferred new fact : Hostile(Nono) from ['Enemy(Nono, America)'] ⇒ Hostile(Nono)

Inferred new fact : Criminal(West, M1, Nono) from ['American(West)'], 'Sells[West, M1, Nono]', 'Hostile(Nono)'] ⇒ Criminal(West)

Goal reached : West is criminal

True

Code:

```
facts = {
   'American(West)': True,
   'Hostile(Nono)': True,
   'Missiles(Nono)': True,
}
def rule1(facts):
   if facts.get('American(West)', False) and facts.get('Hostile(Nono)', False):
      return 'Criminal(West)'
   return None

def rule2(facts):
   if facts.get('Missiles(Nono)', False) and facts.get('Hostile(Nono)', False):
      return 'SoldWeapons(West, Nono)'


def forward_chaining(facts, rules):
   new_facts = facts.copy()
   inferred = True
   while inferred:
      inferred = False
      for rule in rules:
         result = rule(new_facts)
         if result and result not in new_facts:-
            new_facts[result] = True
            inferred = True
            print(f"New fact inferred: {result}")
   return new_facts
rules = [rule1, rule2]

inferred_facts = forward_chaining(facts, rules)

print("\nFinal facts:")
for fact in inferred_facts:
   print(fact)
```

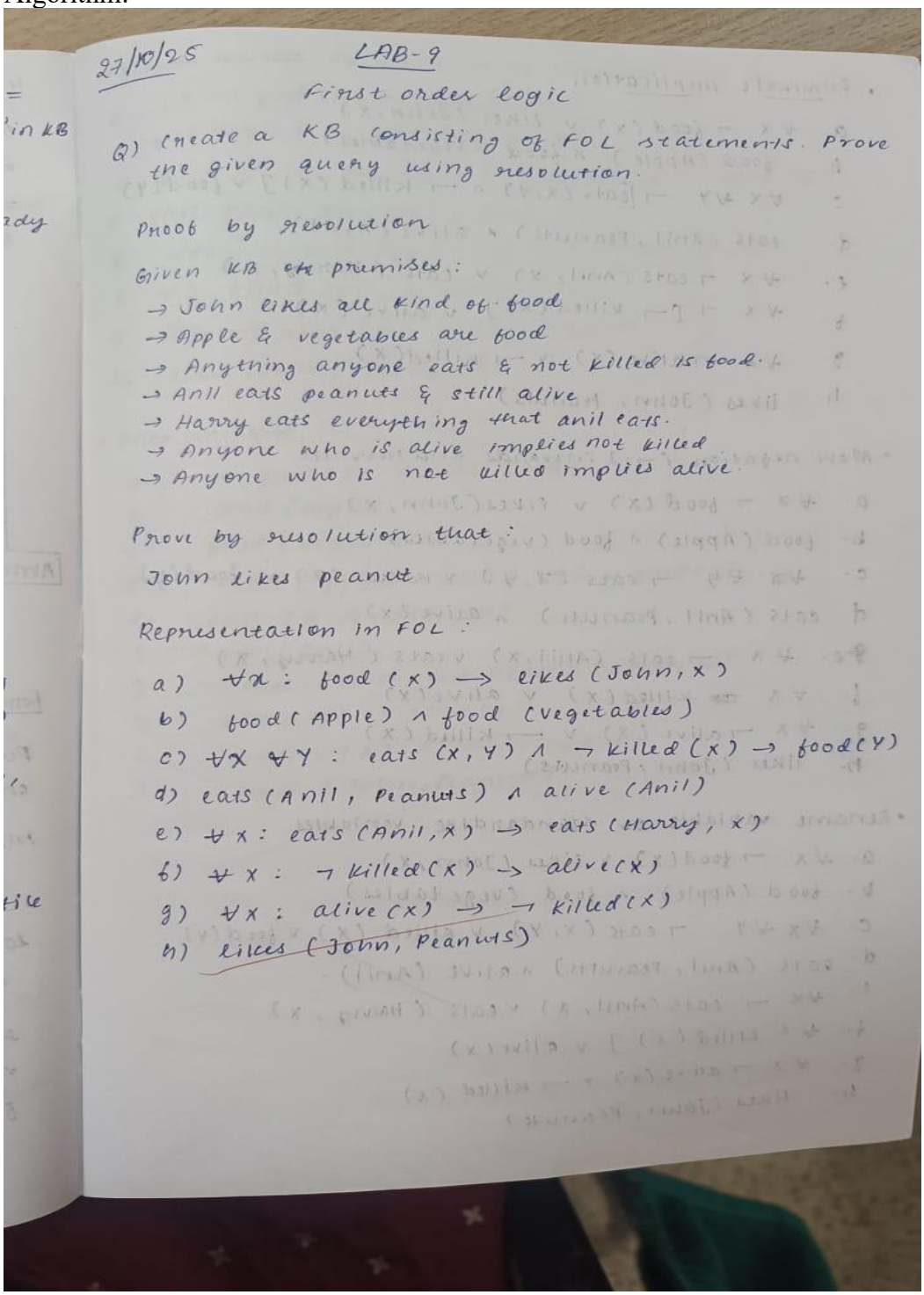
Output:

```
New fact inferred: Criminal(West)
New fact inferred: SoldWeapons(West, Nono)

Final facts:
American(West)
Hostile(Nono)
Missiles(Nono)
Criminal(West)
SoldWeapons(West, Nono)
```

LAB - 9

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

Algorithm:



27/10/25

LAB-9

First order logic

Q) Create a KB consisting of FOL statements. Prove the given query using resolution.

Proof by resolution

Given KB of premises:

→ John likes all kind of food
→ Apple & vegetables are food
→ Anything anyone eats & not killed is food.
→ Anil eats peanuts & still alive
→ Harry eats everything that anil eats.
→ Anyone who is alive implies not killed
→ Anyone who is not killed implies alive.

Prove by resolution that:

John likes peanut

Representation in FOL:

a) $\forall x$: food(x) → likes(John, x)
b) food(Apple) ∧ food(Vegetables)
c) $\forall x \forall y$: eats(x, y) ∧ ¬ killed(x) → food(y)
d) eats(Anil, Peanuts) ∧ alive(Anil)
e) $\forall x$: eats(Anil, x) → eats(Harry, x)
f) $\forall x$: ¬ killed(x) → alive(x)
g) $\forall x$: alive(x) → ¬ killed(x)
h) likes(John, Peanuts)

• Eliminate implication

a. $\forall x \neg food(x) \vee likes(John, x)$

b. $food(Apple) \wedge food(vegetables)$

c. $\forall x \forall y \neg [eats(x,y) \wedge \neg killed(x)] \vee food(y)$

d. $eats(Anil, Peanuts) \wedge alive(Anil)$

e. $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$

f. $\forall x \neg [\neg killed(x)] \vee alive(x)$

g. $\forall x \neg alive(x) \vee \neg killed(x)$

h. $likes(John, Peanuts)$

• Move negation ($\neg$) inwards and rewrite

a. $\forall x \neg food(x) \vee likes(John, x)$

b. $food(Apple) \wedge food(vegetables)$

c. $\forall x \forall y \neg eats(x,y) \vee killed(x) \vee food(y)$

d. $eats(Anil, Peanuts) \wedge alive(x)$

e. $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$

f. $\forall x killed(x) \vee alive(x)$

g. $\forall x \neg alive(x) \vee \neg killed(x)$

h. $likes(John, Peanuts)$

• Rename variable or standardize variables

a. $\forall x \neg food(x) \vee likes(John, x)$

b. $food(Apple) \wedge food(vegetables)$

c. $\forall x \forall y \neg eats(x, y) \vee killed(x) \vee food(y)$

d. $eats(Anil, Peanuts) \wedge alive(Anil)$

e. $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$

f. $\forall x killed(x)] \vee alive(x)$

g. $\forall x \neg alive(x) \vee \neg killed(x)$

h. $likes(John, Peanuts)$

• Rename variable or standardize variables:

a. $\forall x \neg food(x) \vee likes(John, x)$

b. $food(Apple) \wedge food(Vegetables)$

c. $\forall y \forall z \neg eats(y, z) \vee killed(y) \vee food(z)$

d. $eats(Anil, Peanuts) \wedge alive(Anil)$

e. $\forall w \neg eats(Anil, w) \vee eats(Harry, w)$

f. $\forall g killed(g)] \vee alive(g)$

g. $\forall k \neg alive(k) \vee \neg killed(k)$

h. $likes(John, Peanuts)$

• Drop universe

a. $\neg food(x) \vee likes(John, x)$

b. $food(Apple)$

c. $food(Vegetable)$

d. $\neg eats(y, z) \vee killed(y) \vee food(z)$

e. $eats(Anil, Peanuts)$

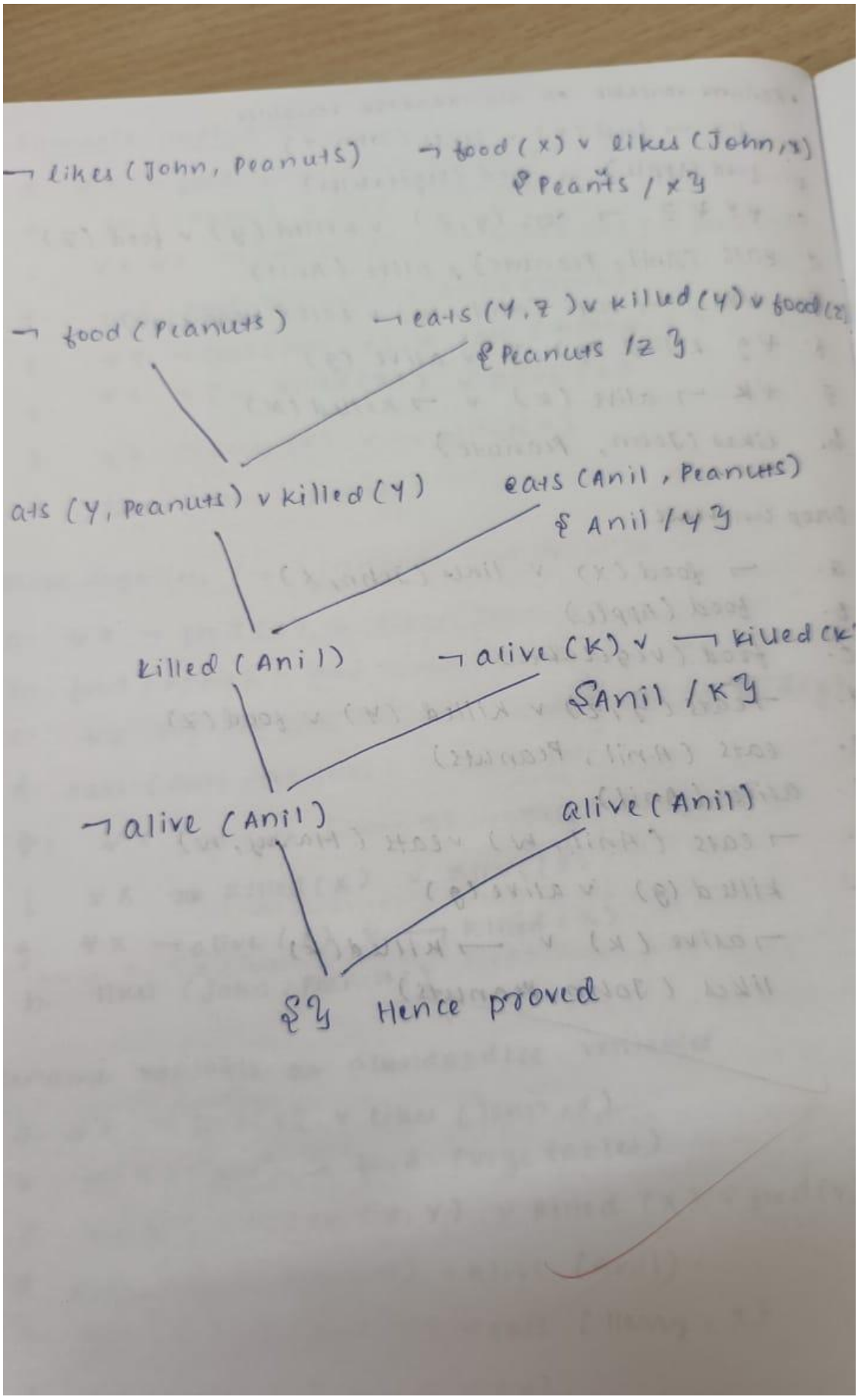
f. $alive(Anil)$

g. $\neg eats(Anil, w) \vee eats(Harry, w)$

h. $killed(g) \vee alive(g)$

i. $\neg alive(k) \vee \neg killed(k)$

j. $likes(John, Peanuts)$


¬ likes (John, Peanuts)
¬ food (x) v likes (John, x)
{Peants / x}
¬ food (Peanuts)
¬ eats (Y, z) v killed (Y) v food (z)
{Peanuts /z}
ats (Y, Peanuts) v killed (Y)
eats (Anil, Peanuts)
{Anil / Y}
killed (Anil)
¬ alive (K) v ¬ killed (K)
{Anil / K}
¬ alive (Anil)
alive (Anil)
{} Hence proved

Algorithm:

1. Input:
   - Knowledge base (KB)
   - Query (Q)
2. Convert KB and $\neg Q$ to clausal form:
   - eliminate implications
   - move negations inward
   - standardize variables
   - skolemize (remove $\exists$ quantifiers)
   - Drop universal quantifiers
   - convert to CNF
3. Apply resolution:
   - Repeatedly resolve pairs of clauses that contain complementary literals
   - Add new clauses to the KB
   - Stop if:
     - Empty clause ($\perp$) is derived → Q is true or
     - no new clause can be → Q is false
4. Output True / False for query Q.

Code:

```
def negate_literal(lit):
    return lit[1:] if lit.startswith("~") else "~" + lit

def resolve(ci, cj):
    ci = set(ci)
    cj = set(cj)
    resolvents = []

    for di in ci:
        ndi = negate_literal(di)
        if ndi in cj:
            new_clause = (ci - {di}) | (cj - {ndi})
            if len(new_clause) == 0:
                resolvents.append({"res": set(), "pair": (ci, cj)})
            else:
                resolvents.append({"res": new_clause, "pair": (ci, cj)})
    return resolvents


# CLAUSES (CNF)
clauses = [
    {"~Food(x)", "Likes(John,x)"},
    {"~Eats(x,y)", "~Killed(y)", "Food(y)"},
    {"Eats(Anil,Peanut)"},
    {"Alive(Anil)"},
    {"~Alive(z)", "~Killed(z)"},
    {"~Likes(John,Peanut)"}   # Negated Query
]

# Resolution Steps Storage
steps = []

changed = True
while changed:
    changed = False
    new = []

    for i in range(len(clauses)):
        for j in range(i+1, len(clauses)):
            ci = clauses[i]
            cj = clauses[j]
            resolvents = resolve(ci, cj)

            for r in resolvents:
                res = r["res"]
                if res == set(): # NIL Found
```

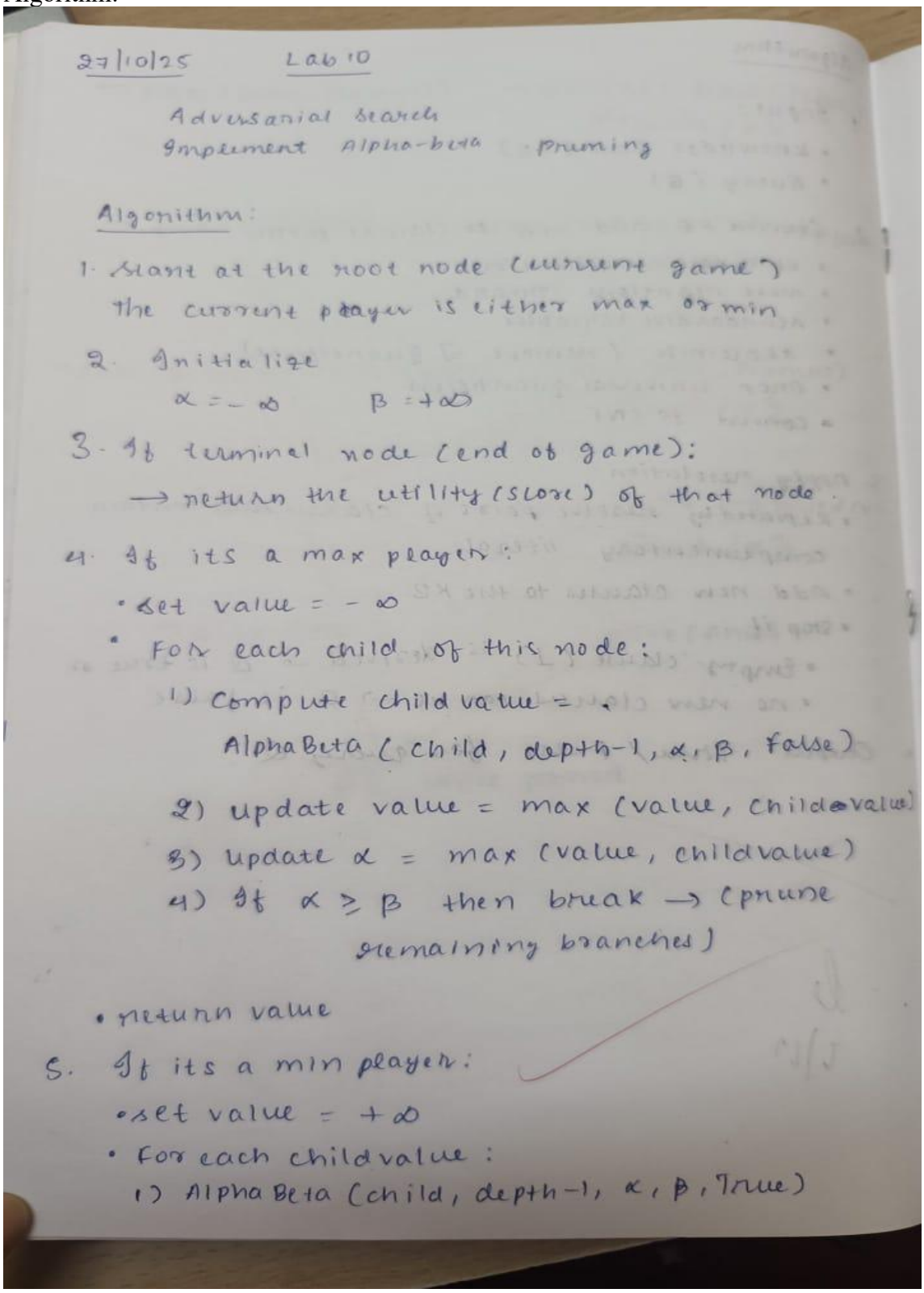
```
                steps.append((ci, cj, set()))
                print("\n NIL (Contradiction Found)")
                print("=> Query Proven TRUE")
                changed = False
                break

            if res not in clauses and res not in new:
                new.append(res)
                steps.append((ci, cj, res))
                changed = True
        if changed is False and resolvents and res == set():
            break

    for c in new:
        clauses.append(c)


print("      RESOLUTION STEPS")

for (a, b, c) in steps:
    if c == set():
        print(f"{a}  +  {b}  =>  NIL")
    else:
        print(f"{a}  +  {b}  =>  {c}")

# PRINT CLAUSES AFTER DERIVATION
print("\nRemaining Clauses:")
for c in clauses:
    print(c)
```

Output:

```
Knowledge base clauses:
   Food(vegetable)
   Alive(Anil)
   Food(apple)
   Alive(x) OR ~Killed(x)
   ~Eats(Anil,x) OR Eats(Harry,x)
   ~Killed(x) OR ~Alive(x)
   Killed(y) OR ~Eats(x,y) OR Food(y)
   Eats(Anil,peanuts)
   ~Food(x) OR Likes(John,x)

Query: Likes(John,peanuts)
Negated query clause will be added to KB and resolution attempted.

Result: True | Derived empty clause (success)
```

LAB - 10
Implement Alpha-Beta Pruning.

Algorithm:



27/10/25 Lab 10

Adversarial Search
Implement Alpha-beta pruning

Algorithm:

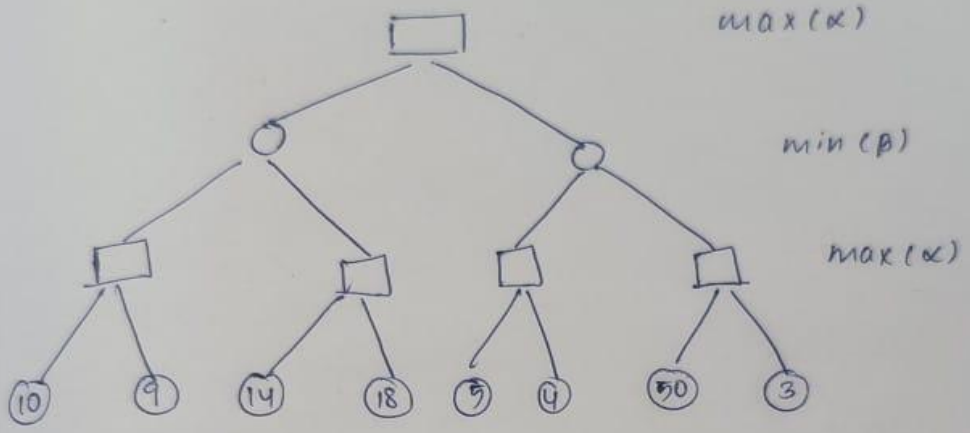
1. Start at the root node (current game)
the current player is either max or min
2. Initialize
$\alpha = -\infty$ $\beta = +\infty$
3. If terminal node (end of game):
→ return the utility (score) of that node.
4. If its a max player:
- Set value = $-\infty$
- For each child of this node:
  1) Compute child value = AlphaBeta (child, depth-1, α, β, false)
  2) update value = max (value, childvalue)
  3) update α = max (value, childvalue)
  4) If $\alpha \geq \beta$ then break → (prune remaining branches)
- return value
5. If its a min player:
- set value = $+\infty$
- For each childvalue:
  1) Alpha Beta (child, depth-1, α, β, True)

2) update value = min (value, childvalue)

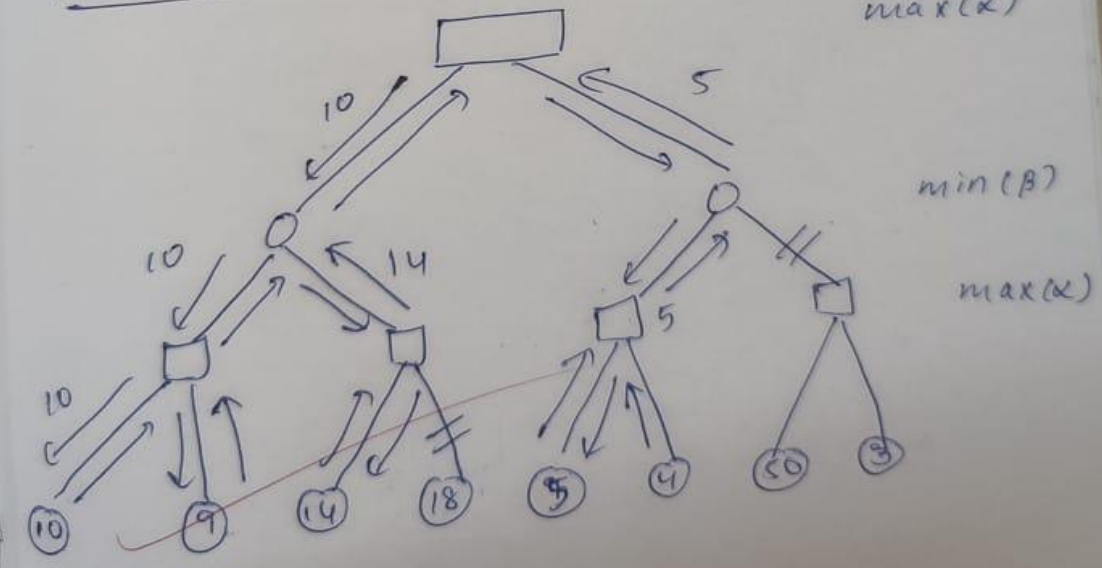
3) update β = min (β, value)

4) if α ≥ β then break → (prune remaining branches)

- return value



solution:



Ans 6/11/25

Code:

```
def alpha_beta(node_index, depth, max_depth, alpha, beta, is_max, values, explored, pruned, path):


    # Number of leaves = 2^max_depth
    total_leaves = len(values)

    # If we reached a leaf node, return its value
    if depth == max_depth:
        leaf_index = node_index - (2 ** max_depth - 1)
        if 0 <= leaf_index < total_leaves:
            val = values[leaf_index]
            explored.append((list(path), val))
            return val
        else:
            return 0  # Safety fallback

    if is_max:
        value = float('-inf')
        for i in range(2):  # left & right children
            child_index = node_index * 2 + i + 1
            path.append(child_index)
            value = max(value, alpha_beta(child_index, depth + 1, max_depth,
                                          alpha, beta, False, values, explored, pruned, path))
            path.pop()
            alpha = max(alpha, value)
            if beta <= alpha:
                pruned.append((node_index, child_index, 'Beta cutoff'))
                break
        return value

    else:
        value = float('inf')
        for i in range(2):
            child_index = node_index * 2 + i + 1
            path.append(child_index)
            value = min(value, alpha_beta(child_index, depth + 1, max_depth,
                                          alpha, beta, True, values, explored, pruned, path))
            path.pop()
            beta = min(beta, value)
            if beta <= alpha:
                pruned.append((node_index, child_index, 'Alpha cutoff'))
                break
        return value


if __name__ == "__main__":
```

```
values = [3, 5, 6, 9, 1, 2, 0, -1]  # leaf node values
max_depth = 3                       # since 2^3 = 8 leaves
explored, pruned = [], []
print("SIRIPURAPU MANASWI : 1BM23CS331")
print("Leaf node values:", values)

result = alpha_beta(0, 0, max_depth, float('-inf'), float('inf'),
                    True, values, explored, pruned, [0])

print("\nValue of root node (MAX mode):", result)
print("\nExplored leaf paths:")
for p, val in explored:
    print(f"Path {p} -> Value {val}")

print("\nPruned branches:")
for item in pruned:
    print(item)
```

Output:

```
Leaf node values: [3, 5, 6, 9, 1, 2, 0, -1]

Value of root node (MAX mode): 5

Explored leaf paths:
Path [0, 1, 3, 7] -> Value 3
Path [0, 1, 3, 8] -> Value 5
Path [0, 1, 4, 9] -> Value 6
Path [0, 2, 5, 11] -> Value 1
Path [0, 2, 5, 12] -> Value 2

Pruned branches:
(4, 9, 'Beta cutoff')
(2, 5, 'Alpha cutoff')
```