VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

RUQAIYYA MAHREEN (1BM23CS351)

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
Aug-2025 to Dec-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 Ruqaiyya Mahreen (1BM23CS351)**,** who is a 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.

SANDHYA A KULKARNI Associate Professor Department of CSE, BMSCE	Dr. Kavitha Sooda Professor & HOD Department of CSE, BMSCE

Index

Github Link:
https://github.com/Ruqaiyya1BM23CS351/AILab

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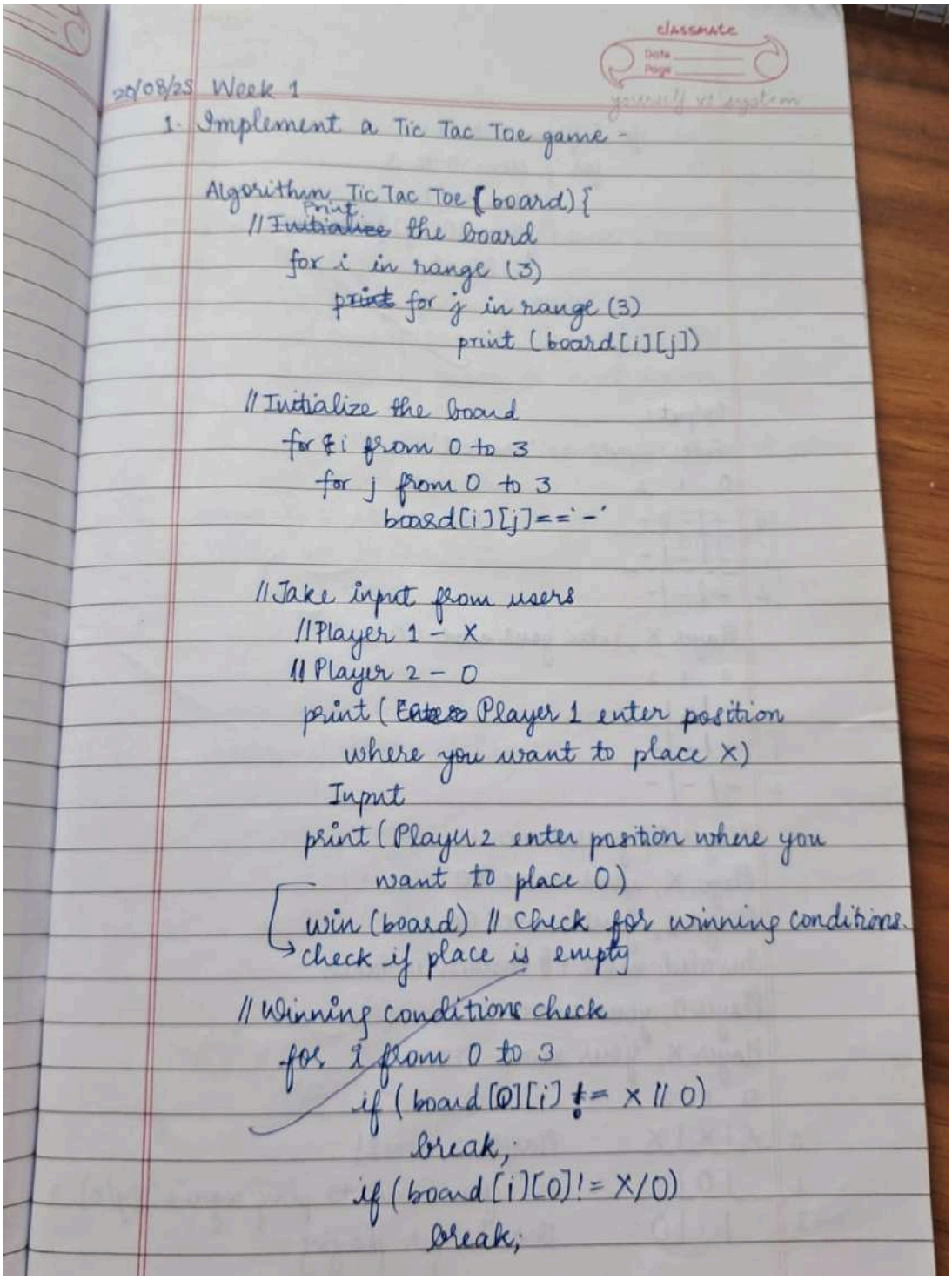
Program 1

Implement Tic –Tac –Toe Game

Implement vacuum cleaner agent

Algorithm:



20/08/25 Week 1

1. Implement a Tic Tac Toe game -

```
Algorithm Tic Tac Toe (board) {
  // Initialize the board
     for i in range (3)
        for j in range (3)
              print (board[i][j])

// Initialize the board
   for i from 0 to 3
     for j from 0 to 3
          board[i][j] == '-'

// Take input from users
   // Player 1 - X
   // Player 2 - O
   print (Player 1 enter position
      where you want to place X)
     Input
   print (Player 2 enter position where you
        want to place O)
   win (board) // Check for winning conditions.
   check if place is empty

// Winning conditions check
   for i from 0 to 3
      if (board[0][i] != X // O)
          break;
      if (board[i][0] != X/O)
          break;
```

```
for i from 0 to 3
    for j from 0 to 3
        if (i==j)
            if(board[i][j] != 'X' || 'O')
                break;
```

Output:

Enter moves as 'row col'

```
  0 1 2
0 -|-|-
1 -|-|-
2 -|-|-
```

Player X, enter your move : 0 1

```
  0 1 2
0 -|X|-
1 -|-|-
2 -|-|-
```

Player O, your move: 11

Player X, your move: 00

Player O, your move: 00

Invalid move! Position is taken

Player O, your move: 22

Player X, your move: 02

```
  0 1 2
0 X|X|X
1 -|O|-
2 -|-|O
```

Player X wins!

Do you want to play again? (y/n): n

Thanks for playing

2) Implement vacuum cleaner

Clean = 0
dirty = 1

Algorithm Vacuum Cleaner (rooms)
    for i from 0 to 3
        for j from 0 to 3
            if (rooms[i][j] == 'clean')
                move to next room
            else
                clean and move to next room

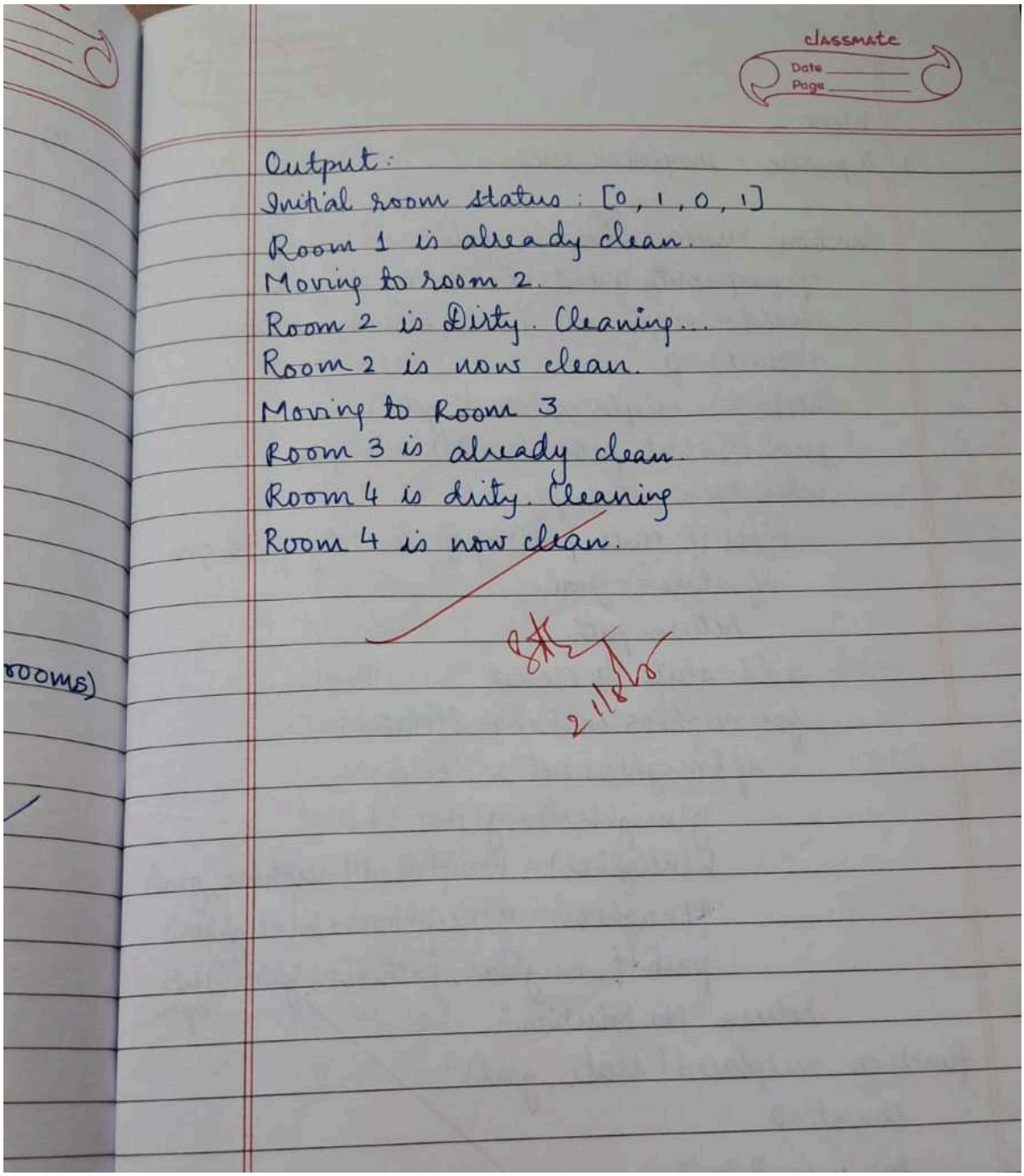
move to next room:
    j++;
    if (j == 4)
        i++;

00	01
10	11

clean and move to next room:
    rooms[i][j] == 'clean'
    j++;
    if (j == 4)
        i++;

2) Vacuum cleaner

```
Algorithm vacuumCleaner (rooms)
  // Initialize all rooms to dirty
  // clean = 0  dirty = 1
  for i from 0 to 1
      for j from 0 to 1
          rooms[i][j] = 1

  // Start cleaning
  for i from 0 to 1
      for j from 0 to 1
          if(rooms[i][j]== 1) → clean(rooms)
              rooms[i][j]=0
              j++;
              if (j==1)
                  i++;
      else
          j++;
          if(j==1)
              i++;

def clean(rooms):
    rooms[i][j]=0;
```



Code:

TIC-TAC-TOE :

Program:

```
def print_board(board):
    print("\n  0   1   2")
    for i in range(3):
        print(f"{i} {board[i][0]} | {board[i][1]} | {board[i][2]}")
```

```
        if i < 2:
            print("  -----------")
    print()

def check_winner(board):
    # Check rows
    for row in board:
        if row[0] == row[1] == row[2] != '-':
            return row[0]

    # Check columns
    for col in range(3):
        if board[0][col] == board[1][col] == board[2][col] != '-':
            return board[0][col]

    # Check diagonals
    if board[0][0] == board[1][1] == board[2][2] != '-':
        return board[0][0]
    if board[0][2] == board[1][1] == board[2][0] != '-':
        return board[0][2]

    return None

def is_board_full(board):
    for row in board:
        if '-' in row:
            return False
    return True

def is_valid_move(board, row, col):
    return 0 <= row < 3 and 0 <= col < 3 and board[row][col] == '-'

def get_player_move(player):
    while True:
        try:
            move = input(f"Player {player}, enter your move (row col): ")
            row, col = map(int, move.split())
            return row, col
        except (ValueError, IndexError):
            print("Invalid input! Please enter row and column as two numbers (0-2).")

def play_tic_tac_toe():
    # Initialize empty board
    board = [['-' for _ in range(3)] for _ in range(3)]
    current_player = 'X'

    print("Welcome to Tic-Tac-Toe!")
    print("Enter moves as 'row col' )
```

```
    print("Positions are numbered 0, 1, 2")

    # Main game loop
    while True:
        print_board(board)

        # Get player move
        row, col = get_player_move(current_player)

        # Check if move is valid
        if is_valid_move(board, row, col):
            # Make the move
            board[row][col] = current_player

            # Check for winner
            winner = check_winner(board)
            if winner:
                print_board(board)
                print(f" Player {winner} wins!")
                break

            # Check for tie
            if is_board_full(board):
                print_board(board)
                print(" It's a tie!")
                break

            # Switch players
            current_player = 'O' if current_player == 'X' else 'X'
        else:
            print("Invalid move! That position is taken or out of bounds.")

def main():
    while True:
        play_tic_tac_toe()

        # Ask to play again
        play_again = input("\nDo you want to play again? (y/n): ").lower()
        if play_again != 'y':
            print("Thanks for playing!")
            break

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

Output:

```
Welcome to Tic-Tac-Toe!
Enter moves as 'row col' (e.g., '1 2')
Positions are numbered 0, 1, 2

  0   1   2
0 -  | -  | -
  -----------
1 -  | -  | -
  -----------
2 -  | -  | -

Player X, enter your move (row col):  0 1

  0   1   2
0 -  | X  | -
  -----------
1 -  | -  | -
  -----------
2 -  | -  | -

Player O, enter your move (row col):  1 1

  0   1   2
0 -  | X  | -
  -----------
1 -  | O  | -
  -----------
2 -  | -  | -

Player X, enter your move (row col):  0 0

  0   1   2
0 X  | X  | -
  -----------
1 -  | O  | -
  -----------
2 -  | -  | -

Player O, enter your move (row col):  1 1
Invalid move! That position is taken or out of bounds.

  0   1   2
0 X  | X  | -
  -----------
1 -  | O  | -
  -----------
2 -  | -  | -

Player O, enter your move (row col):  2 2

  0   1   2
0 X  | X  | -
  -----------
1 -  | O  | -
  -----------
2 -  | -  | O

Player X, enter your move (row col):  0 2

  0   1   2
0 X  | X  | X
  -----------
1 -  | O  | -
  -----------
2 -  | -  | O

🎉 Player X wins!

Do you want to play again? (y/n):  n
Thanks for playing!
```

Vacuum cleaner

```
import random

# Function to clean a room
def clean_room(rooms, position):
    if rooms[position] == 1:
        print(f"Room {position+1} is Dirty. Cleaning...")
        rooms[position] = 0
        print(f"Room {position+1} is now Clean.")
    else:
        print(f"Room {position+1} is already Clean.")

# Function to move to the next room
def move(position, total_rooms):
    position = (position + 1) % total_rooms
    print(f"Moving to Room {position+1}")
    return position

# Function to run the vacuum cleaner
def run(rooms, steps):
    position = 0  # start at first room
    for _ in range(steps):
        clean_room(rooms, position)
        position = move(position, len(rooms))
    print("Final Room Status:", rooms)


# Initialize 4 rooms randomly (0 = clean, 1 = dirty)
rooms = [random.choice([0, 1]) for _ in range(4)]
print("Initial Room Status:", rooms)

# Run for 8 steps
run(rooms, 8)
```

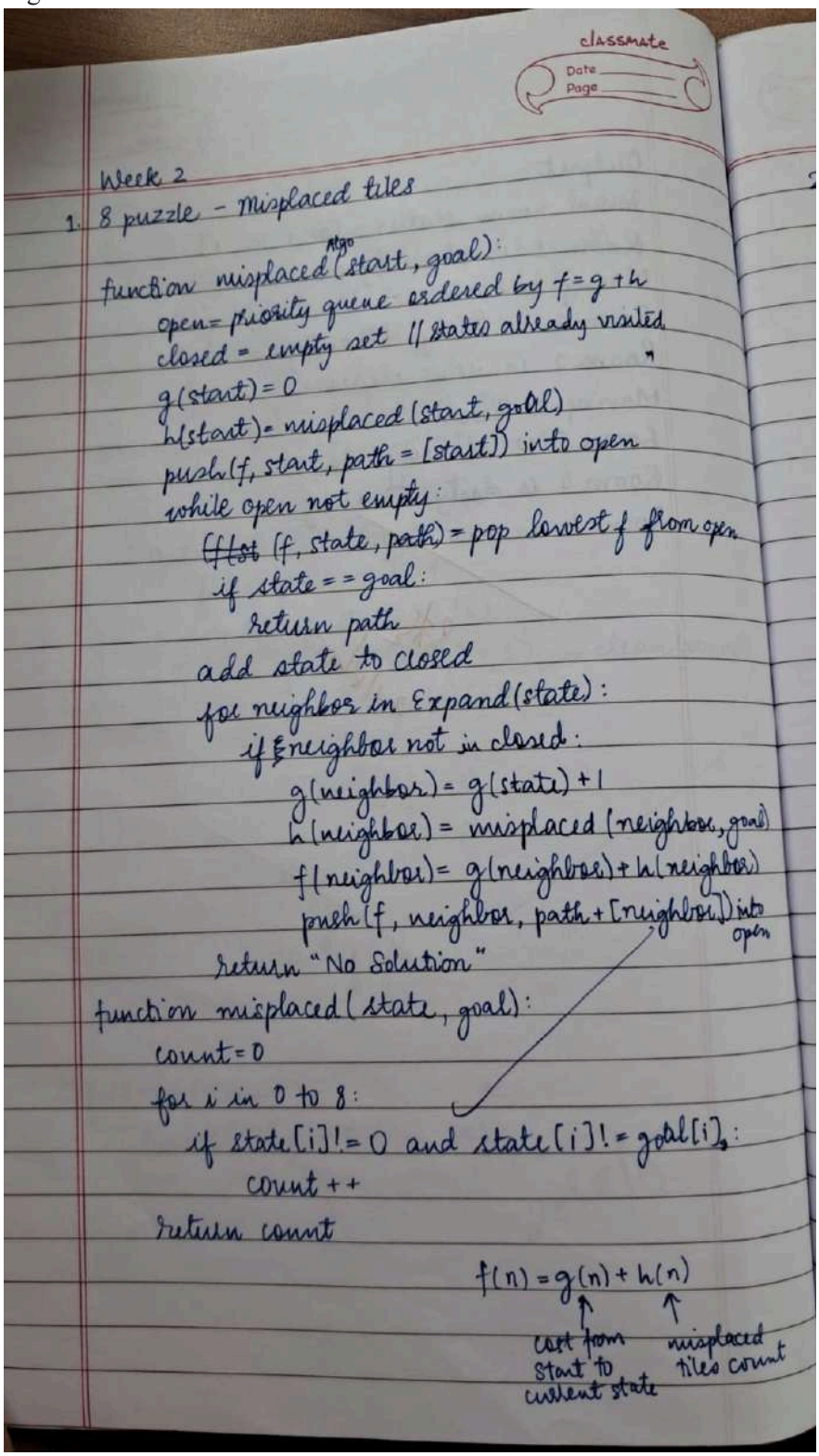
Output:

```
Initial Room Status: [0, 1, 0, 1]
Room 1 is already Clean.
Moving to Room 2
Room 2 is Dirty. Cleaning...
Room 2 is now Clean.
Moving to Room 3
Room 3 is already Clean.
Moving to Room 4
Room 4 is Dirty. Cleaning...
Room 4 is now Clean.
Moving to Room 1
Room 1 is already Clean.
Moving to Room 2
Room 2 is already Clean.
Moving to Room 3
Room 3 is already Clean.
Moving to Room 4
Room 4 is already Clean.
Moving to Room 1
Final Room Status: [0, 0, 0, 0]
```

Program 2

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

Algorithm:



2:- 8 puzzle - Manhattan

function ManhattanAlgo(start, goal):
Put start in open with $f = g + h$
$g = 0$, h = manhattan(start, goal)

~~Output:~~

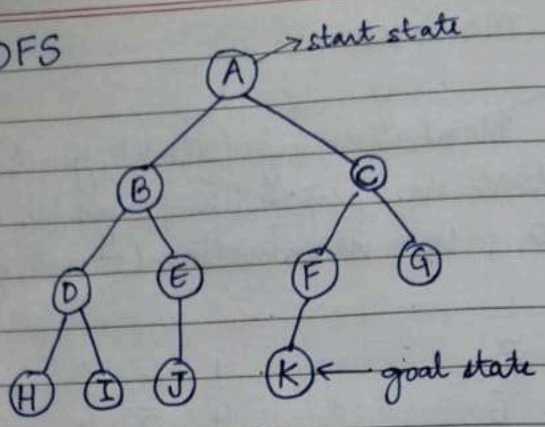
1 2 3	1 2 3	1 2 3
4 5 6	4 5 6	4 5 6
7 8 0	0 7 8	7 8 0
goal state	start state	$f = 2$

Output:
Solution found in 2 moves
(1, 2, 3)
(4, 5, 6)
(0, 7, 8)

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

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

2. IDDFS



A

A B C

A B D E C F G

A B D H I E J C F K G

IDDFS (start, goal, max_depth):
  for depth = 0 to max_depth
    visited = [ ]
    result = DFS(start, goal, depth, visited)
    if result == found
      return true
    return false

DFS(start, goal, depth, visited):
    if node == goal :
      return found
    ~~if limit == 0~~
      return

```
mark node as visited
for each neighbor of node:
    if neighbor not in visited:
        result = DFS(neighbor, goal, limit, -1, visited)
if result == found
    return found
return not found
```

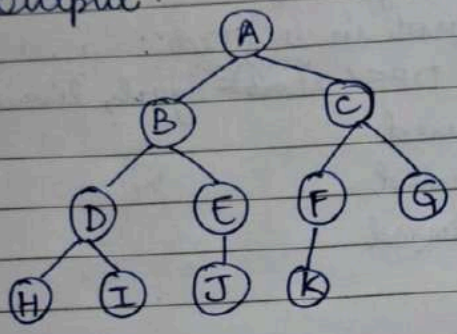
~~Output:~~

```
result = DFS(node.left, goal, limit-1)
if result == found
    return found
result = DFS(node.right, goal, limit-1)
if result == found
    return found
return not_found
```

```
maxdepth(node):
    if node is NULL:
        return 0
    left_depth = maxdepth(node.left)
    right_depth = maxdepth(node.right)
    return 1 + max(left_depth, right_depth)
```

3 8 Puzzle-Manhattan

Output :



goal K found within depth limit.

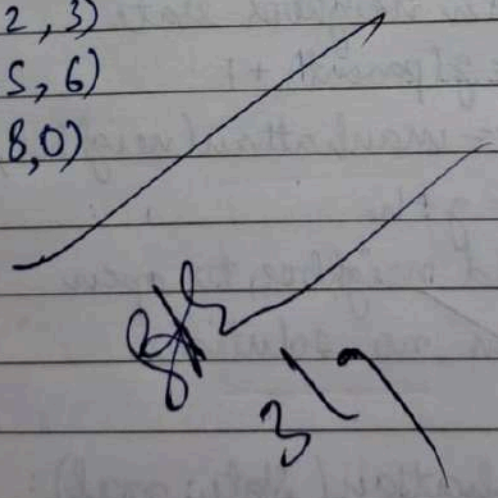
8 Puzzle - Manhattan

```
function ManhattanAlgo(start, goal)
    open = priority queue ordered by f = g + h
    g(start) = 0
    h(start) = misplaced(start, goal)
    while (open not empty)
        take state with smallest f
        if state == ~~path~~ goal
            return path
        for each neighbor state
            g = g(parent) + 1
            h = manhattan(neighbor, goal)
            f = g + h
            Add neighbor to open
    return no solution

function manhattan(state, goal):
    dist = 0
    for each tile in state:
        find position in goal
        add row_diff + col_diff to distance
    return distance.
```

Output:
Solution found in 2 moves
(1, 2, 3)
(4, 5, 6)
(0, 7, 8)

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

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



Code:
Misplaced Tiles – 8 puzzle

```
import heapq

# ---------- Heuristic: Misplaced Tiles ----------
def misplaced_tiles(state, goal):
    """Count number of misplaced tiles (ignores blank 0)."""
    return sum(1 for i in range(len(state)) if state[i] != 0 and state[i] != goal[i])

# ---------- Puzzle Neighbors ----------
def get_neighbors(state):
    neighbors = []
    idx = state.index(0) # position of blank
    x, y = divmod(idx, 3)

    moves = [(-1,0),(1,0),(0,-1),(0,1)] # up, down, left, right
    for dx, dy in moves:
        nx, ny = x + dx, y + dy
        if 0 <= nx < 3 and 0 <= ny < 3:
            new_idx = nx * 3 + ny
            new_state = list(state)
            new_state[idx], new_state[new_idx] = new_state[new_idx], new_state[idx]
            neighbors.append(tuple(new_state))
    return neighbors

# ---------- A* Search ----------
def a_star_misplaced(start, goal):
    open_list = []
    heapq.heappush(open_list, (misplaced_tiles(start, goal), 0, start, [start]))
    closed = set()

    while open_list:
        f, g, state, path = heapq.heappop(open_list)

        if state == goal:
            return path # solution found

        if state in closed:
            continue
        closed.add(state)

        for neighbor in get_neighbors(state):
            if neighbor not in closed:
                g_new = g + 1
                h_new = misplaced_tiles(neighbor, goal)
                f_new = g_new + h_new
                heapq.heappush(open_list, (f_new, g_new, neighbor, path + [neighbor]))
```

```
    return None # no solution found

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

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

    solution = a_star_misplaced(start, goal)

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

Output:

```
Solution found in 2 moves.
(1, 2, 3)
(4, 5, 6)
(0, 7, 8)
-----
(1, 2, 3)
(4, 5, 6)
(7, 0, 8)
-----
(1, 2, 3)
(4, 5, 6)
(7, 8, 0)
-----
```

Manhattan distance – 8 puzzle

```
import heapq
```

```
# ---------- Heuristic: Manhattan Distance ----------
def manhattan_distance(state, goal):
    """Sum of Manhattan distances of each tile from its goal position."""
    distance = 0
    for i, tile in enumerate(state):
        if tile != 0: # skip the blank
            goal_pos = goal.index(tile)
            distance += abs(i // 3 - goal_pos // 3) + abs(i % 3 - goal_pos % 3)
    return distance

# ---------- Puzzle Neighbors ----------
def get_neighbors(state):
    neighbors = []
    idx = state.index(0) # blank position
    x, y = divmod(idx, 3)

    moves = [(-1,0),(1,0),(0,-1),(0,1)] # up, down, left, right
    for dx, dy in moves:
        nx, ny = x + dx, y + dy
        if 0 <= nx < 3 and 0 <= ny < 3:
            new_idx = nx * 3 + ny
            new_state = list(state)
            new_state[idx], new_state[new_idx] = new_state[new_idx], new_state[idx]
            neighbors.append(tuple(new_state))
    return neighbors

# ---------- A* Search ----------
def a_star_manhattan(start, goal):
    open_list = []
    heapq.heappush(open_list, (manhattan_distance(start, goal), 0, start, [start]))
    closed = set()

    while open_list:
        f, g, state, path = heapq.heappop(open_list)

        if state == goal:
            return path # solution found

        if state in closed:
            continue
        closed.add(state)

        for neighbor in get_neighbors(state):
            if neighbor not in closed:
                g_new = g + 1
                h_new = manhattan_distance(neighbor, goal)
                f_new = g_new + h_new
                heapq.heappush(open_list, (f_new, g_new, neighbor, path + [neighbor]))
```

```
    return None # no solution found

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

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

    solution = a_star_manhattan(start, goal)

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

Output:

```
Solution found in 2 moves.
(1, 2, 3)
(4, 5, 6)
(0, 7, 8)
-----
(1, 2, 3)
(4, 5, 6)
(7, 0, 8)
-----
(1, 2, 3)
(4, 5, 6)
(7, 8, 0)
-----
```

Iterative Deepening Depth First Search

```
# ---------- Depth Limited Search ----------
def DLS(graph, node, goal, limit, visited):
    if node == goal:
```

```
        return True
    if limit == 0:
        return False

    visited.add(node)
    for neighbor in graph.get(node, []):
        if neighbor not in visited:
            if DLS(graph, neighbor, goal, limit - 1, visited):
                return True
    return False

# ---------- IDDFS ----------
def IDDFS(graph, start, goal, max_depth):
    for depth in range(max_depth + 1):
        visited = set()
        if DLS(graph, start, goal, depth, visited):
            return True
    return False

# ---------- Example Run ----------
if __name__ == "__main__":
    graph = {
        'A': ['B', 'C'],
        'B': ['D', 'E'],
        'C': ['F'],
        'D': [],
        'E': ['F'],
        'F': []
    }

    start = 'A'
    goal = 'F'

    if IDDFS(graph, start, goal, max_depth=3):
        print(f"Goal {goal} found within depth limit.")
    else:
        print(f"Goal {goal} not found within depth limit.")
```

Output:

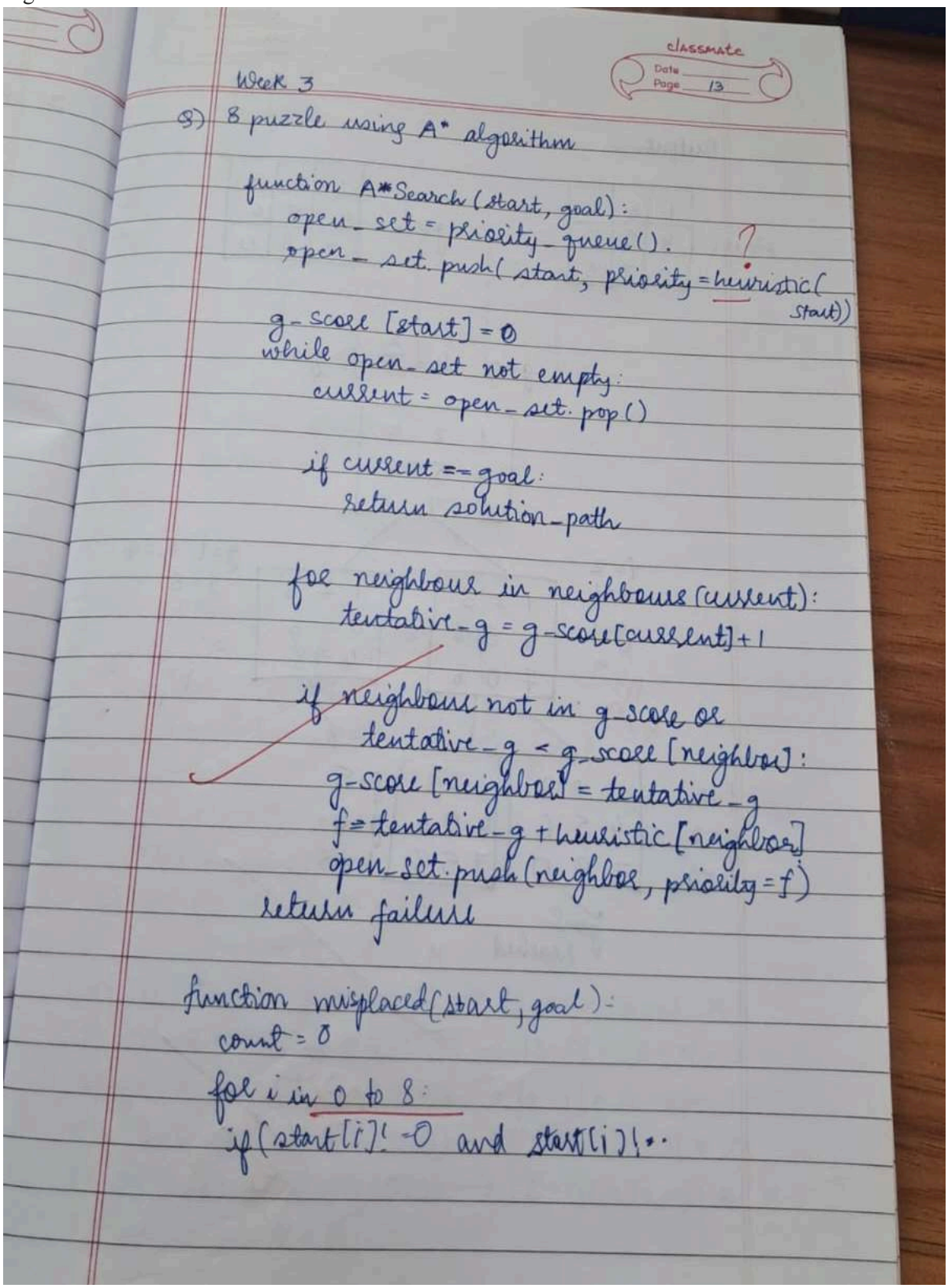
```python
if __name__ == "__main__":
    graph = {
        'A': ['B', 'C'],
        'B': ['D', 'E'],
        'C': ['F'],
        'D': [],
        'E': ['F'],
        'F': []
    }

    start = 'A'
    goal = 'F'

    if IDDFS(graph, start, goal, max_depth=3):
        print(f"Goal {goal} found within depth limit.")
    else:
        print(f"Goal {goal} not found within depth limit.")
```

```
Goal F found within depth limit.
```

Program 3

Implement A* search algorithm

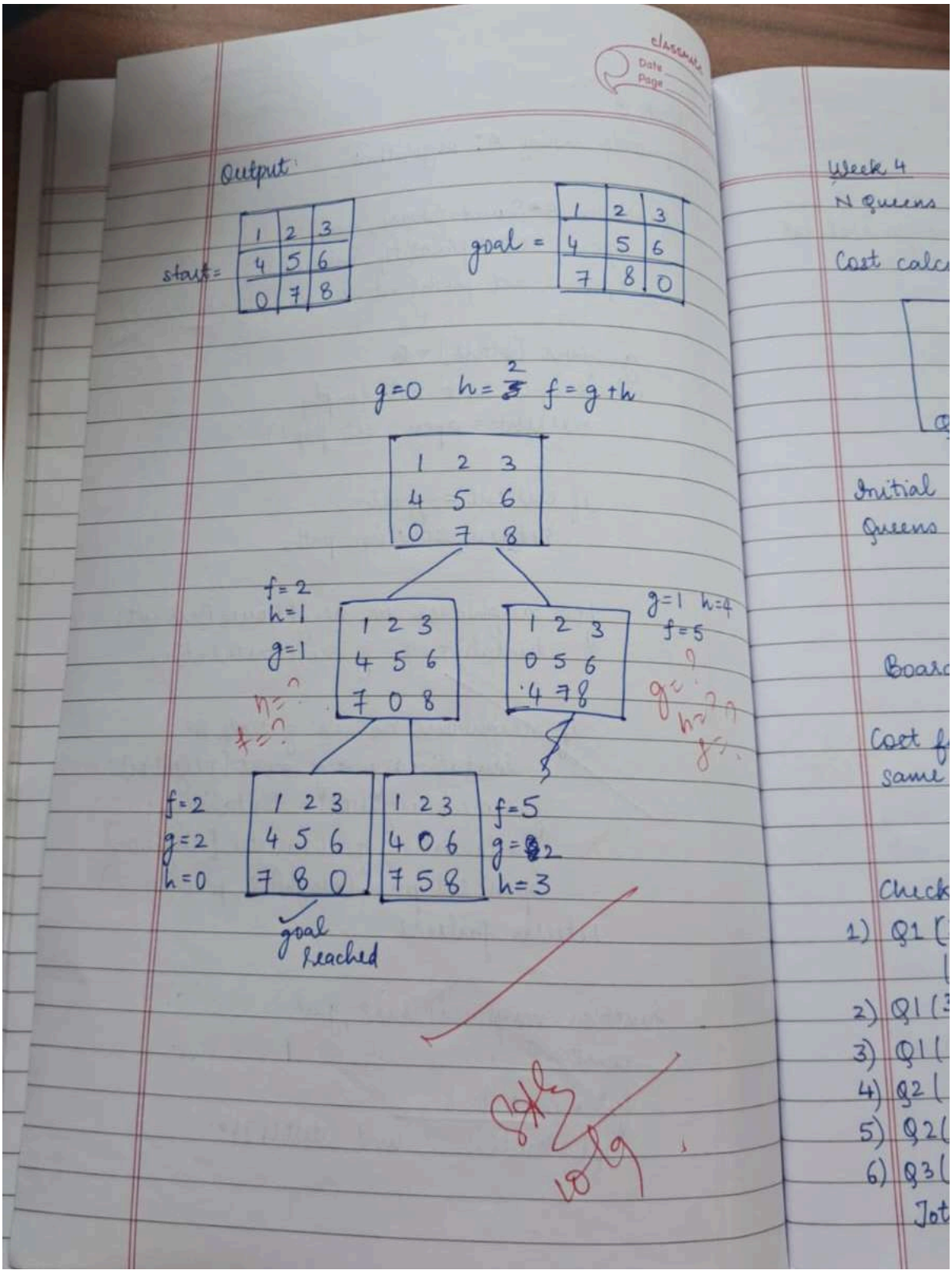
Algorithm:



Week 3

8) 8 puzzle using A* algorithm

```
function A*Search (start, goal):
    open_set = priority_queue().
    open_set.push(start, priority = heuristic(start))
    g_score [start] = 0
    while open_set not empty:
        current = open_set.pop()

        if current == goal:
            return solution_path

        for neighbour in neighbours(current):
            tentative_g = g_score[current] + 1

            if neighbour not in g_score or
                tentative_g < g_score [neighbor]:
                g_score [neighbor] = tentative_g
                f = tentative_g + heuristic [neighbor]
                open_set.push(neighbor, priority = f)
        return failure

function misplaced(start, goal):
    count = 0
    for i in 0 to 8:
        if(start[i] != 0 and start[i] !=
```


Output
start =
1 2 3
4 5 6
0 7 8
goal =
1 2 3
4 5 6
7 8 0
g=0 h=2 f=g+h
1 2 3
4 5 6
0 7 8
f=2
h=1
g=1
1 2 3
4 5 6
7 0 8
g=1 h=4
f=5
1 2 3
0 5 6
4 7 8
f=2
g=2
h=0
1 2 3
4 5 6
7 8 0
goal reached
1 2 3
4 0 6
7 5 8
f=5
h=3

Code:

```
import heapq

# Goal state for the 8 puzzle
goal_state = [[1, 2, 3],
              [4, 5, 6],
              [7, 8, 0]]  # 0 is the blank space

# Directions: up, down, left, right
moves = [(1, 0), (-1, 0), (0, 1), (0, -1)]


def manhattan_distance(state):
    """Calculate Manhattan distance heuristic for a given state."""
    distance = 0
    for i in range(3):
        for j in range(3):
            value = state[i][j]
            if value != 0:
                target_x = (value - 1) // 3
                target_y = (value - 1) % 3
                distance += abs(i - target_x) + abs(j - target_y)
    return distance


def find_blank(state):
    """Find the position of blank (0) in the puzzle."""
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j


def state_to_tuple(state):
    """Convert list state to tuple (for hashing in sets)."""
    return tuple(tuple(row) for row in state)


def a_star(start_state):
    """A* algorithm to solve 8-puzzle."""
    start_h = manhattan_distance(start_state)
    pq = [(start_h, 0, start_state, [])]  # (f, g, state, path)
    visited = set()

    while pq:
        f, g, state, path = heapq.heappop(pq)
```

```
        if state == goal_state:
            return path + [state]

        visited.add(state_to_tuple(state))
        x, y = find_blank(state)

        for dx, dy in moves:
            new_x, new_y = x + dx, y + dy
            if 0 <= new_x < 3 and 0 <= new_y < 3:
                new_state = [row[:] for row in state]  # deep copy
                # Swap blank with neighbor
                new_state[x][y], new_state[new_x][new_y] =
new_state[new_x][new_y], new_state[x][y]

                if state_to_tuple(new_state) not in visited:
                    h = manhattan_distance(new_state)
                    heapq.heappush(pq, (g + 1 + h, g + 1, new_state, path +
[state]))

    return None  # No solution found


# Example usage:
start_state = [[1, 2, 3],
               [4, 5, 6],
               [0, 7, 8]]

solution = a_star(start_state)

print("Steps to reach the goal:")
for step in solution:
    for row in step:
        print(row)
    print()
```

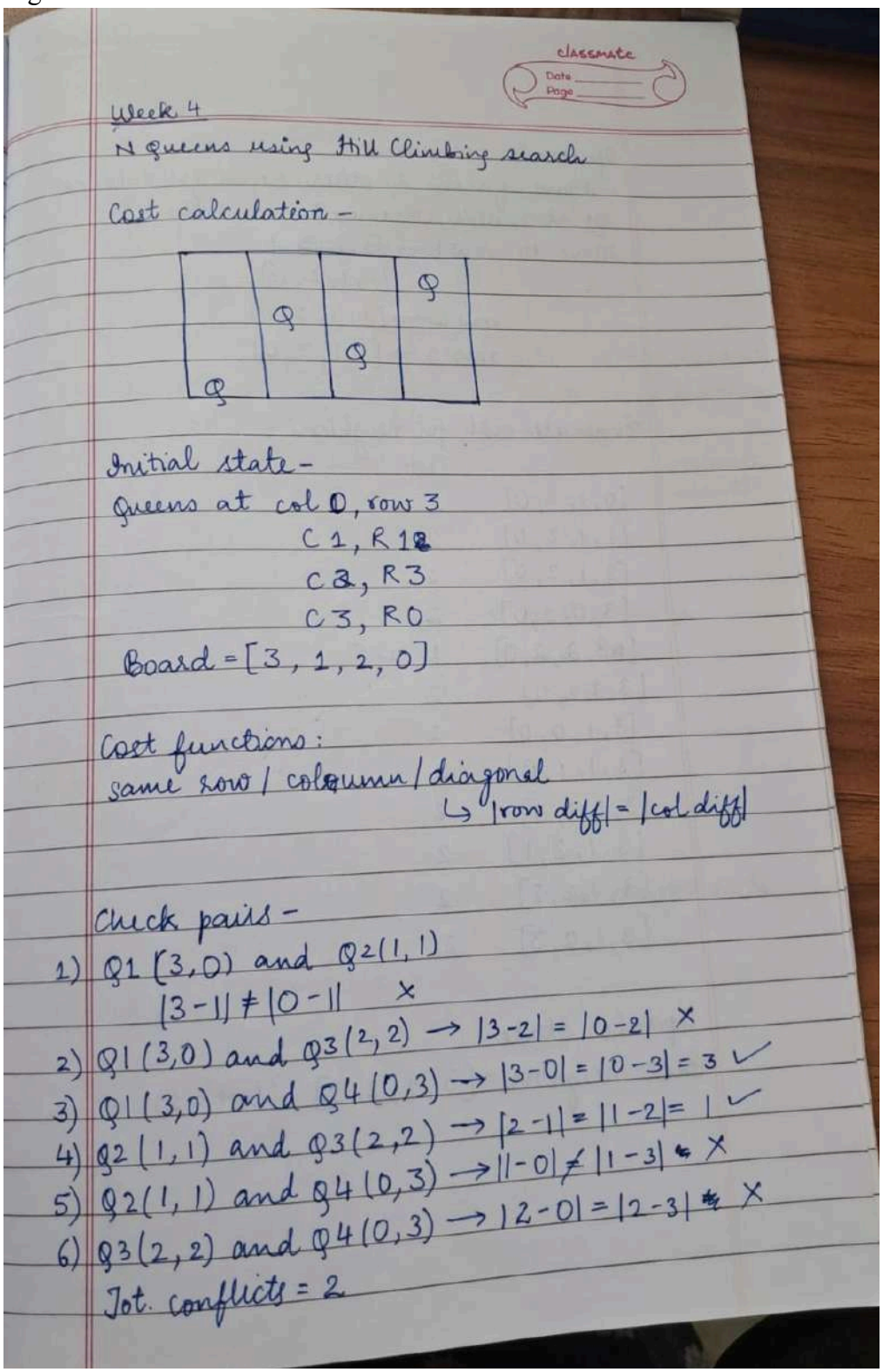
Output:

```
Steps to reach the goal:
[1, 2, 3]
[4, 5, 6]
[0, 7, 8]

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

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

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:



Generate neighbors

Move queen to other rows for each col

Q1 at row 4, column 1

Move to row 1 → ~~[1, 2, 3, 1~~

[0, 1, 2, 0]

row 2 → [1, 1, 2, 0]

row 3 → [2, 1, 2, 0]

Evaluate cost for neighbors -

	Cost
[0, 1, 2, 0]	2
[1, 1, 2, 0]	2
[2, 1, 2, 0]	2
[3, 0, 2, 0]	2
[3, 2, 2, 0]	1 ✓
[3, 3, 2, 0]	2
[3, 1, 0, 0]	2
[3, 1, 1, 0]	2
[3, 1, 3, 0]	2
[3, 1, 2, 1]	2
[3, 1, 2, 2]	2
[3, 1, 2, 3]	2

Update State

Best neighbor = [3, 2, 2, 0] (Cost = 1)

Algorithm –

```
def random_restart (N, max):
    for i in 1 to max:
        current ← random_board (n)
    while true:
        neighbours ← generate_neighbors(current)
        best_neighbor ← neighbor in neighbors
            with min_conflicts(neighbors)
        if evaluate(best_neighbor) >= evaluate
                                    (current):
            break
        else:
            current ← best_neighbor
    if evaluate(current) == 0:
        return current
    return failure
```

Output:

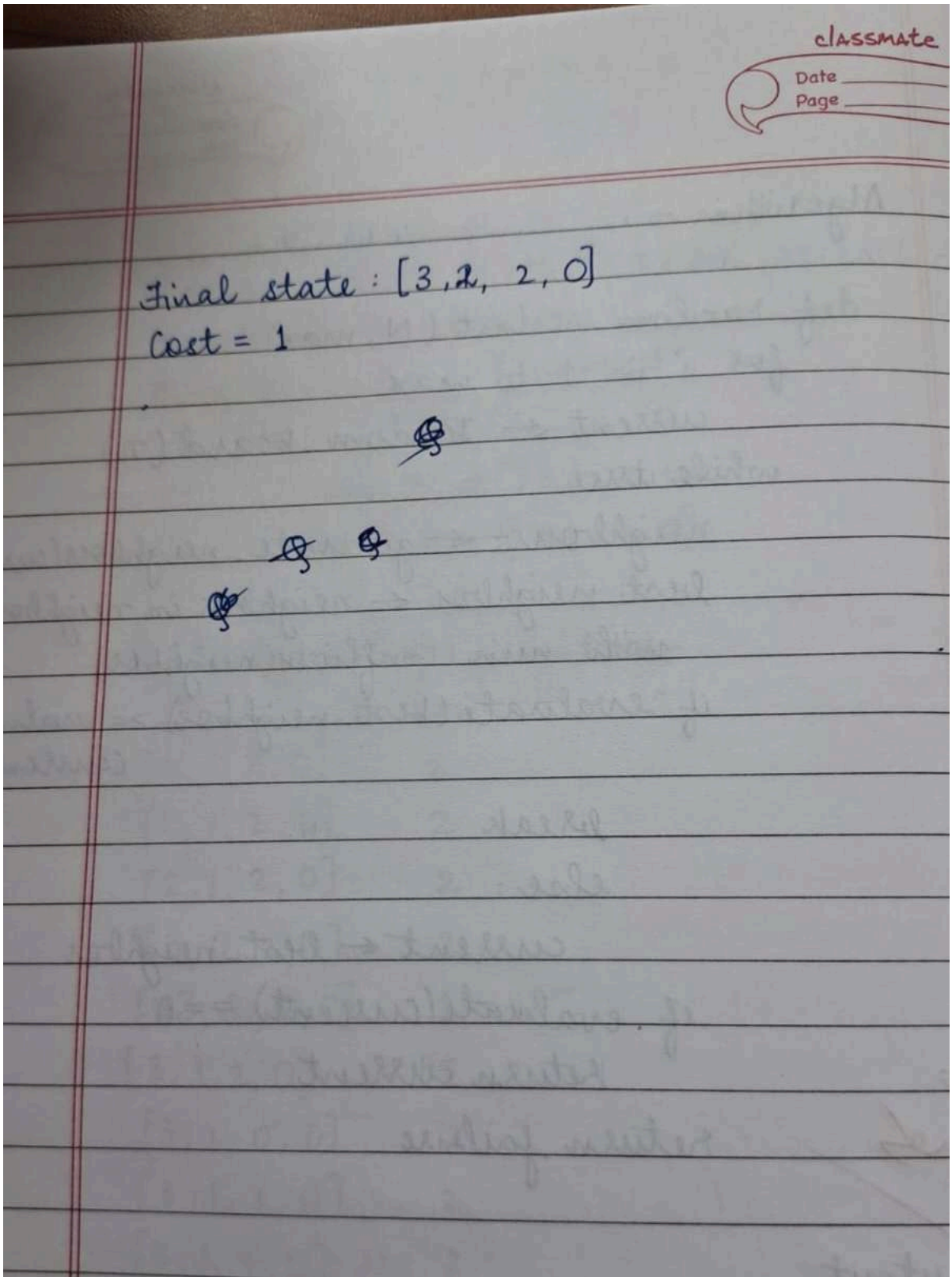
Enter number of queens: 4

Enter initial state as row positions for each column.

For N = 4

Initial state: 3 1 2 0

Cost = 2



Code:
import random

```
# Heuristic: number of pairs of queens attacking each other
def calculate_cost(state):
    cost = 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):
                    cost += 1
    return cost


# Generate all neighbors of the current state
def get_neighbors(state):
    neighbors = []
        n = len(state)
    for col in range(n):
        for row in range(n):
            if state[col] != row: # move queen in col to new row
                    neighbor = state.copy()
                    neighbor[col] = row
                    neighbors.append(neighbor)
    return neighbors


# Hill climbing algorithm
def hill_climb(initial_state):
    current = initial_state
    current_cost = calculate_cost(current)

    print(f"Initial state: {current}, Cost = {current_cost}")

    while True:
        neighbors = get_neighbors(current)
        best_neighbor = None
        best_cost = current_cost

        # Find the best neighbor
        for neighbor in neighbors:
            cost = calculate_cost(neighbor)
            if cost < best_cost:
                    best_cost = cost
                    best_neighbor = neighbor

        # If no better neighbor is found → stop
        if best_neighbor is None:
            print(f"Final state: {current}, Cost = {current_cost}")
            return current, current_cost
```

```
        # Move to the better neighbor
        current, current_cost = best_neighbor, best_cost
        print(f"Move to: {current}, Cost = {current_cost}")


# Example usage
if __name__ == "__main__":
            n = int(input("Enter number of queens (N): "))
    print("Enter initial state as space-separated row positions for each column.")
    print("Example for N=4: '1 3 0 2' means queen at (0,1), (1,3), (2,0), (3,2).")

    initial_state = list(map(int, input("Initial state: ").split()))

    if len(initial_state) != n:
        print("Invalid input: Length of initial state must be N.")
    else:
        solution, cost = hill_climb(initial_state)

        if cost == 0:
            print("Goal state reached!")
        else:
            print("Stuck in local minimum.")
```

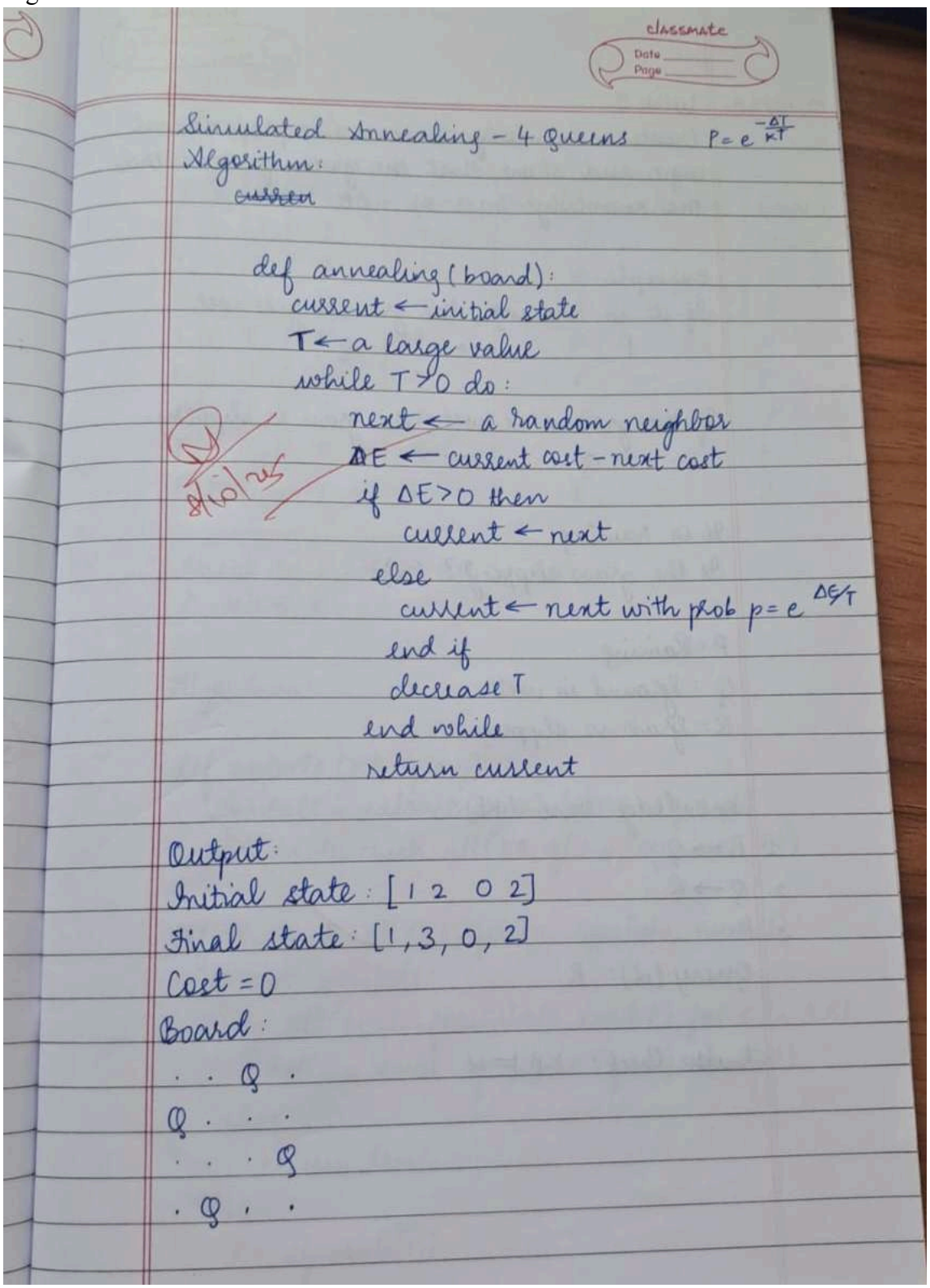
Output:

```
Enter number of queens (N):  4
Enter initial state as space-separated row positions for each column.
Example for N=4: '1 3 0 2' means queen at (0,1), (1,3), (2,0), (3,2).
Initial state:  3 1 2 0
Initial state: [3, 1, 2, 0], Cost = 2
Final state: [3, 1, 2, 0], Cost = 2
```

Program 5

Simulated Annealing to Solve 8-Queens problem

Algorithm:



Simulated Annealing - 4 Queens $P = e^{\frac{-\Delta T}{KT}}$

Algorithm:

```
def annealing(board):
    current ← initial state
    T ← a large value
    while T > 0 do:
        next ← a random neighbor
        ΔE ← current cost - next cost
        if ΔE > 0 then
            current ← next
        else
            current ← next with prob p = e^(ΔE/T)
        end if
        decrease T
    end while
    return current
```

Output:

Initial state: [1 2 0 2]

Final state: [1, 3, 0, 2]

Cost = 0

Board:

. . Q .

Q . . .

. . . Q

. Q . .

Code:

```
import random
import math

def cost(state, N):
    """Compute number of attacking queen pairs."""
    conflicts = 0
    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):
                    conflicts += 1
    return conflicts

def random_neighbor(state, N):
    """Generate a neighbor by moving one queen to another row in a random column."""
    neighbor = state.copy()
    col = random.randrange(N)
    new_row = random.randrange(N-1)
    if new_row >= neighbor[col]:
        new_row += 1
    neighbor[col] = new_row
    return neighbor

def simulated_annealing(N, T0=5.0, alpha=0.995, Tmin=1e-6, max_iters=50000):
    """Solve N-Queens using simulated annealing."""
            # Random initial state: one queen per column
    state = [random.randrange(N) for _ in range(N)]
    current_cost = cost(state, N)
            T = T0
    it = 0

    while T > Tmin and it < max_iters and current_cost != 0:
        neighbor = random_neighbor(state, N)
        neighbor_cost = cost(neighbor, N)
        delta = neighbor_cost - current_cost

        if delta <= 0 or random.random() < math.exp(-delta / T):
            state, current_cost = neighbor, neighbor_cost

        T *= alpha
        it += 1

    return state, current_cost

def print_board(state, N):
    """Pretty-print the board with row and column numbers."""
    print("   " + " ".join(str(c) for c in range(N)))   # column indices
```

```
    for r in range(N):
        row = f"{r} "  # row index
        for c in range(N):
            row += "Q " if state[c] == r else ". "
        print(row)
    print()

# --------------------------
# User input
# --------------------------
N = int(input("Enter number of queens (N): "))

solution, c = simulated_annealing(N)

print(f"\nFinal state (col -> row): {solution}")
print("Cost:", c)
print("\nBoard:")
print_board(solution, N)
```

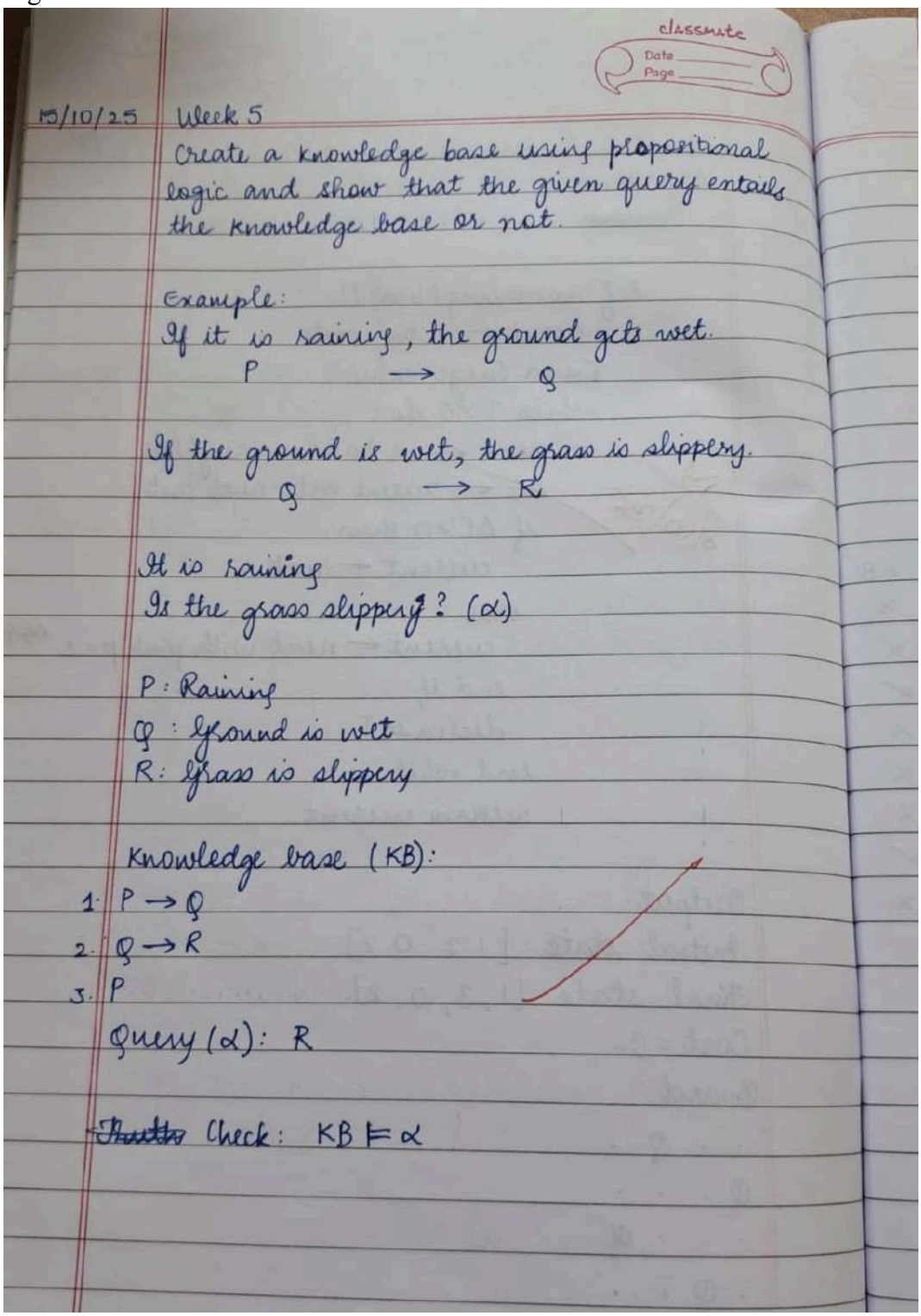
Output:

```
Enter number of queens (N):  5

Final state (col -> row): [4, 1, 3, 0, 2]
Cost: 0

Board:
   0 1 2 3 4
0 . . . Q .
1 . Q . . .
2 . . . . Q
3 . . Q . .
4 Q . . . .
```

Program 6

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

Algorithm:



Truth table enumeration -

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

Check row where KB is true.
∴ KB ⊨ R

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):
    if not symbols:
        if all(eval_formula(s, model) for s in KB):
            return eval_formula (query, model)
        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}))

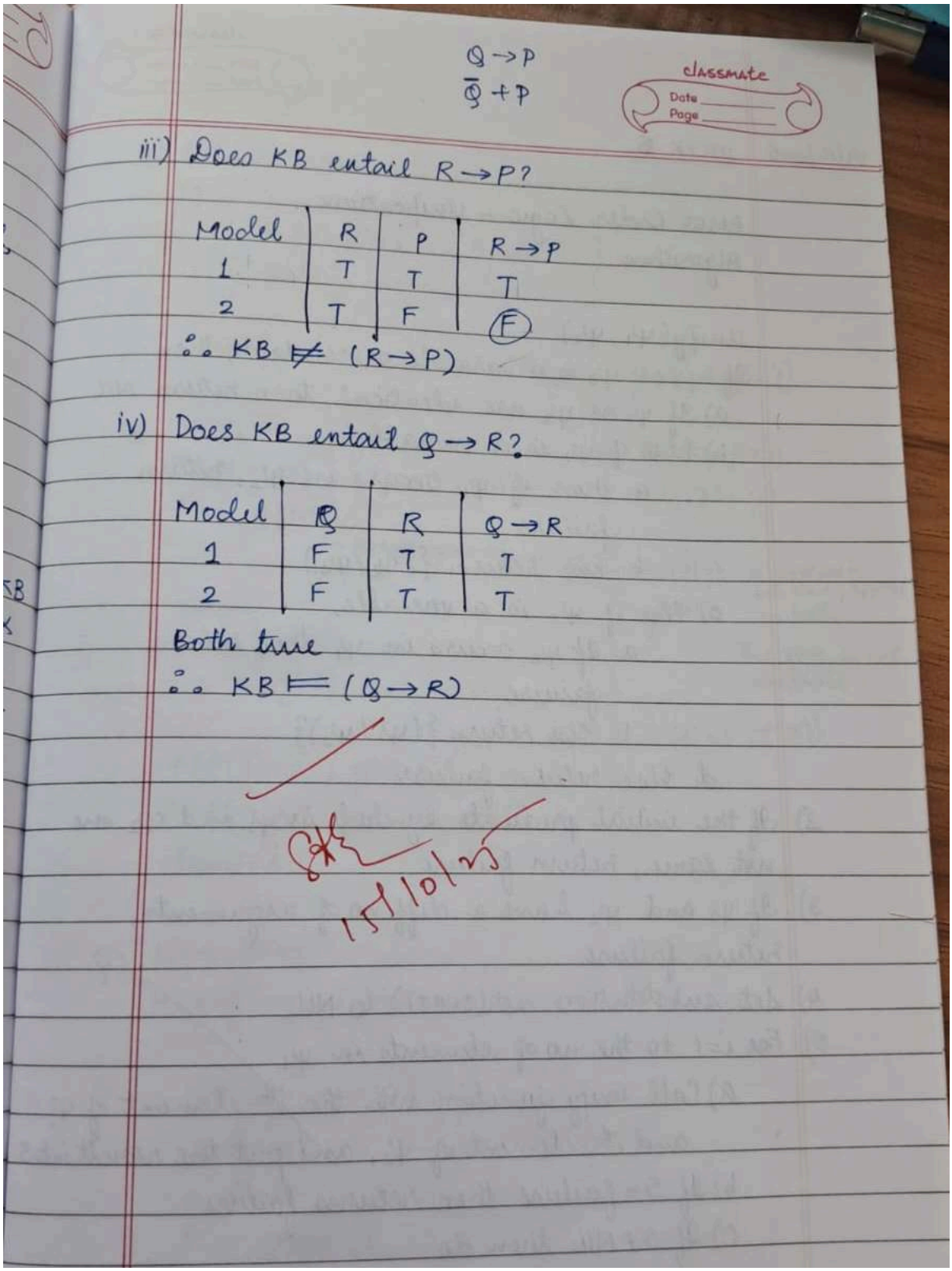
q) KB:
$Q \rightarrow P$
$P \rightarrow \neg Q$
$Q \vee R$

i)

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

KB is true in models:
(P=T, Q=F, R=T)
(P=F, Q=F, R=T)

ii) Does KB entail R?
R = True in both models
∴ KB ⊨ R



Code:
from itertools import product

```
# Define propositional logic operations
def implies(a, b):
        return (not a) or b

# Knowledge Base sentences
def KB(P, Q, R):
        s1 = implies(Q, P) # Q → P
        s2 = implies(P, not Q) # P → ¬Q
        s3 = Q or R # Q ∨ R
        return s1 and s2 and s3 # KB is true only if all hold

# All combinations of truth values for P, Q, R
values = list(product([False, True], repeat=3))

print("P\tQ\tR\tQ→P\tP→¬Q\tQ∨R\tKB")
print("-"*50)

models = []
for P, Q, R in values:
        s1 = implies(Q, P)
        s2 = implies(P, not Q)
        s3 = Q or R
        kb_val = s1 and s2 and s3
   print(f"{P}\t{Q}\t{R}\t{s1}\t{s2}\t{s3}\t{kb_val}")
        if kb_val:
      models.append((P, Q, R))

print("\n Models where KB is True:", models)

# Check entailments
entails_R = all(R for P, Q, R in models)
entails_R_imp_P = all((not R) or P for P, Q, R in models)
entails_Q_imp_R = all((not Q) or R for P, Q, R in models)

print("\nEntailments:")
print("KB ⊨ R :", entails_R)
print("KB ⊨ R → P :", entails_R_imp_P)
print("KB ⊨ Q → R :", entails_Q_imp_R)
```

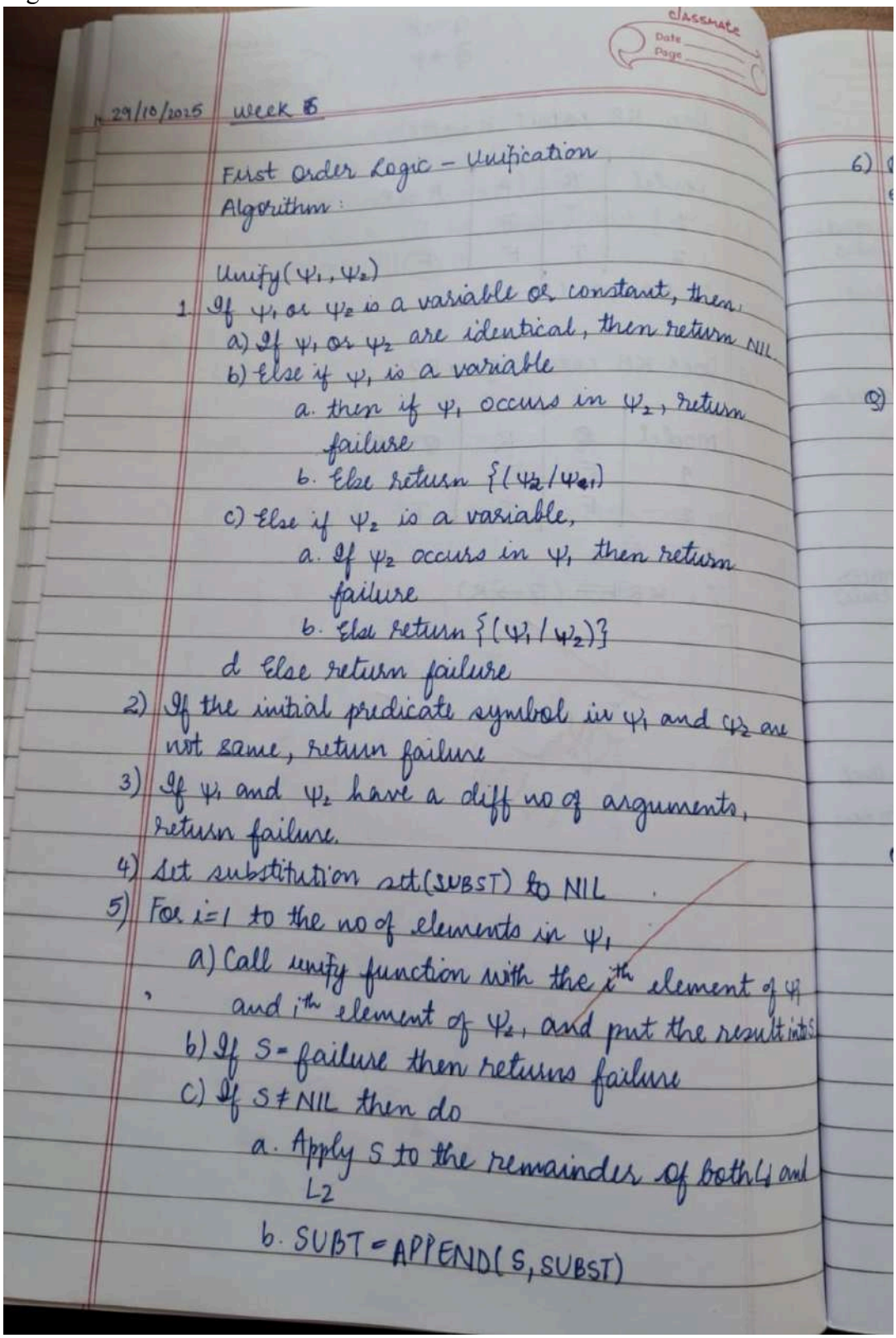
Output:

```
P       Q       R       Q→P     P→¬Q    Q∨R     KB
-----------------------------------------------------
False   False   False   True    True    False   False
False   False   True    True    True    True    True
False   True    False   False   True    True    False
False   True    True    False   True    True    False
True    False   False   True    True    False   False
True    False   True    True    True    True    True
True    True    False   True    False   True    False
True    True    True    True    False   True    False

 Models where KB is True: [(False, False, True), (True, False, True)]

Entailments:
KB ⊨ R : True
KB ⊨ R → P : False
KB ⊨ Q → R : True
```

Program 7

Implement unification in first order logic.

Algorithm:



29/10/2025 Week 5

First Order Logic – Unification

Algorithm:

Unify(ψ_1, ψ_2)

1. If ψ_1 or ψ_2 is a variable or constant, then:
   a) If ψ_1 or ψ_2 are identical, then return NIL.
   b) Else if ψ_1 is a variable
      a. then if ψ_1 occurs in ψ_2, 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 $\{(\psi_1/\psi_2)\}$
   d Else return failure
2) If the initial predicate symbol in ψ_1 and ψ_2 are not same, return failure
3) If ψ_1 and ψ_2 have a diff no of arguments, return failure.
4) Set substitution set(SUBST) to NIL
5) For i=1 to the no of elements in ψ_1
   a) Call unify function with the i^{th} element of ψ_1 and i^{th} element of ψ_2, and put the result into S
   b) If S = failure then returns failure
   c) If S ≠ NIL then do
      a. Apply S to the remainder of both L_1 and L_2
      b. SUBT = APPEND(S, SUBST)

Code:

```
def unify(x, y, substitutions=None):
    if substitutions is None:
        substitutions = {}

    # If both are identical
    if x == y:
        return substitutions

    # If x is a variable
    if isinstance(x, str) and x.islower():
        return unify_var(x, y, substitutions)

    # If y is a variable
    if isinstance(y, str) and y.islower():
        return unify_var(y, x, substitutions)

    # If both are compound expressions (like lists or tuples)
    if isinstance(x, tuple) and isinstance(y, tuple):
        if x[0] != y[0] or len(x) != len(y):
            return None
        for a, b in zip(x[1:], y[1:]):
            substitutions = unify(a, b, substitutions)
            if substitutions is None:
                return None
        return substitutions

    return None


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


def occurs_check(var, x, substitutions):
    if var == x:
        return True
    elif isinstance(x, tuple):
        return any(occurs_check(var, arg, substitutions) for arg in x[1:])
```

```
    elif isinstance(x, str) and x in substitutions:
        return occurs_check(var, substitutions[x], substitutions)
    return False


# Example
expr1 = ("Eats", "x", "Apple")
expr2 = ("Eats", "Riya", "y")

result = unify(expr1, expr2)
print("Unification:", result)
```

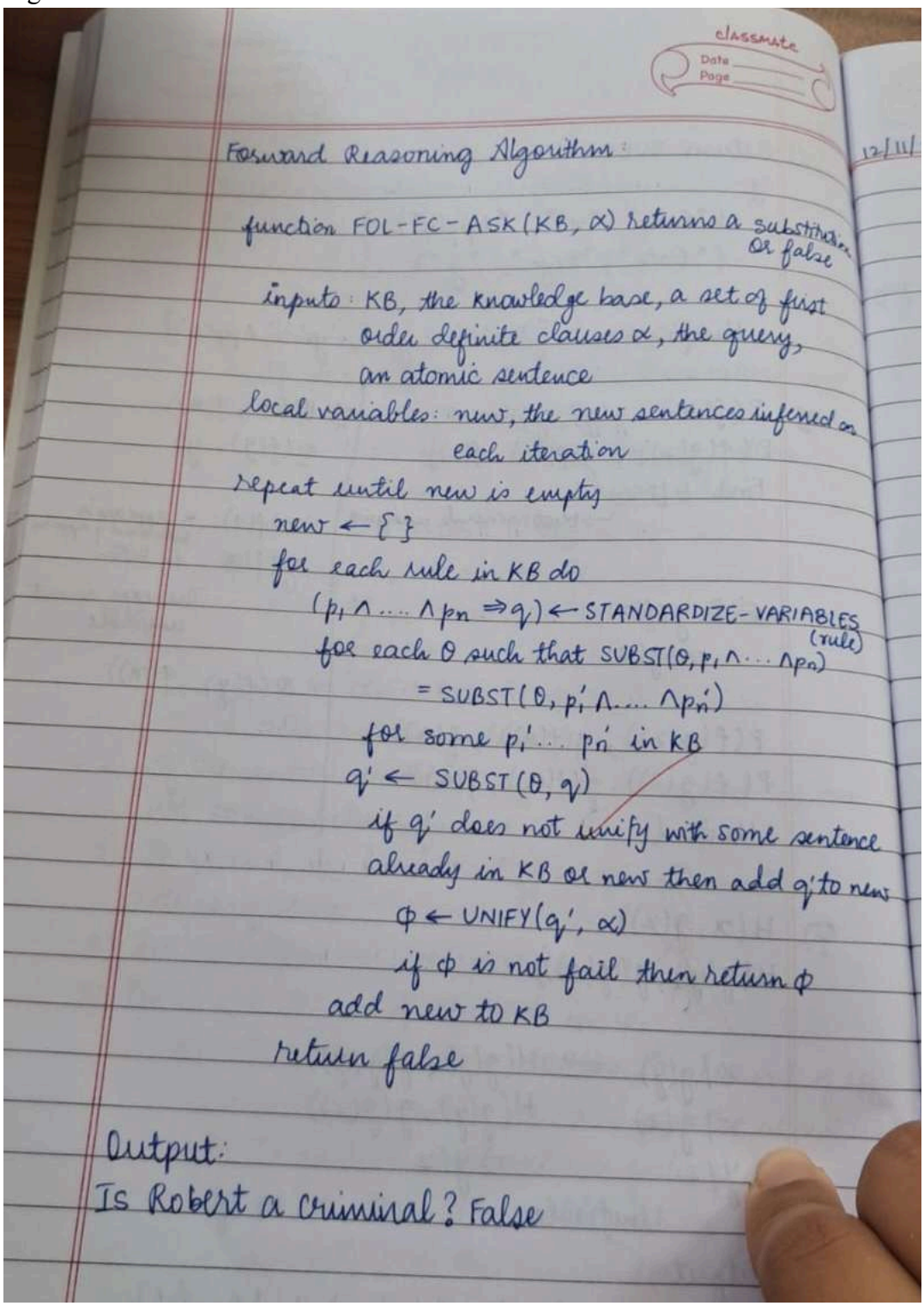
Output:

```
Unification: {'x': 'Riya', 'y': 'Apple'}
```

Program 8

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

Algorithm:



Code:

```
def forward_chaining(KB, query):
    inferred = set()
    new_inferred = True

    while new_inferred:
        new_inferred = False
        for rule in KB:
            premises, conclusion = rule
            if all(p in inferred or p in KB for p in premises) and conclusion not in inferred:
                inferred.add(conclusion)
                new_inferred = True
                if conclusion == query:
                    return True
    return False

# Example Knowledge Base
KB = [
    (["American(Robert)", "Weapon(x)", "Sells(Robert, x, A)", "Hostile(A)"],
"Criminal(Robert)"),
    (["Missile(x)"], "Weapon(x)"),
    (["Owns(A, x)", "Missile(x)"], "Sells(Robert, x, A)"),
    (["Enemy(A, America)"], "Hostile(A)")
]

facts = {
    "American(Robert)",
    "Enemy(A, America)",
    "Owns(A, T1)",
    "Missile(T1)"
}
# Add base facts to KB
for fact in facts:
    KB.append(([], fact))
# Query
query = "Criminal(Robert)"
print("Is Robert a criminal?", forward_chaining(KB, query))
```

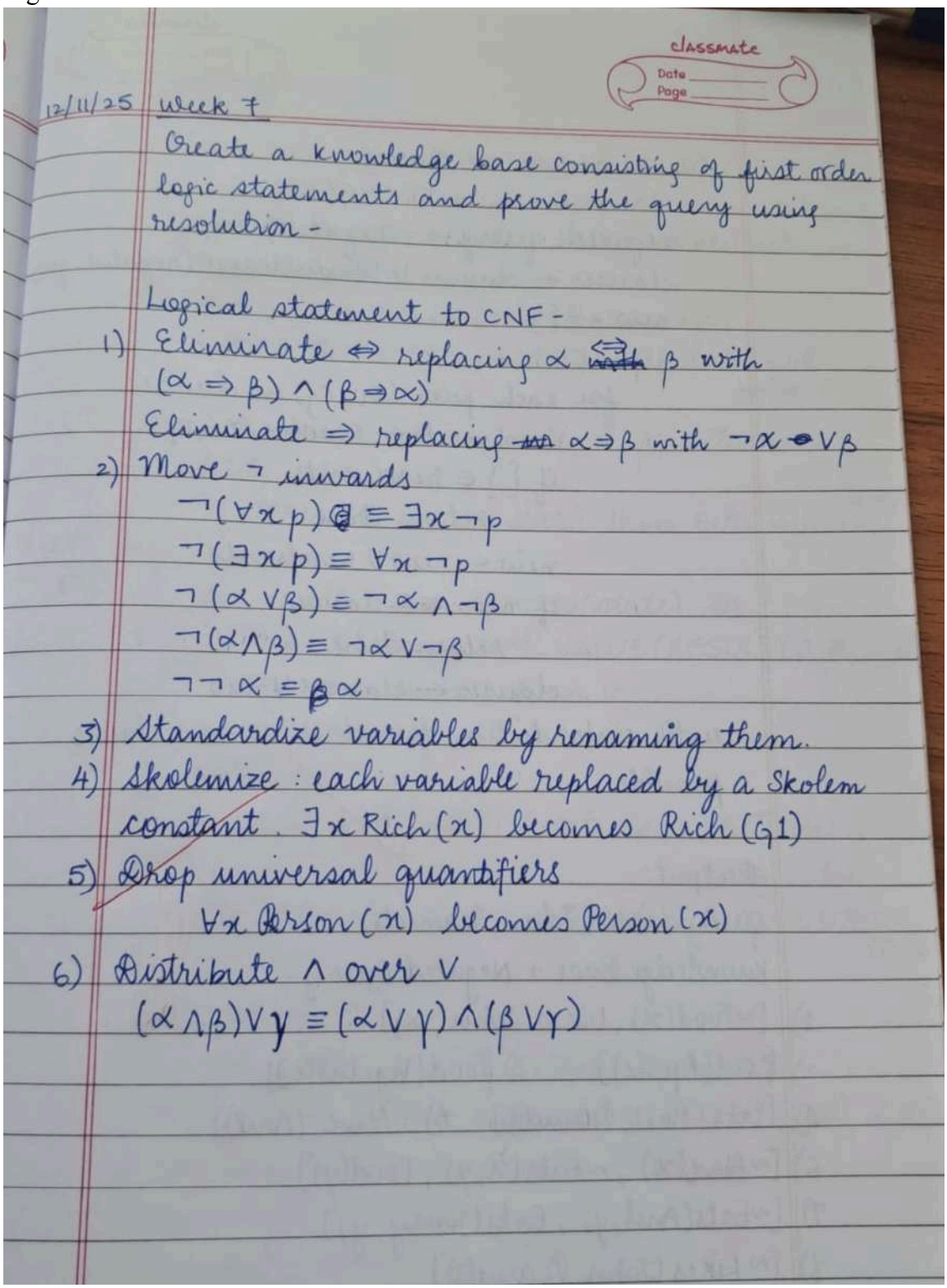
Output:

```
Is Robert a criminal? False
```

Program 9

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

Algorithm:



12/11/25 Week 7

Create a knowledge base consisting of first order logic statements and prove the query using resolution -

Logical statement to CNF -

1) Eliminate ⇔ replacing $\alpha \Leftrightarrow \beta$ with $(\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)$

Eliminate ⇒ replacing $\alpha \Rightarrow \beta$ with $\neg\alpha \vee \beta$

2) Move ¬ inwards

$\neg(\forall x\, p) \equiv \exists x \neg p$

$\neg(\exists x\, p) \equiv \forall x \neg p$

$\neg(\alpha \vee \beta) \equiv \neg\alpha \wedge \neg\beta$

$\neg(\alpha \wedge \beta) \equiv \neg\alpha \vee \neg\beta$

$\neg\neg\alpha \equiv \alpha$

3) Standardize variables by renaming them.

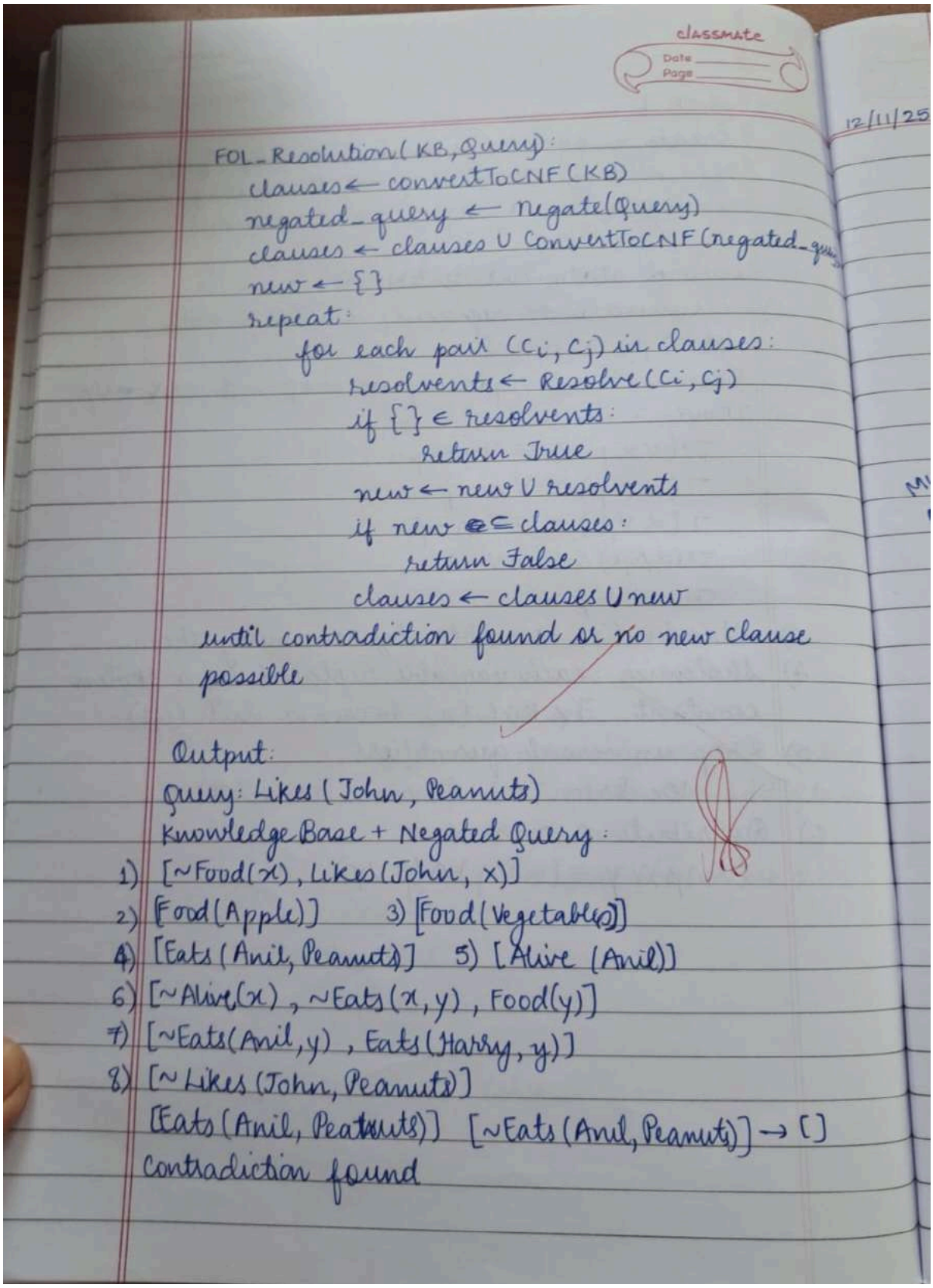
4) Skolemize : each variable replaced by a Skolem constant. $\exists x$ Rich(x) becomes Rich(G1)

5) Drop universal quantifiers

$\forall x$ Person(x) becomes Person(x)

6) Distribute $\wedge$ over $\vee$

$(\alpha \wedge \beta) \vee \gamma \equiv (\alpha \vee \gamma) \wedge (\beta \vee \gamma)$



FOL_Resolution(KB, Query):
clauses ← convertToCNF(KB)
negated_query ← Negate(Query)
clauses ← clauses ∪ ConvertToCNF(negated_query)
new ← {}
repeat:
for each pair (Ci, Cj) in clauses:
resolvents ← Resolve(Ci, Cj)
if {} ∈ resolvents:
return True
new ← new ∪ resolvents
if new ⊆ clauses:
return False
clauses ← clauses ∪ new
until contradiction found or no new clause possible

Output:
Query: Likes(John, Peanuts)
Knowledge Base + Negated Query:
1) [~Food(x), Likes(John, x)]
2) [Food(Apple)] 3) [Food(Vegetables)]
4) [Eats(Anil, Peanuts)] 5) [Alive(Anil)]
6) [~Alive(x), ~Eats(x, y), Food(y)]
7) [~Eats(Anil, y), Eats(Harry, y)]
8) [~Likes(John, Peanuts)]
[Eats(Anil, Peanuts)] [~Eats(Anil, Peanuts)] → []
Contradiction found

Code:

```
  import copy
# ------------------------------
# Predicate Structure
# ------------------------------
class Predicate:
    def __init__(self, name, args, negated=False):
        self.name = name
        self.args = args if isinstance(args, tuple) else tuple(args)
        self.negated = negated

    def __eq__(self, other):
        return (self.name == other.name and
                    self.args == other.args and
                    self.negated == other.negated)

    def __hash__(self):
        return hash((self.name, self.args, self.negated))

    def __repr__(self):
        neg = "~" if self.negated else ""
        args_str = ",".join(str(a) for a in self.args)
        return f"{neg}{self.name}({args_str})"

    def negate(self):
        return Predicate(self.name, self.args, not self.negated)

    def substitute(self, theta):
        """Apply substitution theta to this predicate"""
        new_args = tuple(substitute_term(arg, theta) for arg in self.args)
        return Predicate(self.name, new_args, self.negated)

def substitute_term(term, theta):
    """Apply substitution to a term"""
    if isinstance(term, str) and term.islower():  # variable
        if term in theta:
            return substitute_term(theta[term], theta)
        return term
    elif isinstance(term, tuple):
        return tuple(substitute_term(t, theta) for t in term)
    return term

# ------------------------------
# Unification Algorithm
# ------------------------------
def unify(x, y, theta=None):
    if theta is None:
        theta = {}
    if theta == "FAIL":
```

```
        return "FAIL"
    elif x == y:
        return theta
    elif isinstance(x, str) and x.islower():  # variable
        return unify_var(x, y, theta)
    elif isinstance(y, str) and y.islower():  # variable
        return unify_var(y, x, theta)
    elif isinstance(x, tuple) and isinstance(y, tuple):
        if len(x) != len(y):
            return "FAIL"
        theta = unify(x[0], y[0], theta)
        if theta == "FAIL":
            return "FAIL"
        return unify(x[1:], y[1:], theta)
    else:
        return "FAIL"

def unify_var(var, x, theta):
    if var in theta:
        return unify(theta[var], x, theta)
    elif isinstance(x, str) and x.islower() and x in theta:
        return unify(var, theta[x], theta)
    elif occurs_check(var, x, theta):
        return "FAIL"
    else:
        new_theta = copy.deepcopy(theta)
        new_theta[var] = x
        return new_theta

def occurs_check(var, x, theta):
    if var == x:
        return True
    elif isinstance(x, str) and x.islower() and x in theta:
        return occurs_check(var, theta[x], theta)
    elif isinstance(x, tuple):
        return any(occurs_check(var, xi, theta) for xi in x)
    return False

# ------------------------------
# Variable Standardization
# ------------------------------
var_counter = 0

def standardize_variables(clause):
    """Rename all variables in a clause to unique names"""
    global var_counter
    mapping = {}
    new_clause = []
```

```
    for pred in clause:
        new_args = []
        for arg in pred.args:
            if isinstance(arg, str) and arg.islower():  # variable
                    if arg not in mapping:
                    mapping[arg] = f"{arg}{var_counter}"
                    var_counter += 1
                    new_args.append(mapping[arg])
            else:
                    new_args.append(arg)
        new_clause.append(Predicate(pred.name, new_args, pred.negated))

    return new_clause

# ------------------------------
# Resolution Algorithm
# ------------------------------
def resolve(ci, cj):
    """Resolve two clauses using FOL resolution"""
    ci = standardize_variables(ci)
    cj = standardize_variables(cj)

    resolvents = []

    for i, pi in enumerate(ci):
        for j, pj in enumerate(cj):
            # Check if predicates can be resolved (opposite signs, same name)
            if pi.negated != pj.negated and pi.name == pj.name:
                    # Try to unify the arguments
                    theta = unify(pi.args, pj.args)

                    if theta != "FAIL":
                    # Create resolvent by removing resolved predicates and applying substitution
                    new_clause = []

                    # Add literals from ci except pi
                    for k, pred in enumerate(ci):
                    if k != i:
                        new_clause.append(pred.substitute(theta))

                    # Add literals from cj except pj
                    for k, pred in enumerate(cj):
                    if k != j:
                        new_clause.append(pred.substitute(theta))

                    # Remove duplicates
                    new_clause = list(set(new_clause))
```

```
                resolvents.append(new_clause)

    return resolvents

def fol_resolution(kb, query):
    """FOL resolution algorithm"""
        # Negate query and add to KB
    clauses = [clause[:] for clause in kb]  # deep copy
    clauses.append([query.negate()])

    print(f"\nKnowledge Base + Negated Query:")
    for i, clause in enumerate(clauses):
        print(f"  {i+1}. {clause}")
    print()

    iteration = 0
    while True:
        iteration += 1
        n = len(clauses)
        pairs = [(clauses[i], clauses[j]) for i in range(n) for j in range(i + 1, n)]

        new_clauses = []
        for (ci, cj) in pairs:
            resolvents = resolve(ci, cj)

            for resolvent in resolvents:
                    if len(resolvent) == 0:
                    print(f"Iteration {iteration}: Derived empty clause from:")
                    print(f"  {ci}")
                    print(f"  {cj}")
                    print("  → [] (Contradiction found!)")
                    return True

                    # Check if this is a new clause
                    if resolvent not in clauses and resolvent not in new_clauses:
                new_clauses.append(resolvent)

        if not new_clauses:
            print(f"Iteration {iteration}: No new clauses derived. Query cannot be proved.")
            return False

        print(f"Iteration {iteration}: Generated {len(new_clauses)} new clause(s)")
        for clause in new_clauses:
            clauses.append(clause)

# ------------------------------
# Example Usage
# ------------------------------
```

```
if __name__ == "__main__":
        # Define knowledge base
    kb = [
        # John likes all food: Food(x) => Likes(John, x)
        [Predicate("Food", ("x",), negated=True), Predicate("Likes", ("John", "x"))],

        # Food(Apple)
        [Predicate("Food", ("Apple",))],

        # Food(Vegetables)
        [Predicate("Food", ("Vegetables",))],

        # Eats(Anil, Peanuts)
        [Predicate("Eats", ("Anil", "Peanuts"))],

        # Alive(Anil)
        [Predicate("Alive", ("Anil",))],

        # If alive and eats something, that thing is food: Alive(x) ∧ Eats(x,y) => Food(y)
        [Predicate("Alive", ("x",), negated=True),
         Predicate("Eats", ("x", "y"), negated=True),
         Predicate("Food", ("y",))],

        # Harry eats everything Anil eats: Eats(Anil,y) => Eats(Harry,y)
        [Predicate("Eats", ("Anil", "y"), negated=True),
         Predicate("Eats", ("Harry", "y"))]
            ]

        # Query: Does John like Peanuts?
    query = Predicate("Likes", ("John", "Peanuts"))

    print("=" * 60)
    print("FIRST-ORDER LOGIC RESOLUTION THEOREM PROVER")
    print("=" * 60)
    print(f"\nQuery: {query}")
    print("-" * 60)

    result = fol_resolution(kb, query)

    print("\n" + "=" * 60)
    if result:
        print("✅ Query is PROVED using resolution!")
    else:
        print("❌ Query CANNOT be proved.")
    print("=" * 60)
```

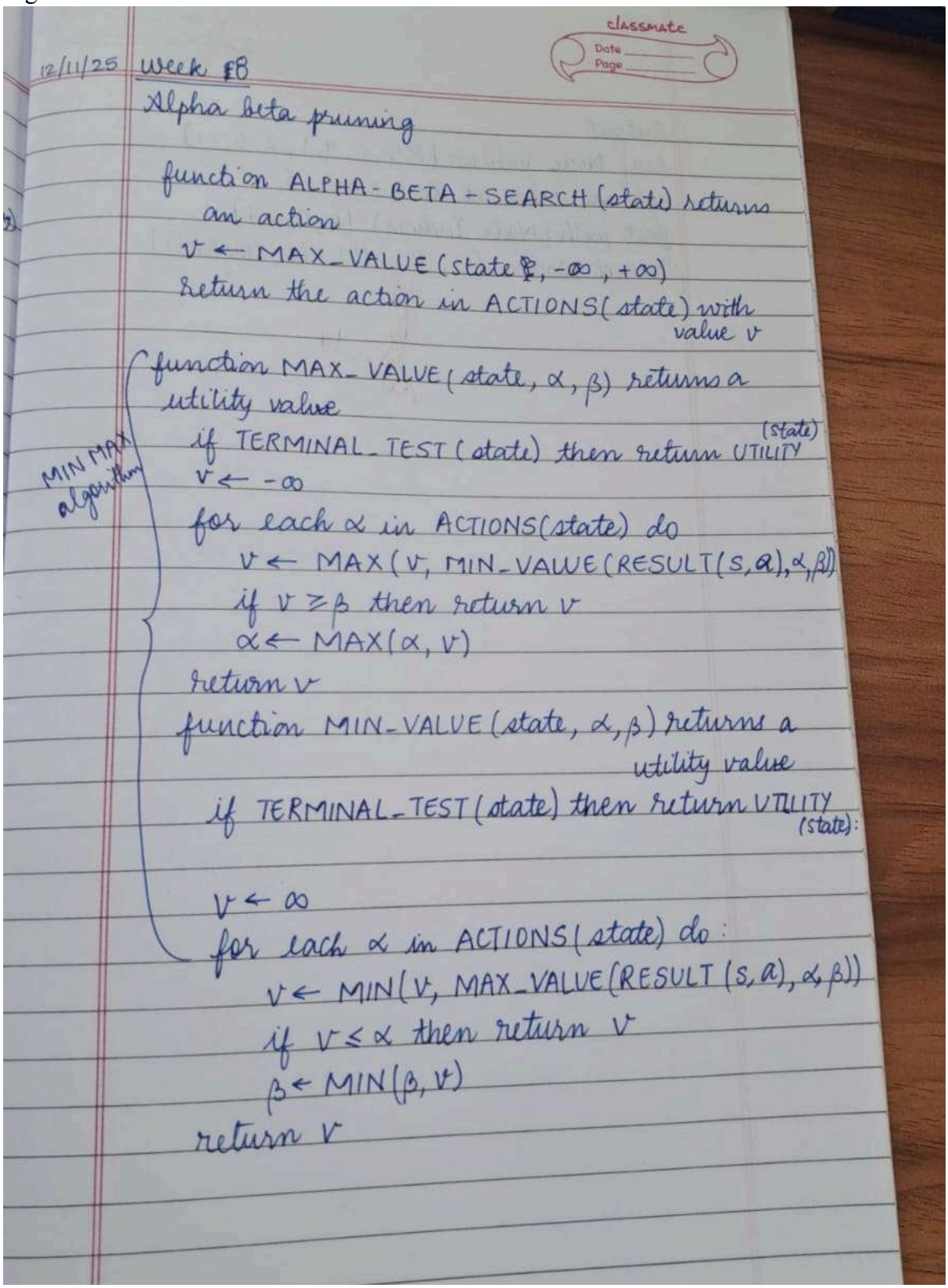
Output:

```
============================================================
FIRST-ORDER LOGIC RESOLUTION THEOREM PROVER
============================================================

Query: Likes(John,Peanuts)
------------------------------------------------------------

Knowledge Base + Negated Query:
  1. [~Food(x), Likes(John,x)]
  2. [Food(Apple)]
  3. [Food(Vegetables)]
  4. [Eats(Anil,Peanuts)]
  5. [Alive(Anil)]
  6. [~Alive(x), ~Eats(x,y), Food(y)]
  7. [~Eats(Anil,y), Eats(Harry,y)]
  8. [~Likes(John,Peanuts)]

Iteration 1: Generated 8 new clause(s)
Iteration 2: Generated 16 new clause(s)
Iteration 3: Derived empty clause from:
  [Eats(Anil,Peanuts)]
  [~Eats(Anil,Peanuts)]
  → [] (Contradiction found!)

============================================================
✅ Query is PROVED using resolution!
============================================================
```

Program 10

Implement Alpha-Beta Pruning.

Algorithm:



Output:
Leaf Node Values: [3,5,6,9,1,2,0,-1]
Optimal value at Root Node: 5
Best path (Node Indices): [0,0,0,1]
Pruned Nodes: [(1, 'Right'), (1, 'Right')]

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Code:

```
import math
# Alpha-Beta Pruning Algorithm
def alpha_beta(depth, node_index, maximizing_player, values, alpha, beta, max_depth, path,
pruned):
        # Base case: leaf node
    if depth == max_depth:
        return values[node_index], [node_index]

    if maximizing_player:
        best = -math.inf
        best_path = []
        for i in range(2):  # two children per node
            val, child_path = alpha_beta(depth + 1, node_index * 2 + i, False, values, alpha, beta,
max_depth, path, pruned)
            if val > best:
                    best = val
                    best_path = [node_index] + child_path
            alpha = max(alpha, best)
            if beta <= alpha:
                    pruned.append((node_index, "Right" if i == 0 else "Left"))
                    break
        return best, best_path
    else:
        best = math.inf
        best_path = []
        for i in range(2):
            val, child_path = alpha_beta(depth + 1, node_index * 2 + i, True, values, alpha, beta,
max_depth, path, pruned)
            if val < best:
                    best = val
                    best_path = [node_index] + child_path
            beta = min(beta, best)
            if beta <= alpha:
                    pruned.append((node_index, "Right" if i == 0 else "Left"))
                    break
        return best, best_path


# Example usage
if __name__ == "__main__":
        # Example game tree (leaf node values)
    values = [3, 5, 6, 9, 1, 2, 0, -1]

    print("Leaf Node Values:", values)
    path = []
    pruned = []
```

```
    max_depth = 3
    result, best_path = alpha_beta(0, 0, True, values, -math.inf, math.inf, max_depth, path,
pruned)

    print("\nOptimal Value at Root Node:", result)
    print("Best Path (Node Indices):", best_path)
    print("Pruned Nodes:", pruned)
```

Output:

```
Leaf Node Values: [3, 5, 6, 9, 1, 2, 0, -1]

Optimal Value at Root Node: 5
Best Path (Node Indices): [0, 0, 0, 1]
Pruned Nodes: [(1, 'Right'), (1, 'Right')]
```