VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

Amogh Krishna J S (1BM23CS029)

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

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

B.M.S. College of Engineering,

Bull Temple Road, Bangalore 560019

(Affiliated To Visvesvaraya Technological University, Belgaum)

Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Amogh Krishna J S (1BM23CS029),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

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

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Github Link:
https://github.com/jsak737/AI_LAB

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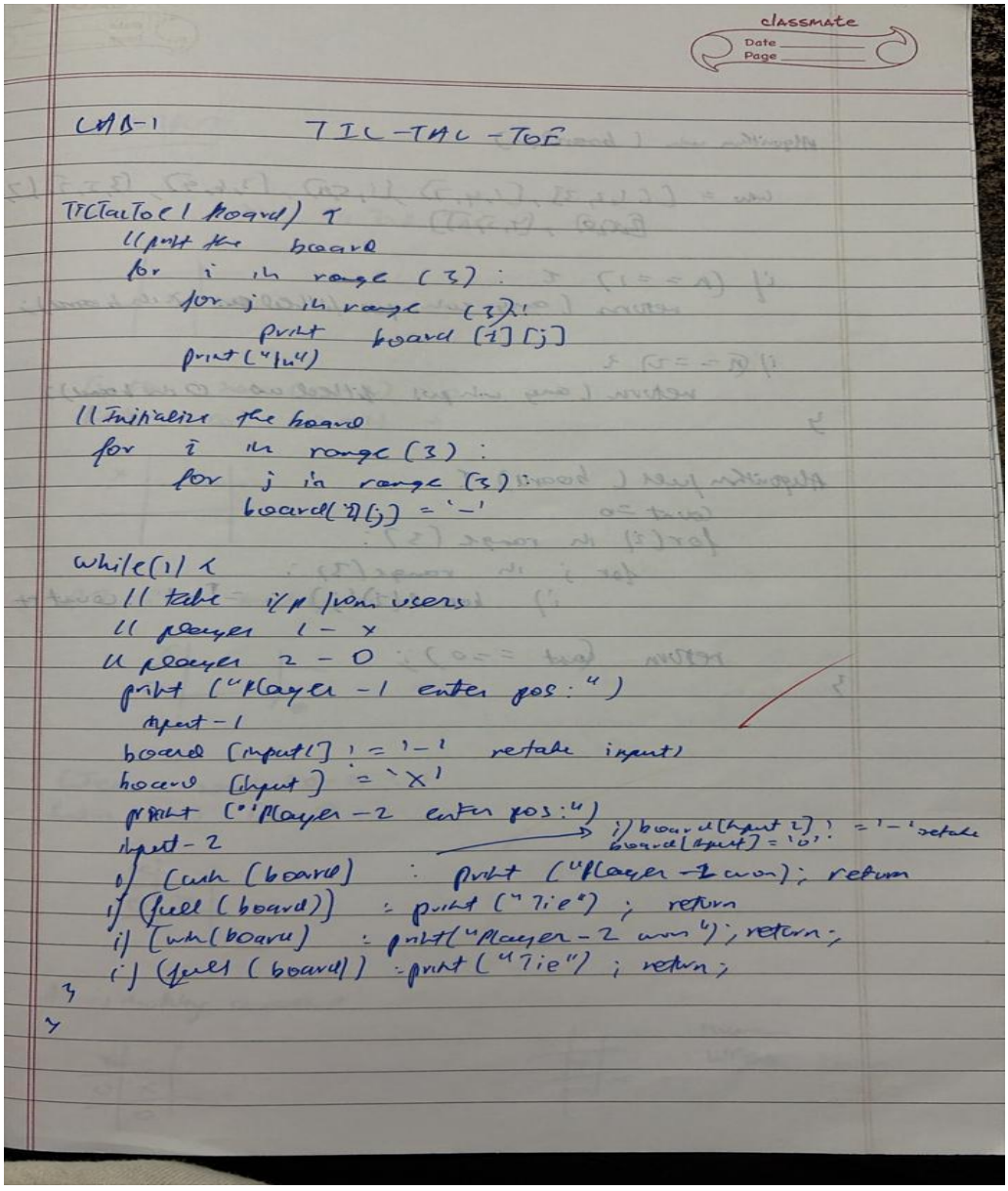
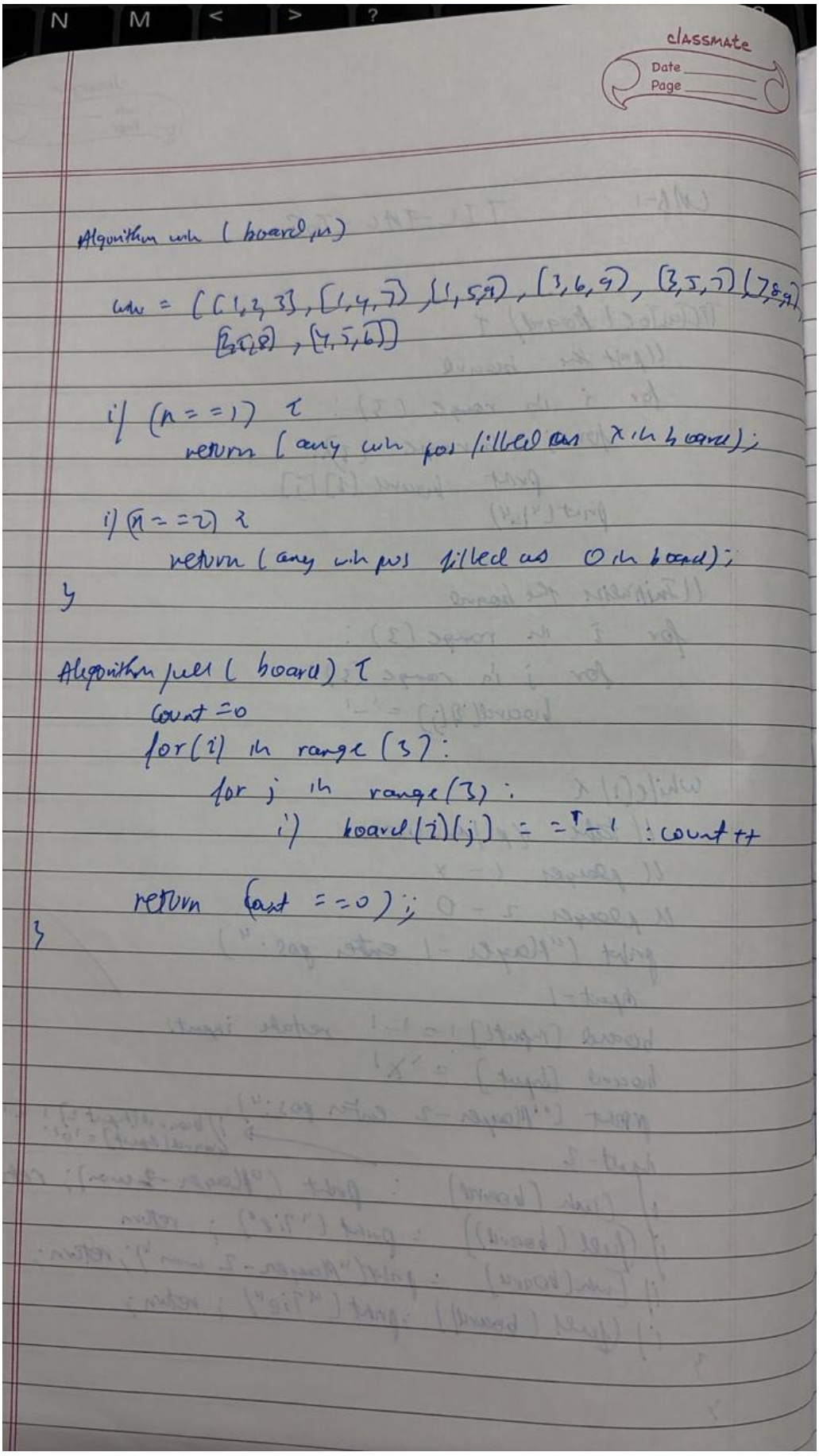
Program 1

Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

Tic-Tac-Toe

Algorithm

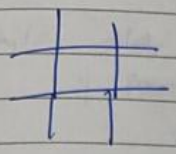




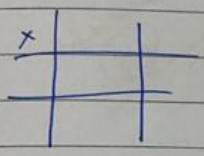
```
Algorithm win ( board, ps)

win = [[1,2,3],[1,4,7],[1,5,9],[3,6,9],[3,5,7],[7,8,9],
       [2,5,8],[4,5,6]]

if (ps==1) {
    return (any win pos filled as X in board);

if (ps==2) {
    return (any win pos filled as O in board);
}

Algorithm full ( board) {
    count=0
    for(i) in range(3):
        for j in range(3):
            if board[i][j] == '-1' : count++

    return (count==0);
}
```

OUTPUT:

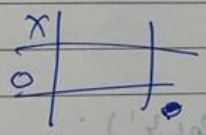
welcome to Tic Tac Toe



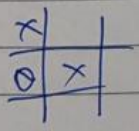
Enter row (0-2) : 0
Enter col (0-2) : 0



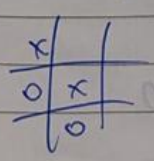
AI is making a move

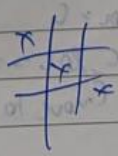


Enter row (0-2) : 1
Enter col (0-2) : 1



AI is making a move





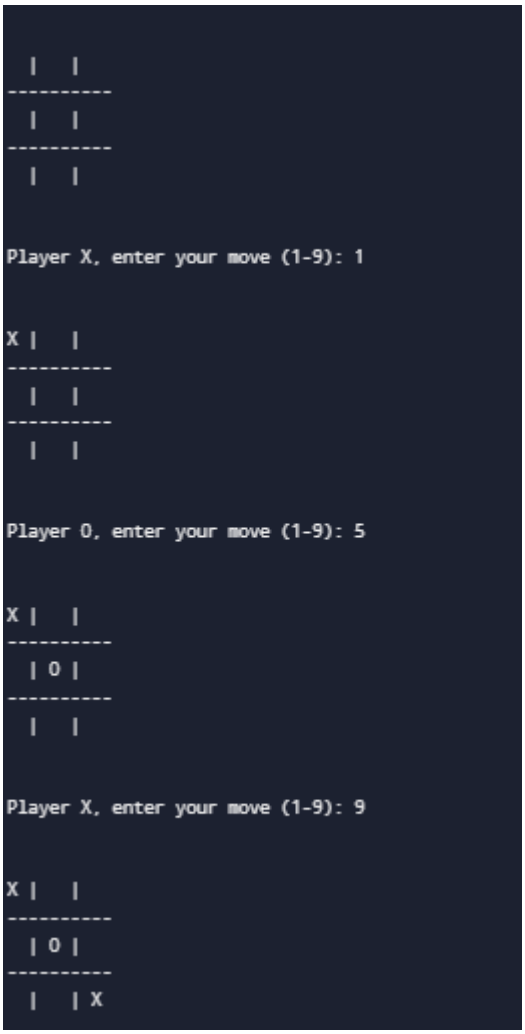
human wins

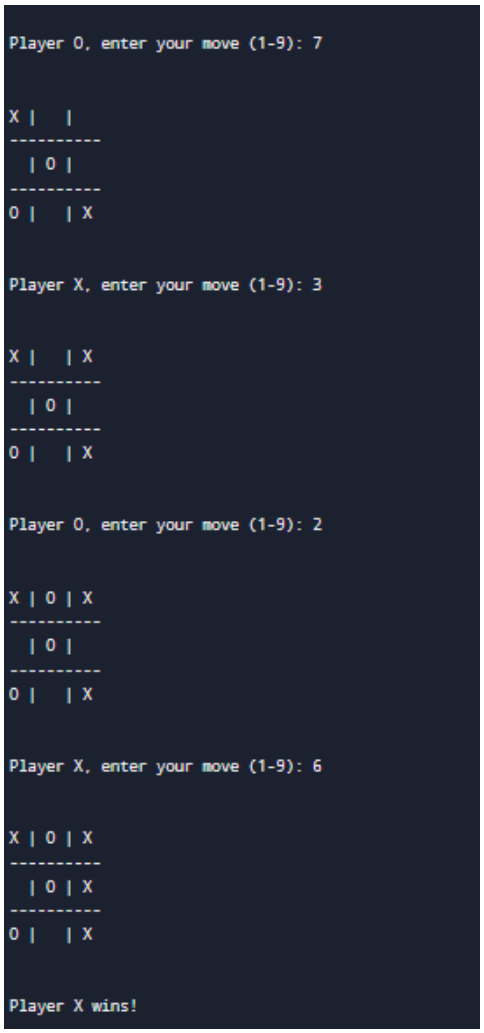
Code

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

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

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

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

    print_board(board)

    if check_winner(board, current_player):
        print(f"Player {current_player} wins!")
```

```
        break
    if " " not in board:
        print("It's a draw!")
        break

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

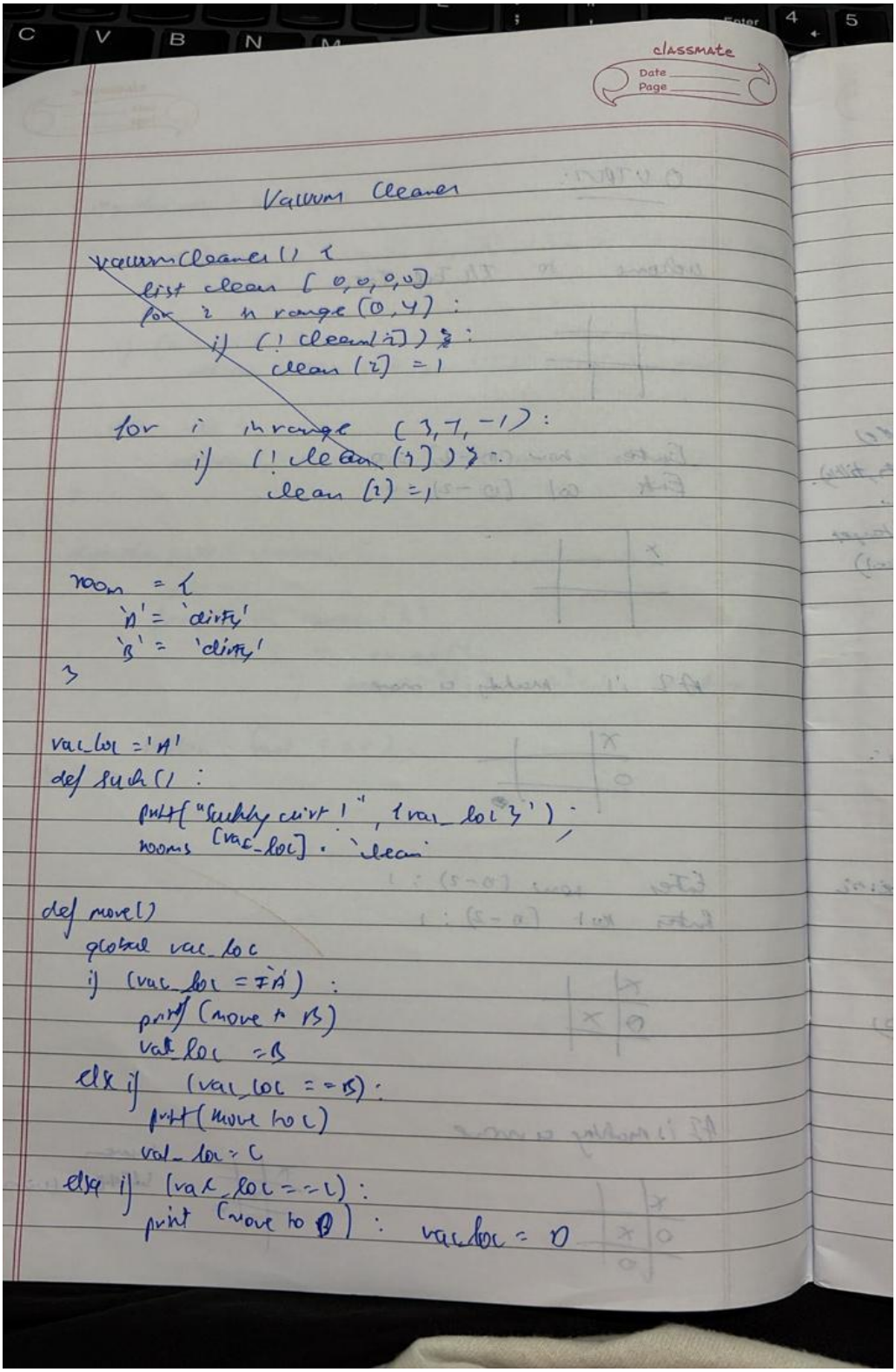
Output

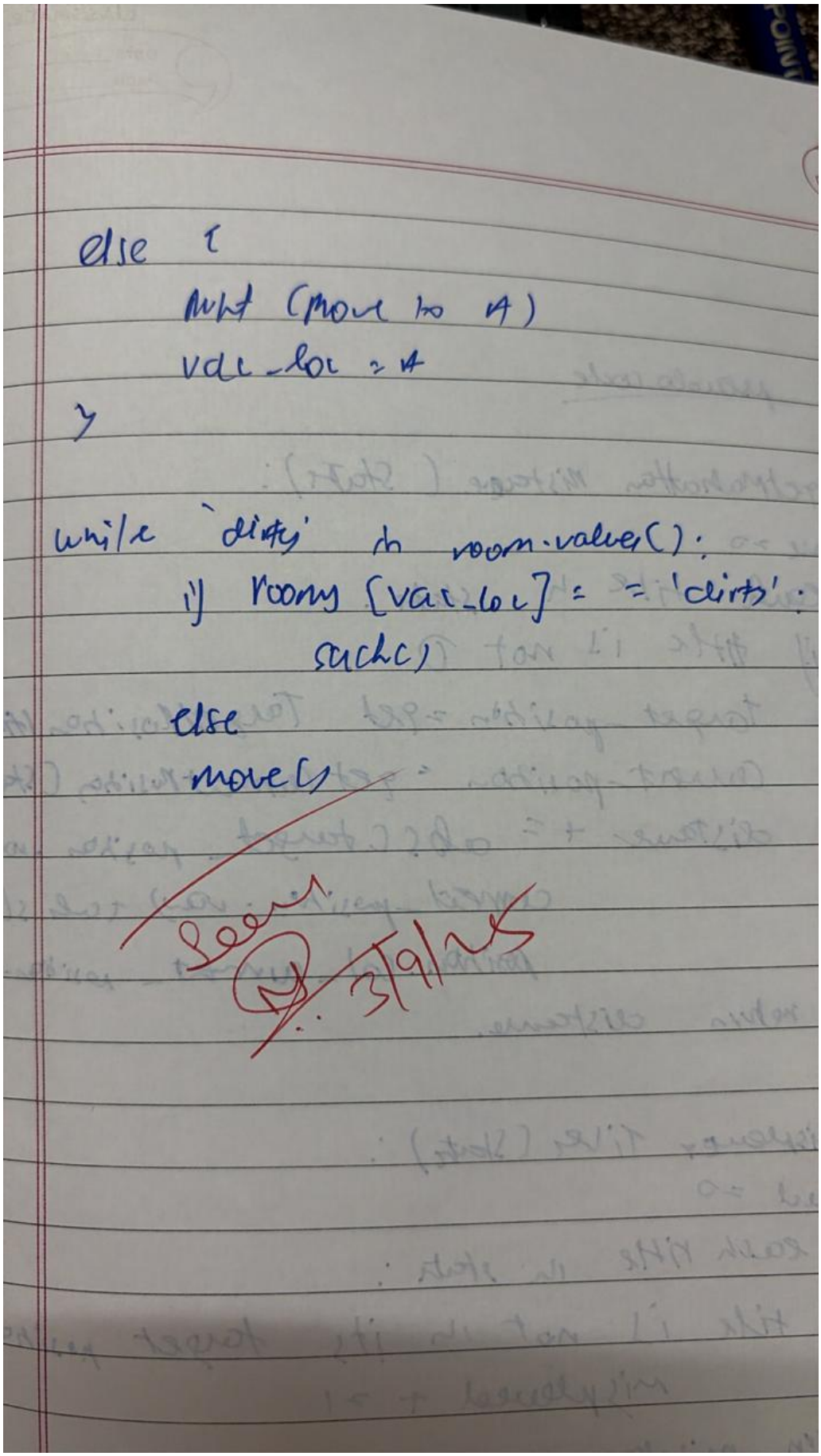




Vacuum Cleaner

Algorithm




else {
print (move to A)
val_loc = A
}
while 'dirty' in room.values():
if room[val_loc] == 'dirty':
suck()
else
move()
Soon
3/9/25

Code

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

def movebot(pos):

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

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

    if rooms[botpos]==1:

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

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

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

Output

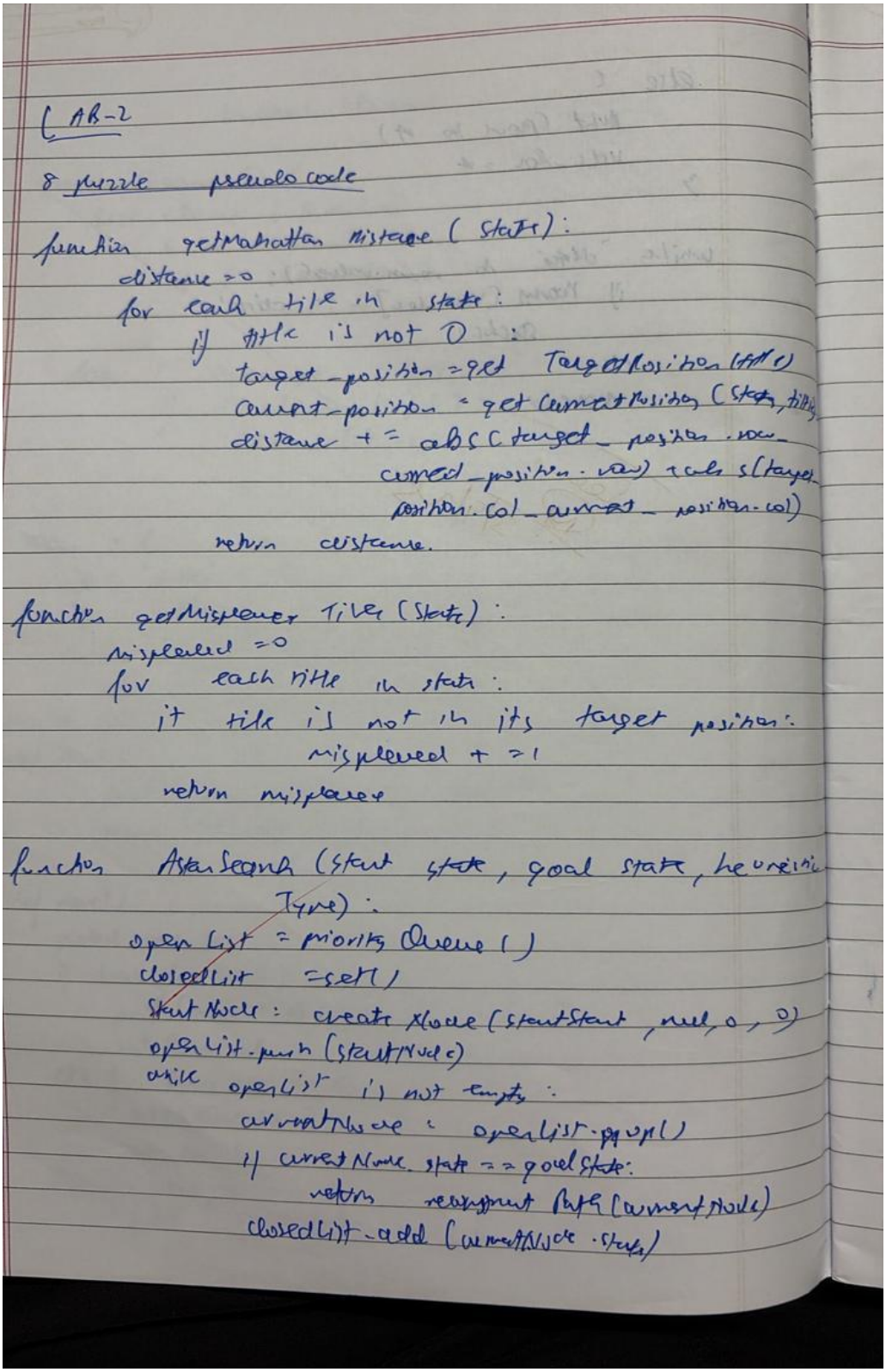
```
Enter Initial Position2
[1, 1, 1, 1]
2
[1, 0, 1, 1]
3
[1, 0, 0, 1]
1
[0, 0, 0, 1]
4
cost=4
```

Program 2

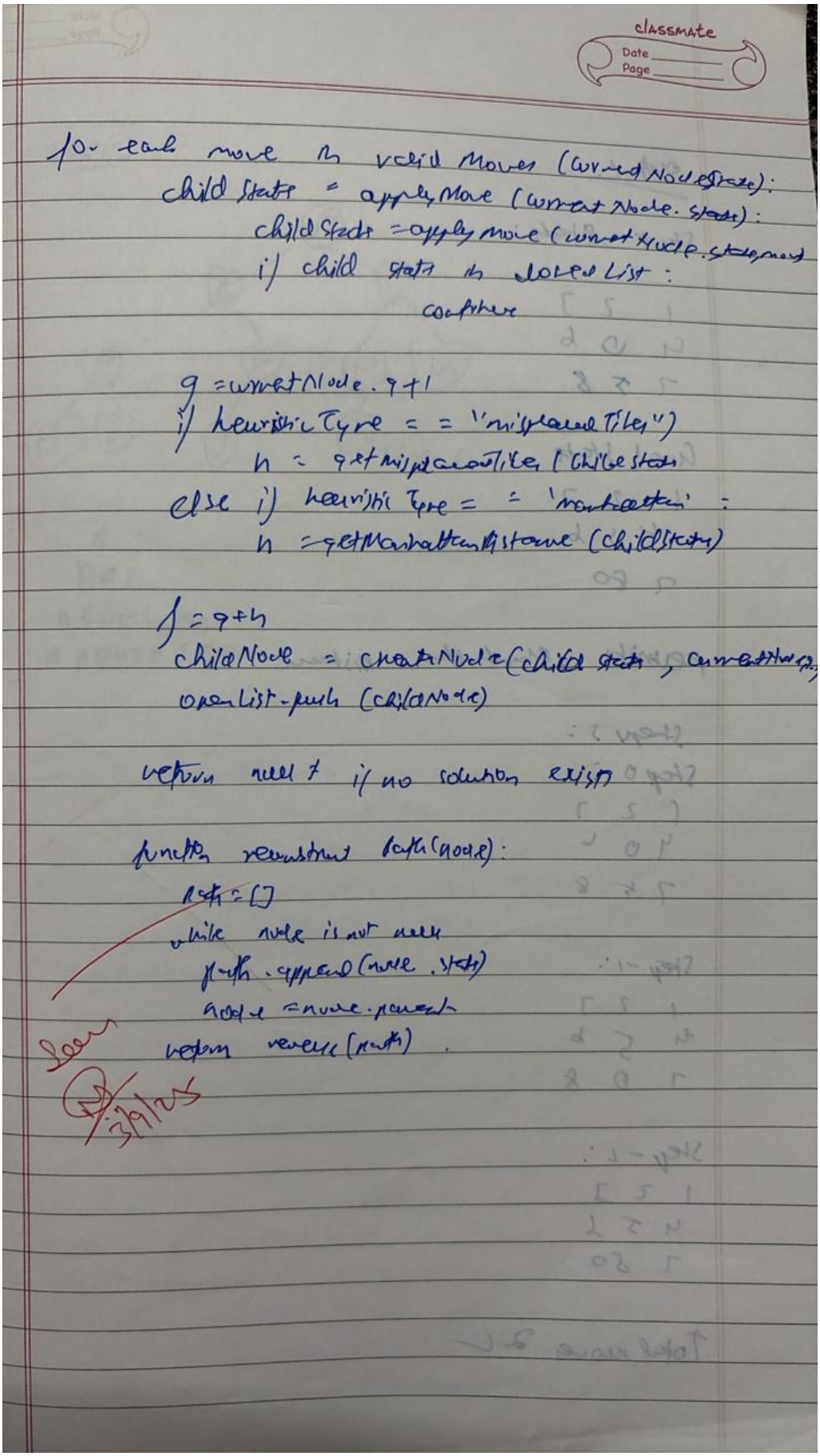
Implement 8 puzzle problems using Depth First Search (DFS)
Implement Iterative deepening search algorithm

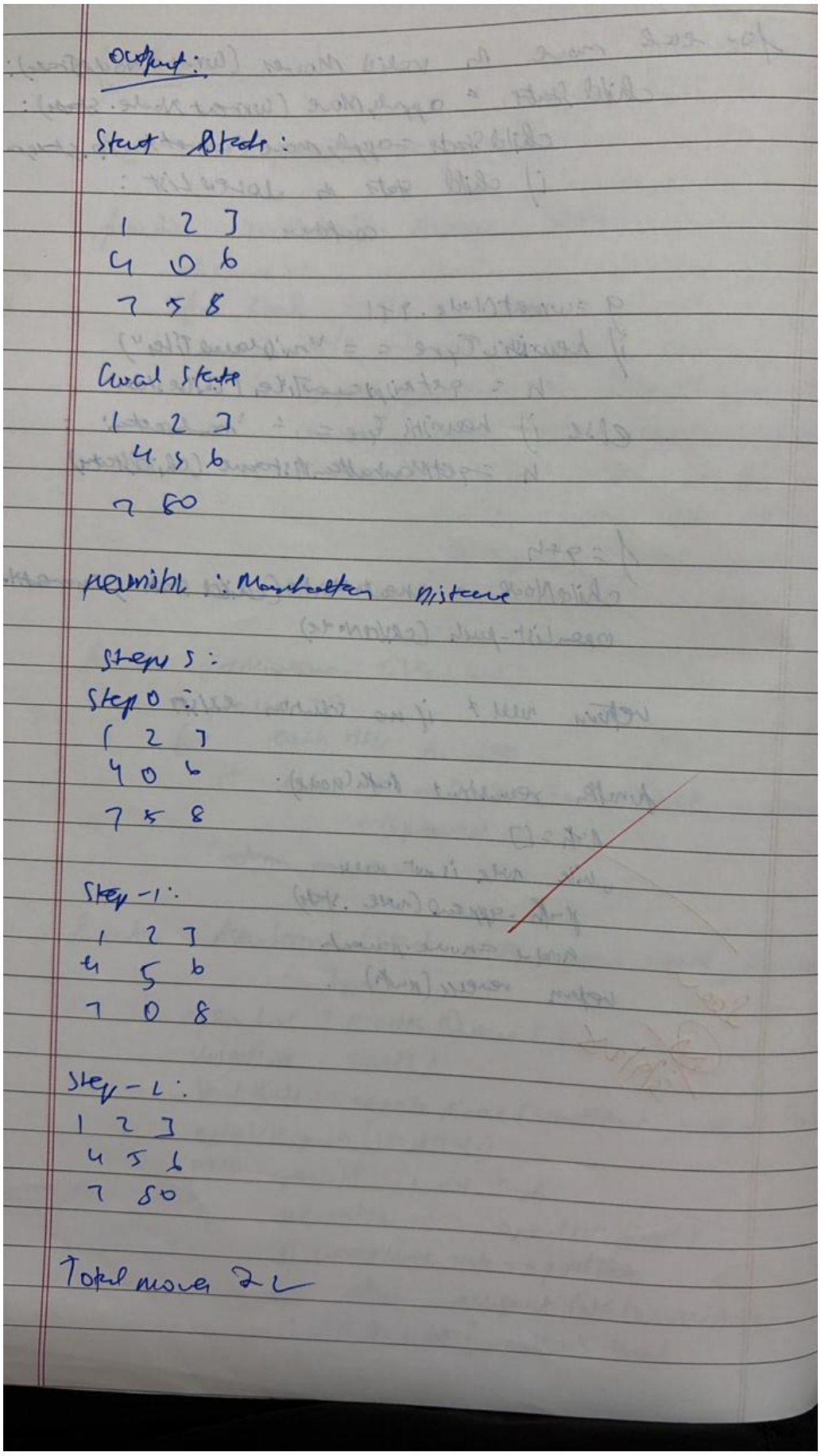
8 Puzzle Problem

Algorithm



```
LAB-2

8 puzzle pseudo code

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

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

function AstarSearch(start state, goal state, heuristic
                Type):
    openList = priorityQueue()
    closedList = set()
    startNode = createNode(startState, null, 0, 0)
    openList.push(startNode)
    while openList is not empty:
        currentNode = openList.pop()
        if currentNode.state == goalState:
            return reconstructPath(currentNode)
        closedList.add(currentNode.state)
```


classmate
Date
Page
for each move in validMoves(currentNodeState):
childState = applyMove(currentNode.state):
childState = applyMove(currentNode.state,move)
if childState in closedList:
continue
g = currentNode.g+1
if heuristicType == 'misplacedTiles':
h = getMisplacedTiles(childState)
else if heuristicType == 'manhattan':
h = getManhattanDistance(childState)
f = g+h
childNode = createNode(childState, currentNode,
openList.push(childNode)
return null if no solution exists
function reconstructPath(node):
path = []
while node is not null
path.append(node.state)
node = node.parent
return reverse(path)
Learn
3/9/25


Output:
Start State:
1 2 3
4 0 6
7 5 8
Goal State
1 2 3
4 5 6
7 8 0
Heuristic: Manhattan Distance
Step 5:
Step 0:
1 2 3
4 0 6
7 5 8
Step -1:
1 2 3
4 5 6
7 0 8
Step -2:
1 2 3
4 5 6
7 8 0
Total moves 2

Code

```
import time

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

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

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

        if depth > max_depth:
            continue

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

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

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

        possible_moves_indices = find_possible_moves(current_state)

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

```
            next_state[blank_index], next_state[move_index] = next_state[move_index],
next_state[blank_index]

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

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


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

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

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

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

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

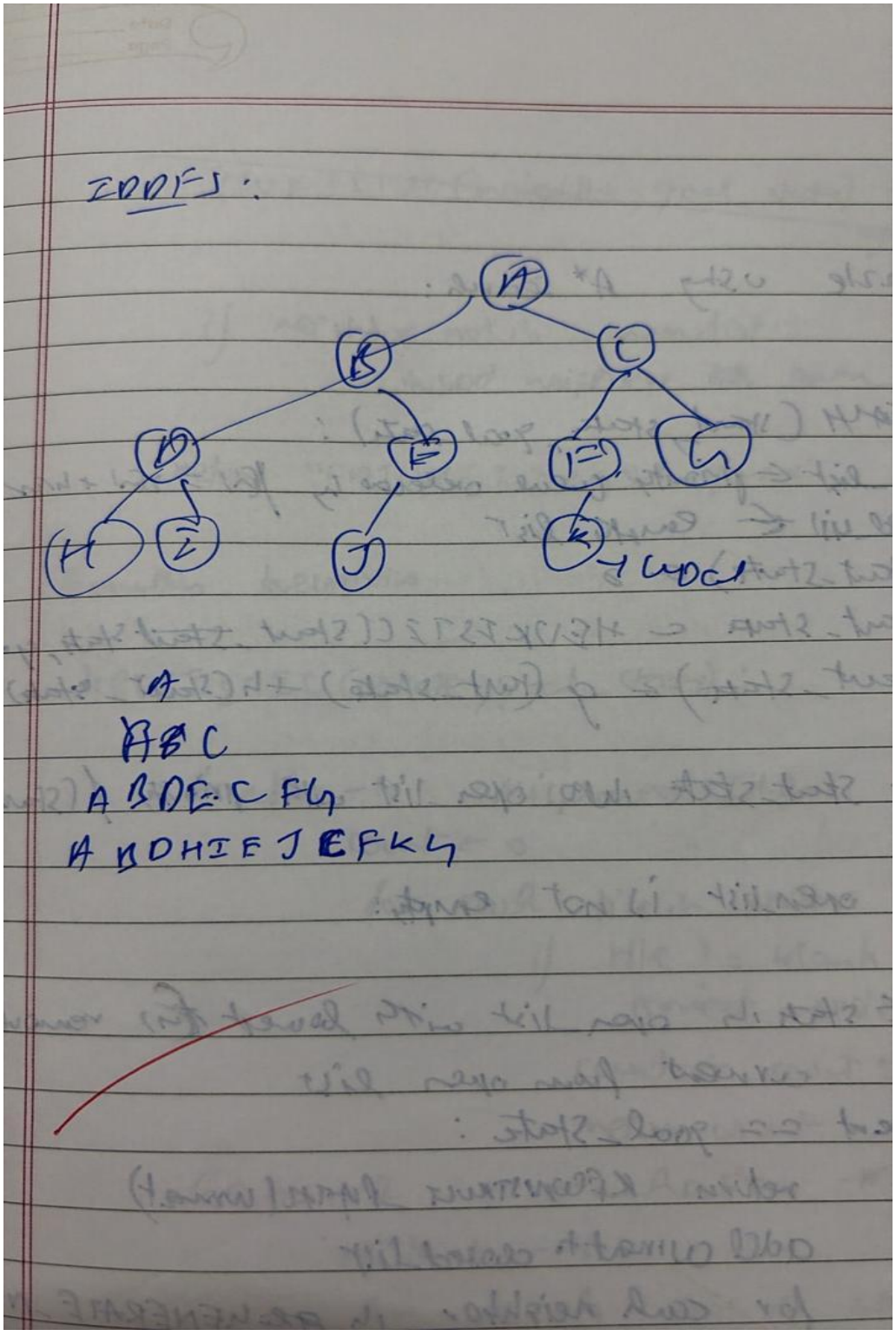
Output

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

IDDFS

Algorithm



Code

```
import time

def find_possible_moves(state):
    index = state.index('_')

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

def depth_limited_dfs(state, goal_state, limit, path, visited):
    if state == goal_state:
        return path

    if limit <= 0:
        return None

    visited.add(tuple(state))

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

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

```
            return result
    return None

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

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

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

# Measure execution time
start_time = time.time()
solution_path, depth_reached = iddfs(initial_state, goal_state, max_depth=30)
end_time = time.time()

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

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

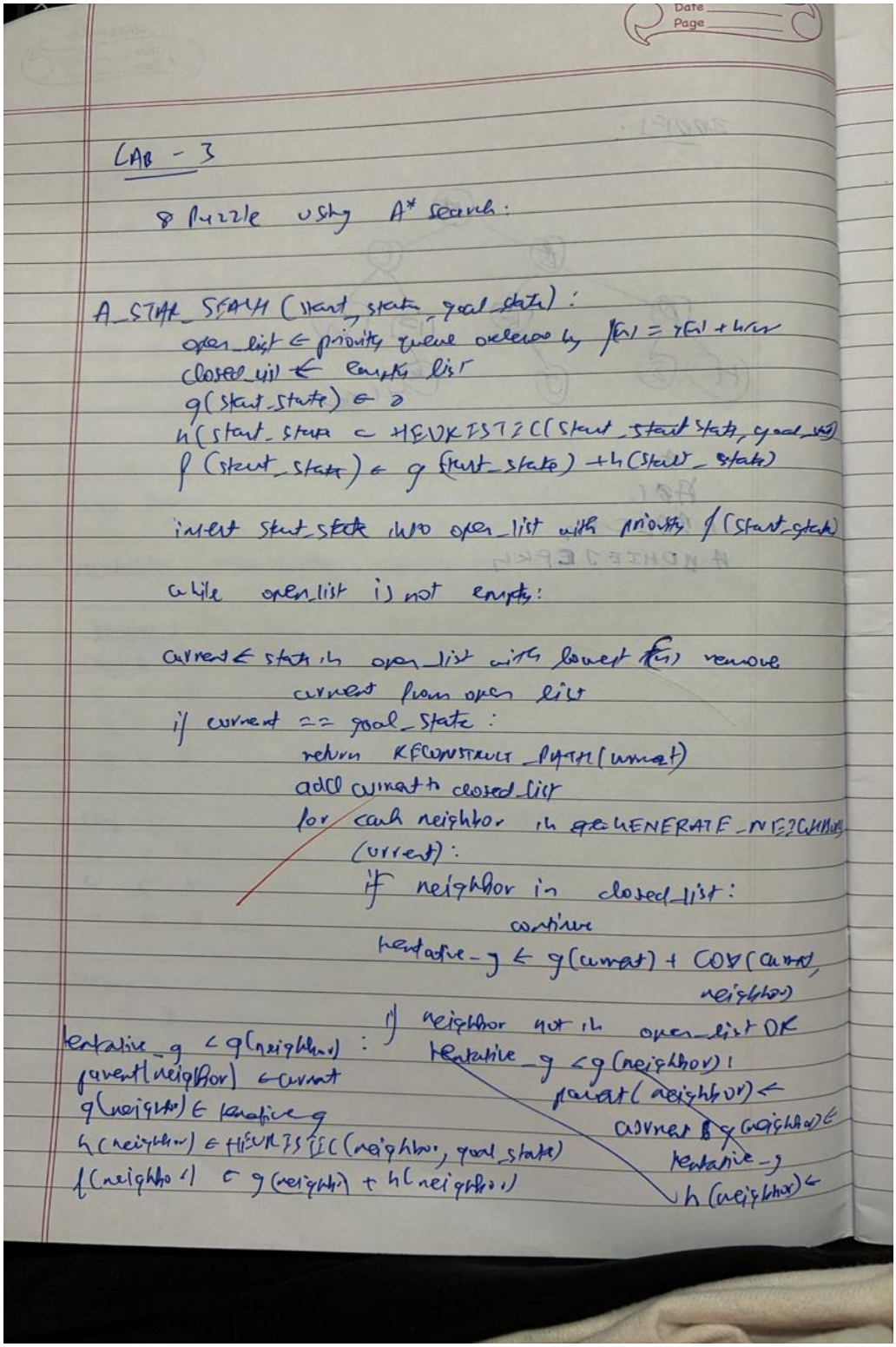
Output

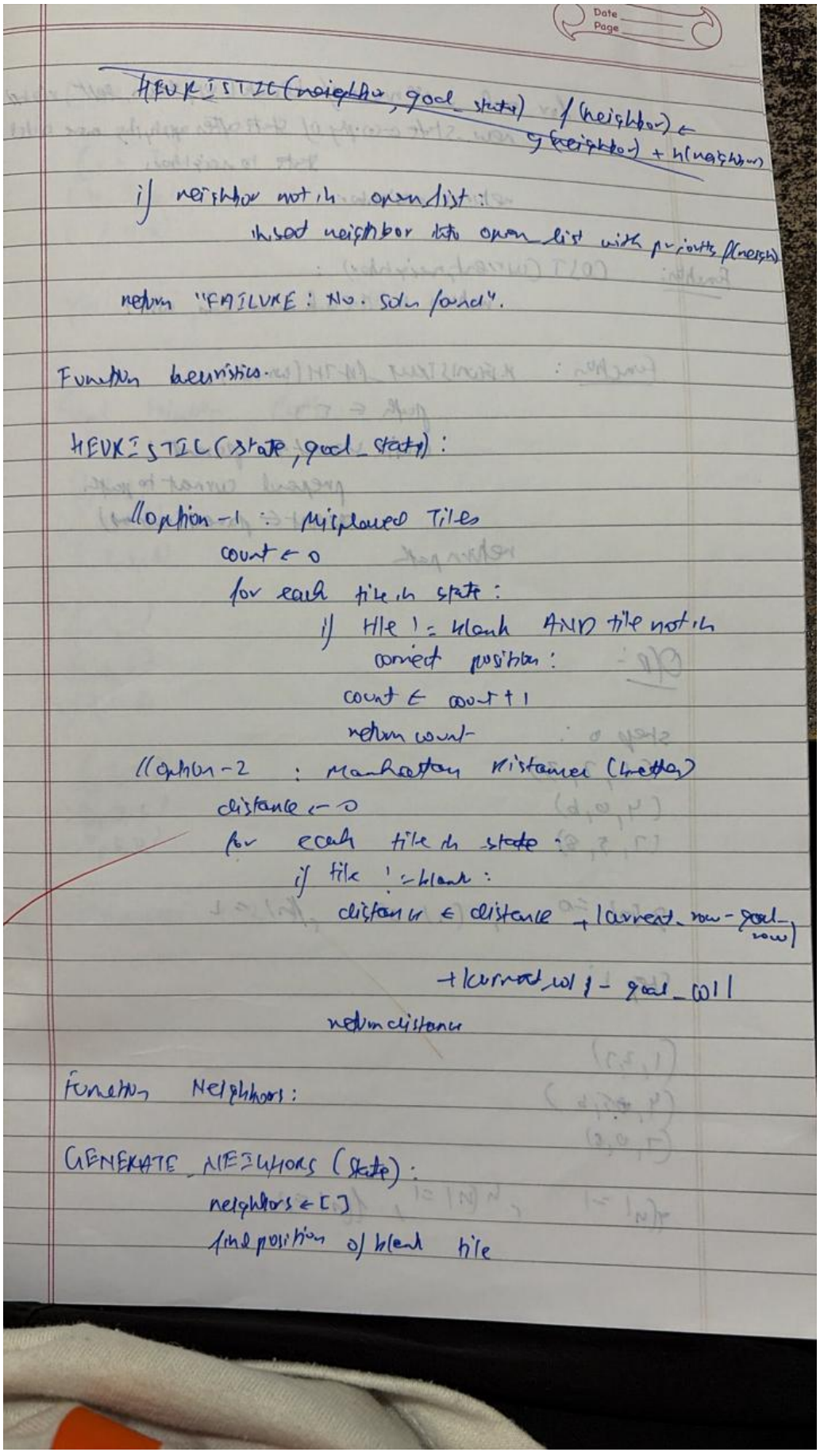
```
Searching at depth limit = 0
Searching at depth limit = 1
Searching at depth limit = 2
Searching at depth limit = 3
Searching at depth limit = 4
Searching at depth limit = 5


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

Execution time: 0.000194 seconds
Depth reached: 5

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

Program 3

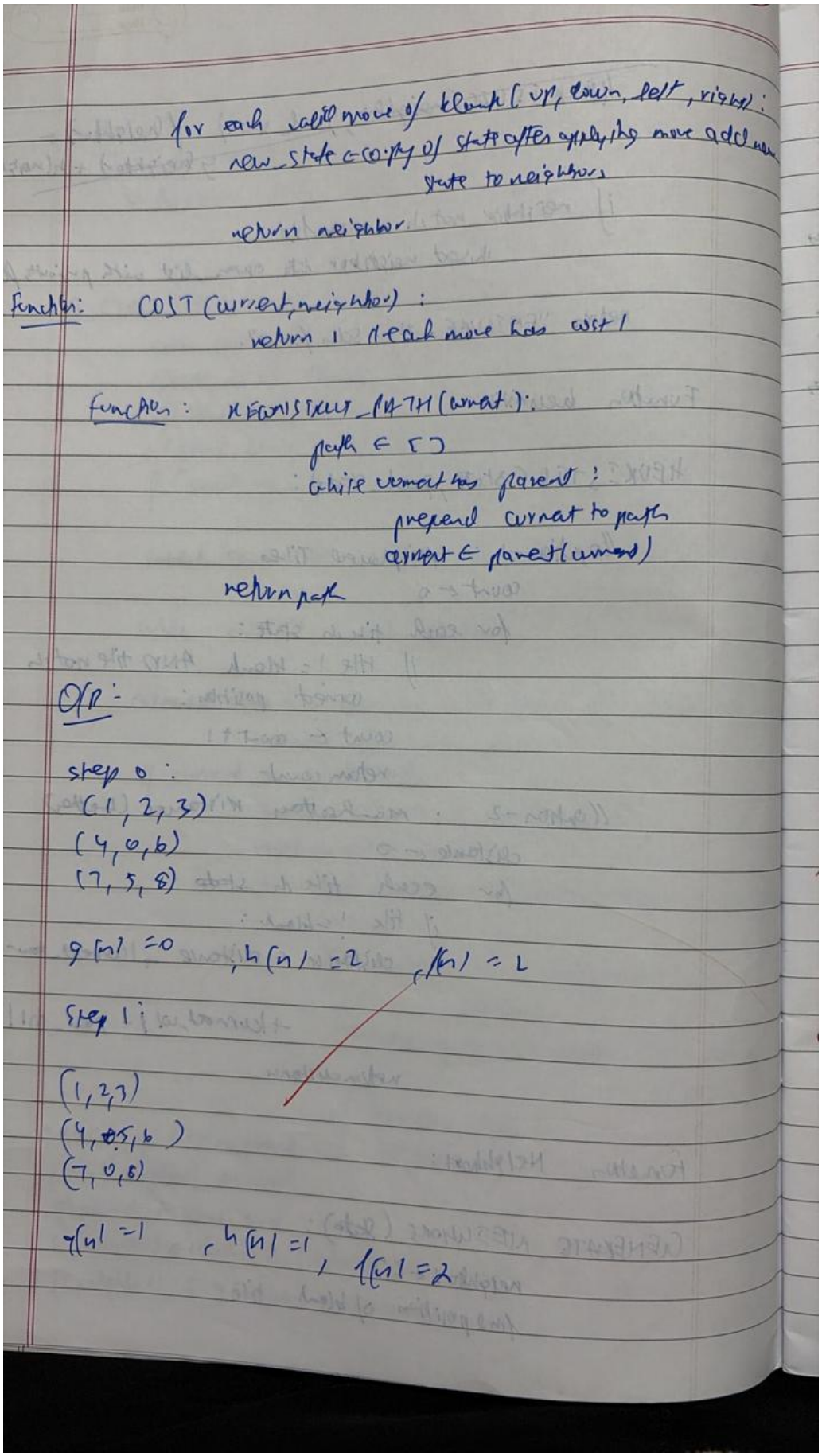
Implement A* search algorithm

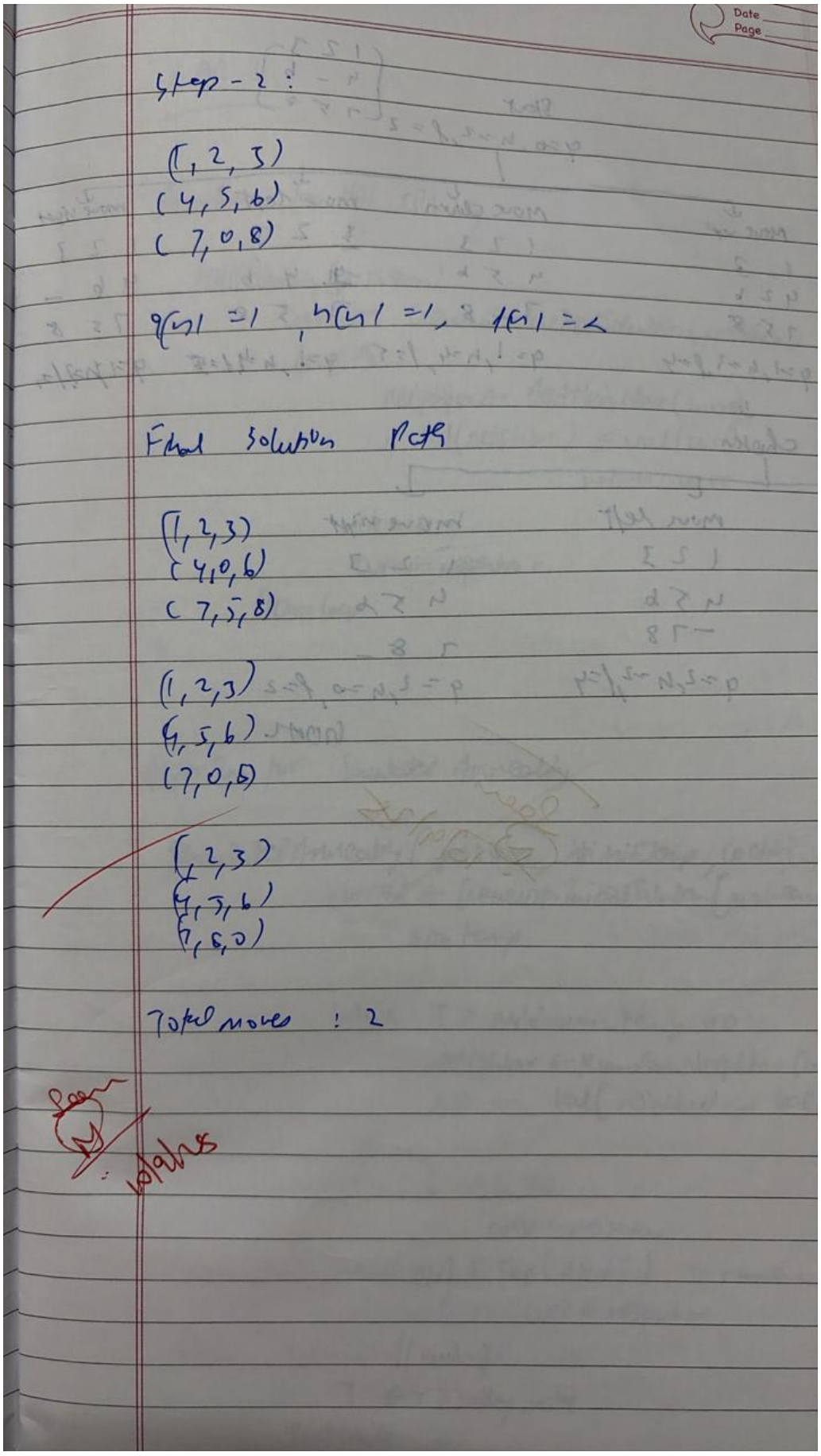
Algorithm





```
HEURISTIC(neighbor, goal_state) // h(neighbor) ←
                                g(neighbor) + h(neighbor)
    if neighbor not in open_list:
        insert neighbor into open_list with priority f(neighbor)

return "FAILURE: No solution found".

Function heuristics.

HEURISTIC(state, goal_state):

    //option-1 : Misplaced Tiles
        count ← 0
        for each tile in state:
            if tile != blank AND tile not in
                correct position:
                count ← count + 1
            return count
    //option-2 : Manhattan distance (better)
        distance ← 0
        for each tile in state:
            if tile != blank:
                distance ← distance + |current_row - goal_row|
                                    + |current_col - goal_col|
            return distance

Function Neighbors:

GENERATE_NEIGHBORS (state):
        neighbors ← []
        find position of blank tile
```


for each valid move of blank (up, down, left, right):
new_state ← copy of state after applying move and add new state to neighbors
return neighbor
function: COST (current, neighbor):
return 1 (each move has cost 1)
function: RECONSTRUCT_PATH (curnat):
path ← []
while curnat has parent:
prepend curnat to path
curnat ← parent(curnat)
return path
O/P:
step 0:
(1, 2, 3)
(4, 0, 6)
(7, 5, 8)
g(n) = 0 , h(n) = 2 , f(n) = 2
step 1:
(1, 2, 3)
(4, 5, 6)
(7, 0, 8)
g(n) = 1 , h(n) = 1 , f(n) = 2



Step - 2 :

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

g(s) = 1 , h(s) = 1, f(s) = 2

Final Solution Path

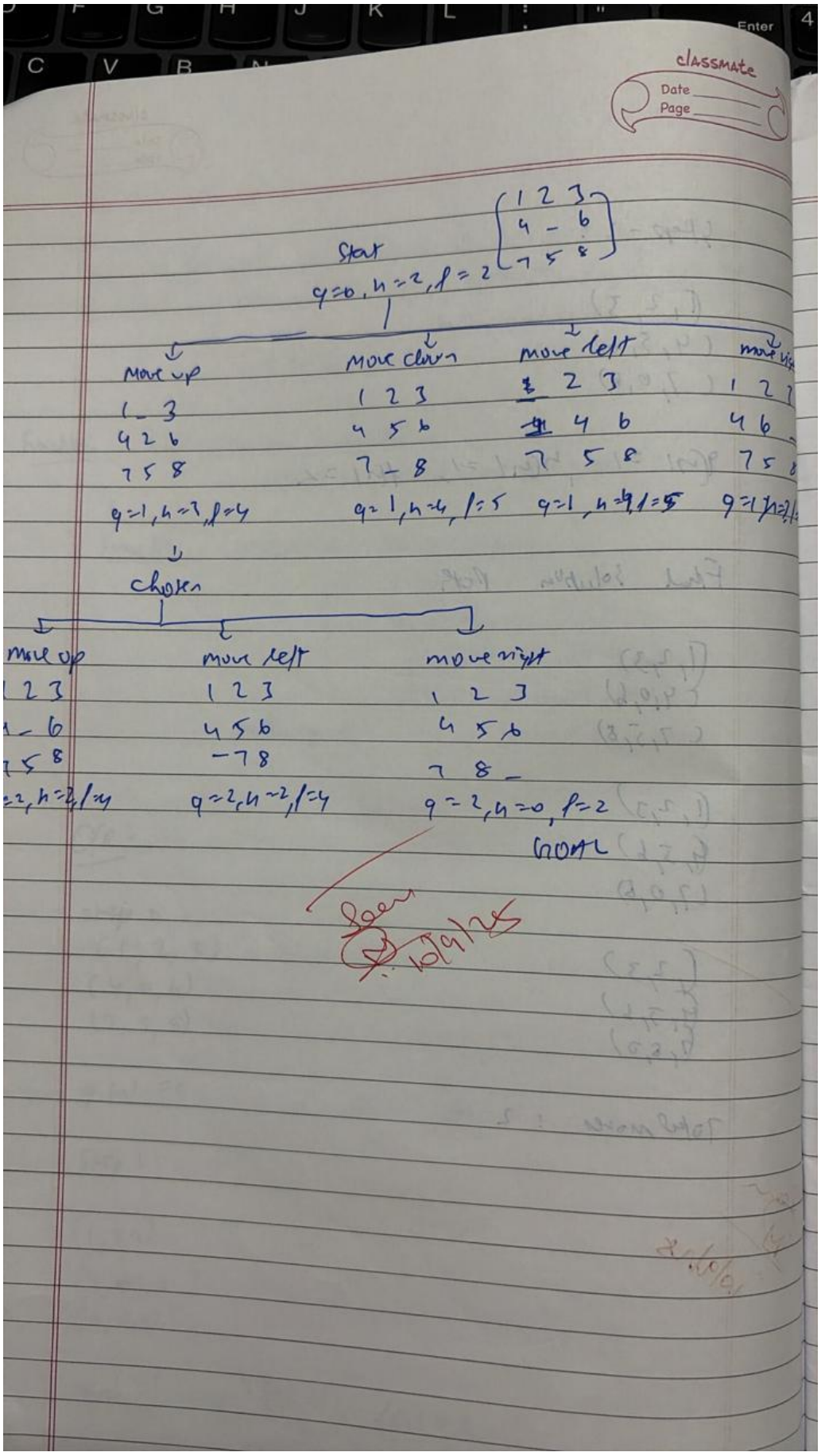
(1, 2, 3)
(4, 0, 6)
(7, 5, 8)

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

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

Total moves : 2

Result


classmate
Date
Page
Start
q=0, h=2, f=2
1 2 3
4 - 6
7 5 8
Move up
Move down
Move left
Move right
1 _ 3
4 2 6
7 5 8
q=1, h=3, f=4
1 2 3
4 5 6
7 _ 8
q=1, h=4, f=5
_ 2 3
4 1 6
7 5 8
chosen
Move up
Move left
Move right
1 2 3
_ 5 6
7 8
1 2 3
4 5 6
_ 7 8
q=2, h=0, f=2
GOAL
Seen
10/9/25

Code

```
import heapq
import time

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

# Get neighbors by sliding blank (0) up/down/left/right
def get_neighbors(state):
    neighbors = []
    i = state.index(0)  # position of blank
    x, y = divmod(i, 3)
    moves = [(-1,0), (1,0), (0,-1), (0,1)]

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

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

    came_from = {}
    g_score = {start: 0}

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

        if current == goal:
            # Reconstruct path
            path = []
            while current in came_from:
```

```
            path.append(current)
            current = came_from[current]
        path.append(start)
        return path[::-1]

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

  return None  # no solution

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

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

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

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

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

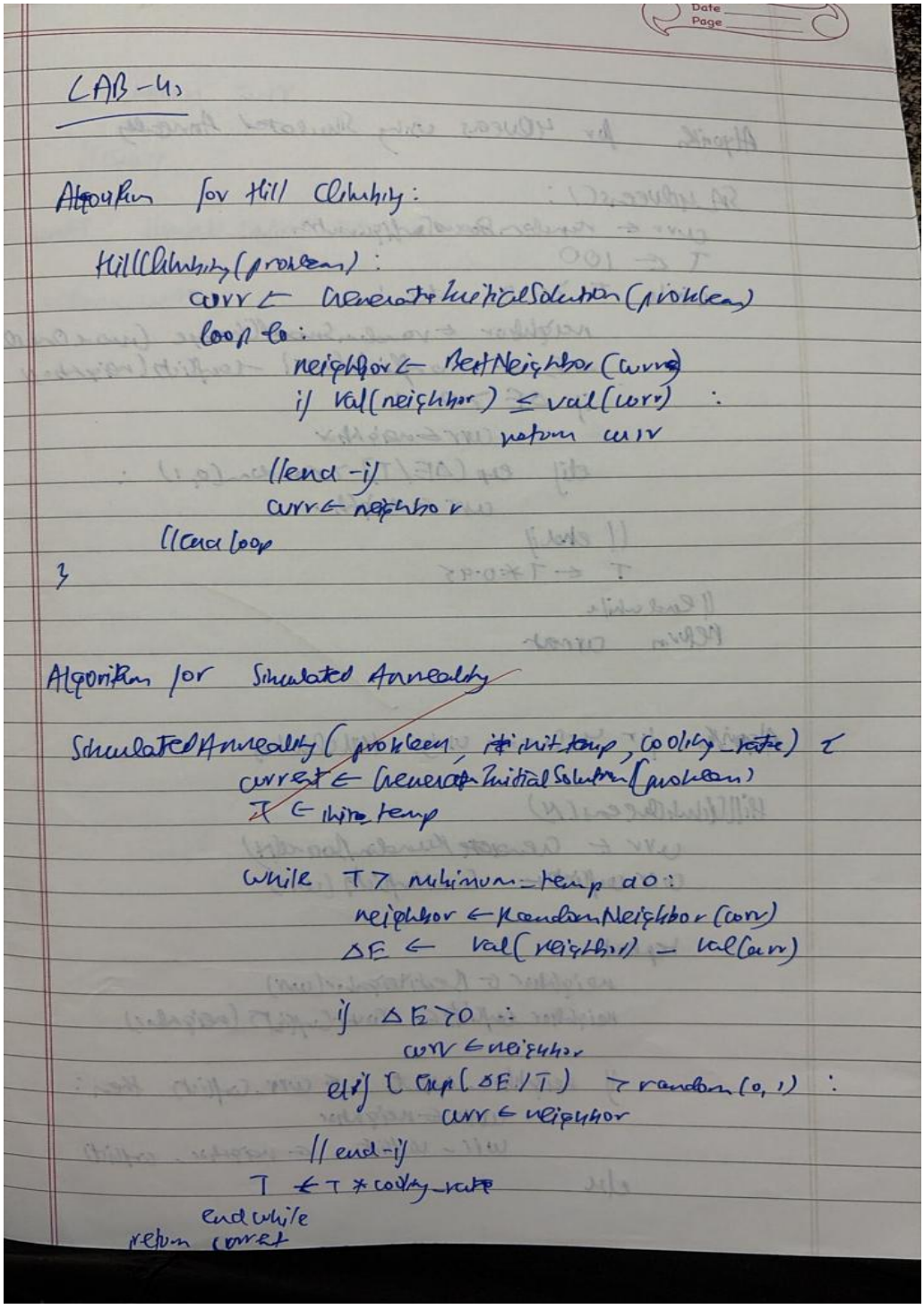
Output

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

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

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

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

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

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

Execution time: 0.000111 seconds
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm



LAB-4:

Algorithm for Hill Climbing:

```
HillClimbing(problem):
    curr ← GenerateInitialSolution(problem)
    loop do:
        neighbor ← BestNeighbor(curr)
        if val(neighbor) ≤ val(curr):
            return curr
        //end-if
        curr ← neighbor
    //end loop
}
```

Algorithm for Simulated Annealing

```
SimulatedAnnealing(problem, initial_temp, cooling_rate) {
    current ← GenerateInitialSolution(problem)
    T ← init_temp
    while T > minimum_temp do:
        neighbor ← RandomNeighbor(curr)
        ΔE ← val(neighbor) − val(curr)
        if ΔE > 0:
            curr ← neighbor
        elif (exp(ΔE/T) > random(0, 1):
            curr ← neighbor
        //end-if
        T ← T * cooling_rate
    end while
return current
```

Code

```
import random
import math

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

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

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

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

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

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

        # climb from this start
        while True:
```

```
        cost = compute_cost(state)
        if cost == 0:
            return state, restarts

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

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

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

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

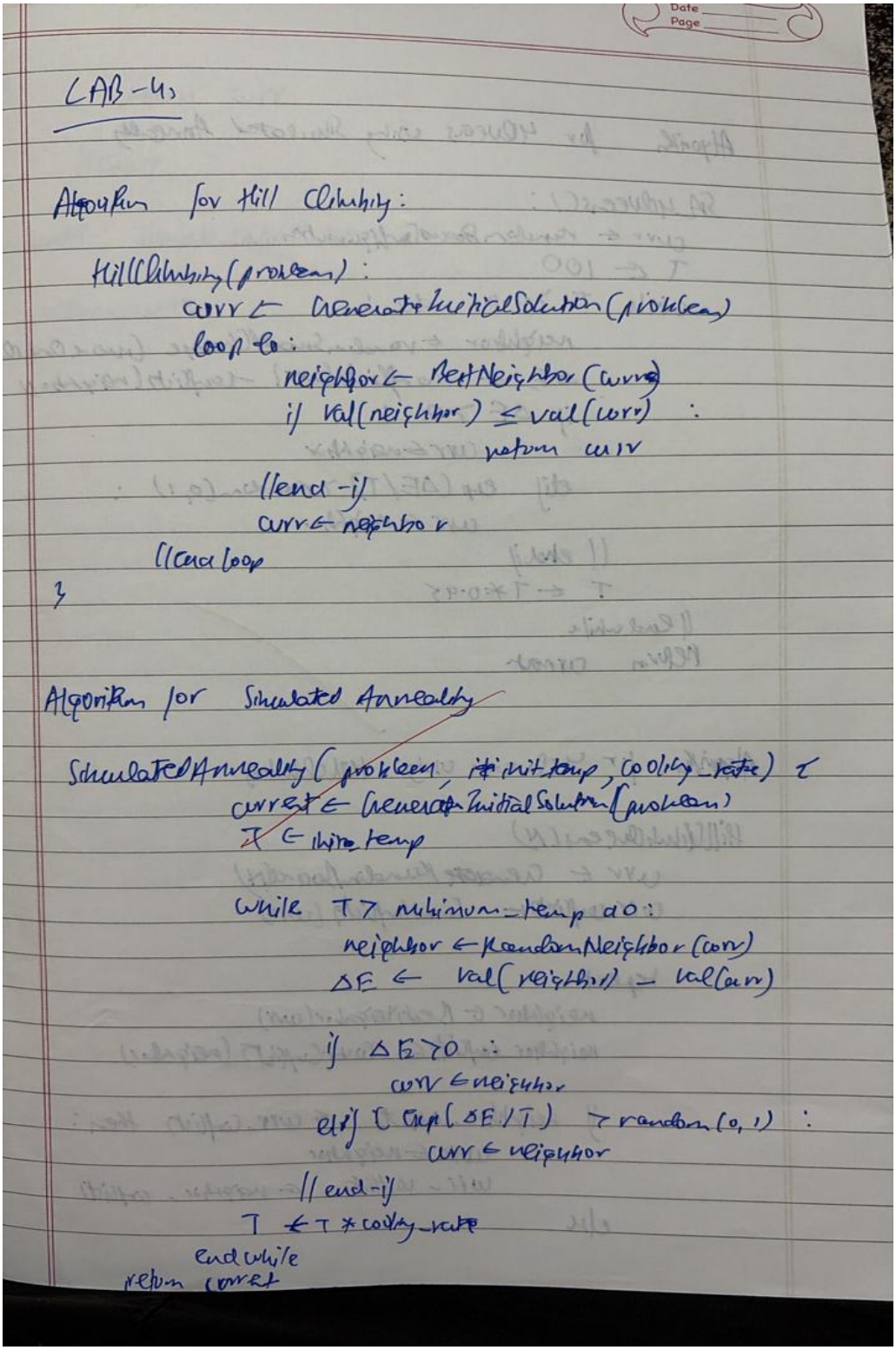
Output

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

Program 5

Simulated Annealing to Solve 8-Queens problem

Algorithm



LAB-4:

Algorithm for Hill Climbing:

```
HillClimbing(problem):
    curr ← GenerateInitialSolution(problem)
    loop do:
        neighbor ← BestNeighbor(curr)
        if val(neighbor) ≤ val(curr):
            return curr
        //end-if
        curr ← neighbor
    //end loop
}
```

Algorithm for Simulated Annealing

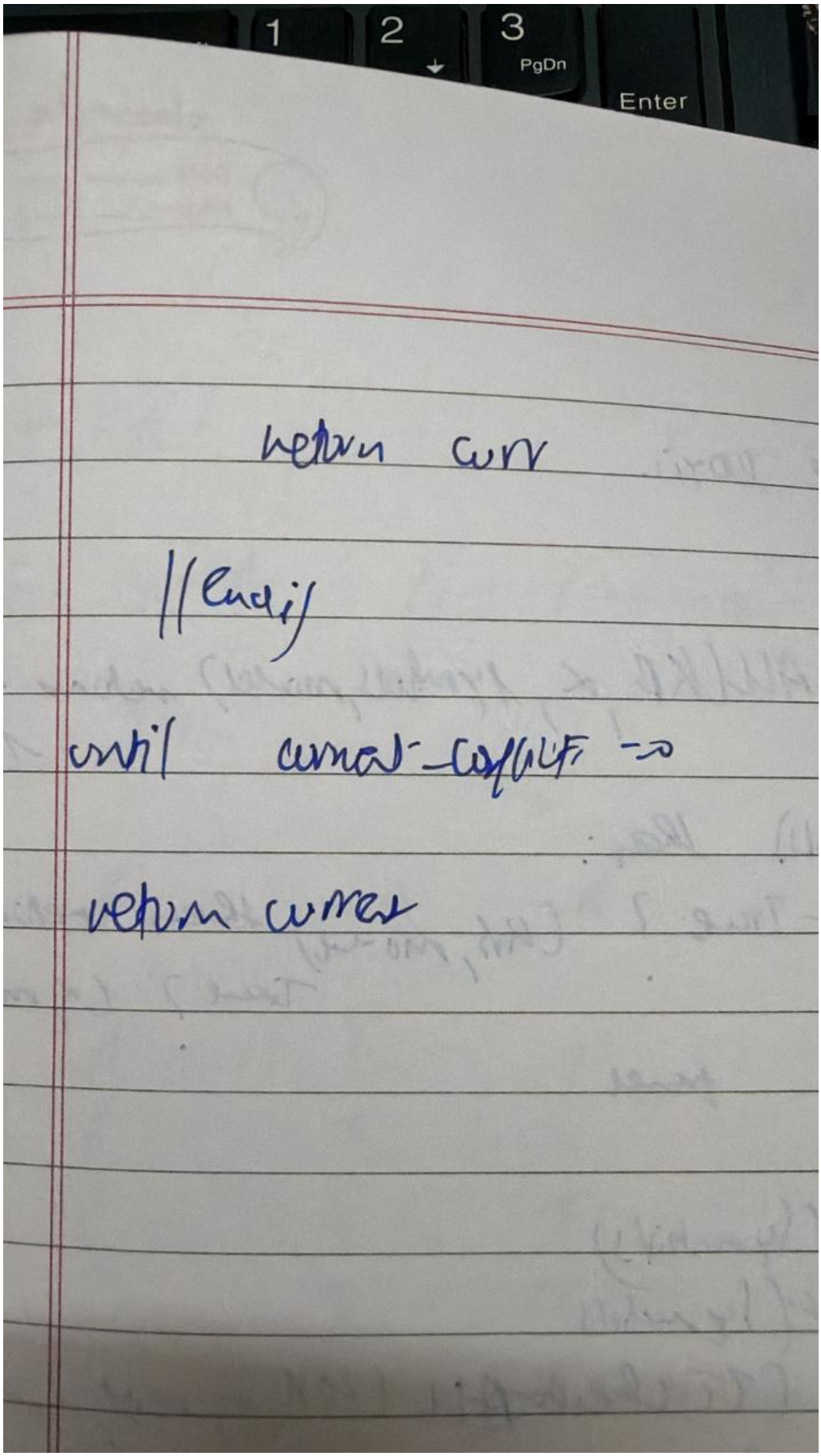
```
SimulatedAnnealing(problem, initial_temp, cooling_rate) {
    current ← GenerateInitialSolution(problem)
    T ← initial_temp

    while T > minimum_temp do:
        neighbor ← RandomNeighbor(curr)
        ΔE ← val(neighbor) − val(curr)

        if ΔE > 0:
            curr ← neighbor
        else if (exp(ΔE/T) > random(0,1):
            curr ← neighbor
        //end-if
        T ← T * cooling_rate
    end while
    return current
```

Algorithm for 4Queens using Simulated Annealing

```
SA_4Queens():
    curr ← randomBoardConfiguration
    T ← 100
    while T > 0.01 do:
        neighbor ← randomSmallChange(moveOneQueen)
        ΔE ← conflicts(curr) - conflicts(neighbor)
        if ΔE > 0:
            curr ← neighbor
        elif exp(ΔE/T) > random(0,1):
            curr ← neighbor
        // endif
        T ← T * 0.95
    // endwhile
    return curr
```

Algorithm for 4Queen using Hill Climbing:

```
HillClimbQueens(N)
    curr ← CreateRandomBoard(N)
    curr_conflicts ← CountConflicts(curr)

    repeat:
        neighbor ← BestNeighbor(curr)
        neighbor_conflicts ← CountConflicts(neighbor)

        if neighbor_conflicts < curr_conflicts then:
            curr ← neighbor
            curr_conflicts ← neighbor_conflicts
        else
```


1
2
3
PgDn
Enter
return curr
//end if
until current->left =>
return current

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, temp=100.0, cooling=0.95):

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

    temperature = temp
    cooling_rate = cooling

    best = current[:]
    best_cost = current_cost

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

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

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

```
            best, best_cost = neighbor[:], neighbor_cost

        temperature *= cooling_rate

    return best, best_cost

def print_board(state):

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


n = 8
solution, cost_val = simulated_annealing(n, max_iter=20000)
print("Best position found:", solution)
print(f"Number of non-attacking pairs: {n*(n-1)//2 - cost_val}")
print("\nBoard:")
print_board(solution)
```

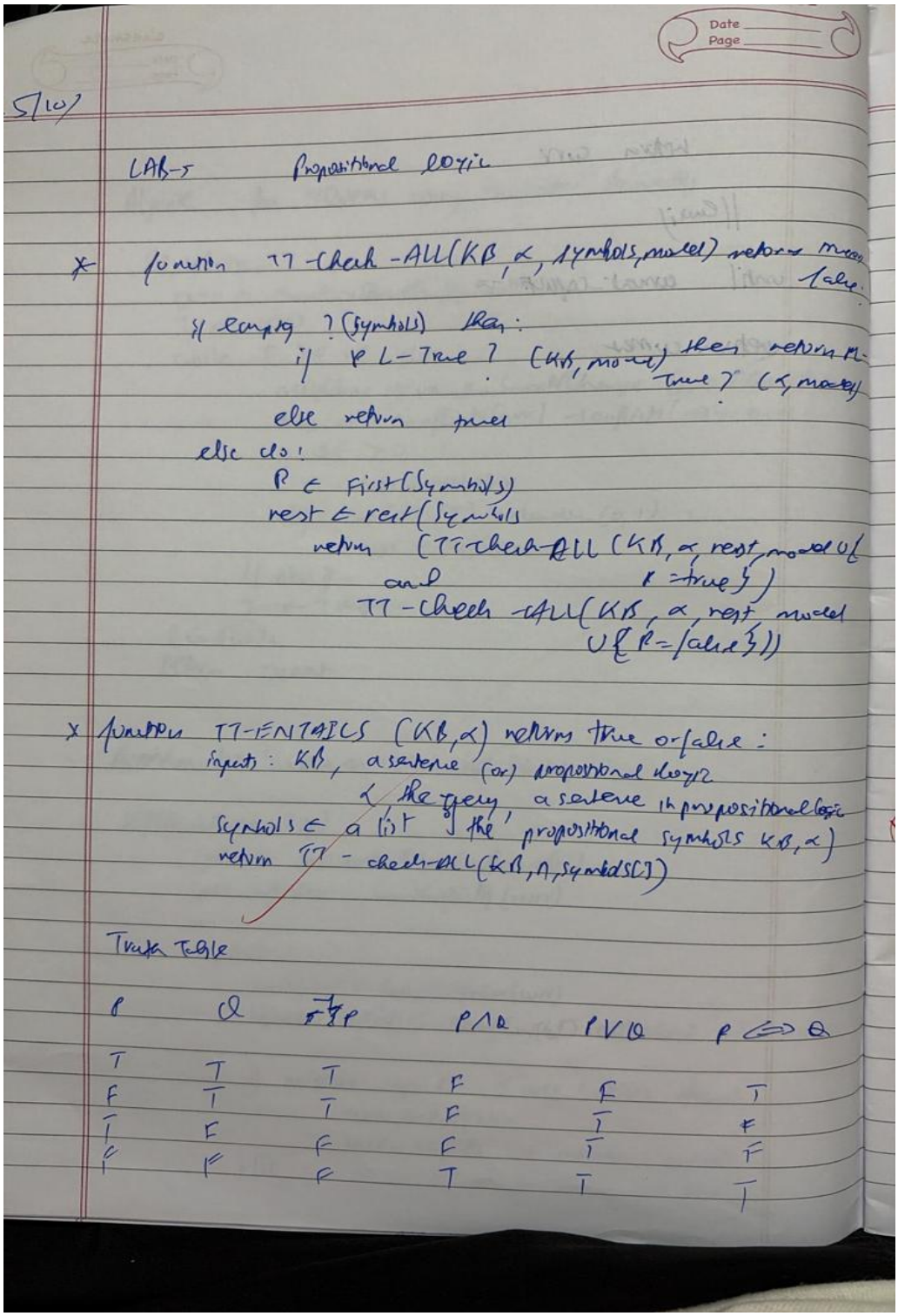
Output

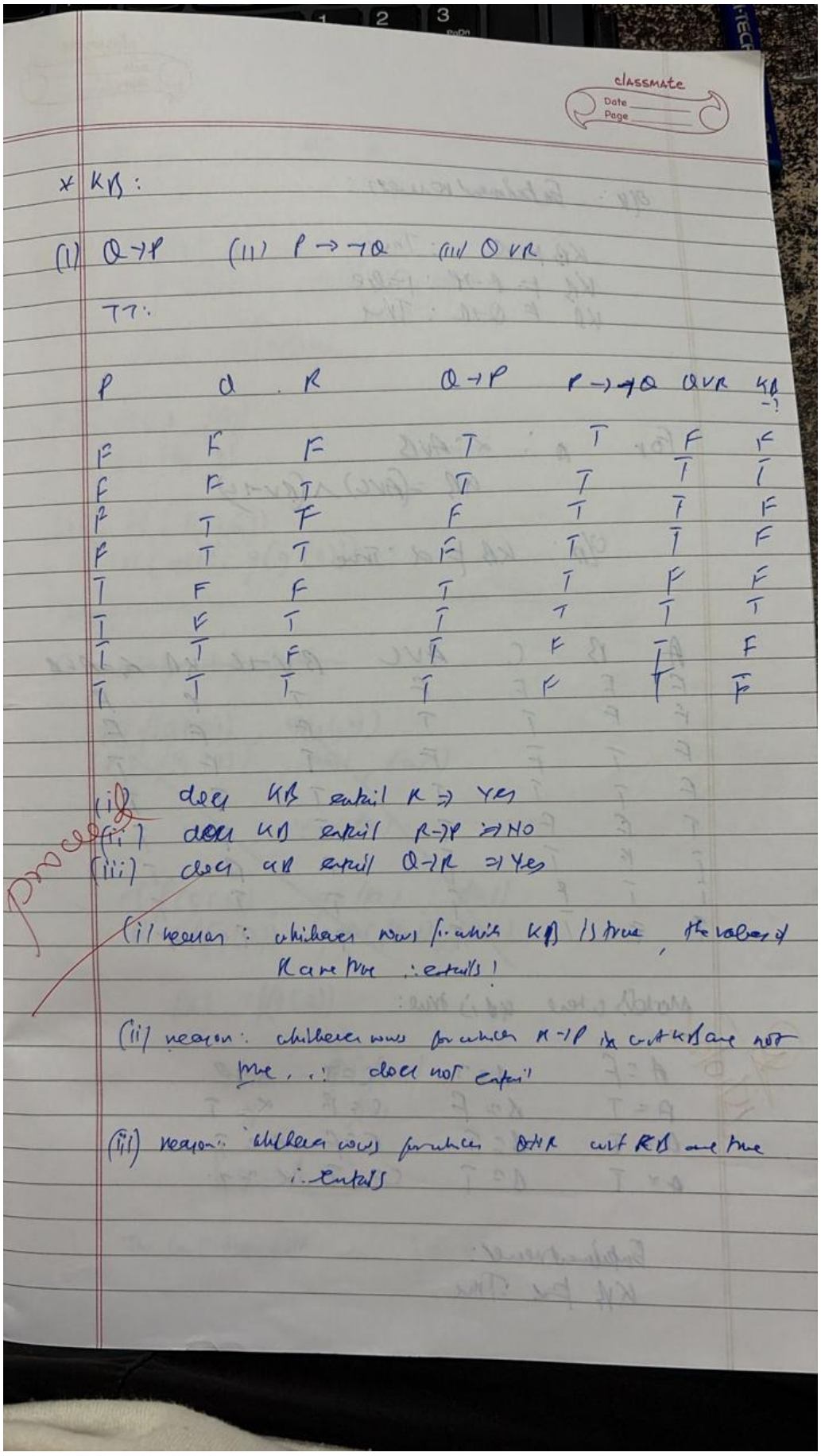
```
Best position found: [6, 3, 1, 7, 5, 0, 2, 4]
Number of non-attacking pairs: 28

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


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

Program 6

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

Algorithm





* KB:

(i) $Q \rightarrow P$ (ii) $P \rightarrow \neg Q$ (iii) $Q \vee R$

TT:

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

(i) does KB entail R ⇒ Yes

(ii) does KB entail $R \rightarrow P$ ⇒ No

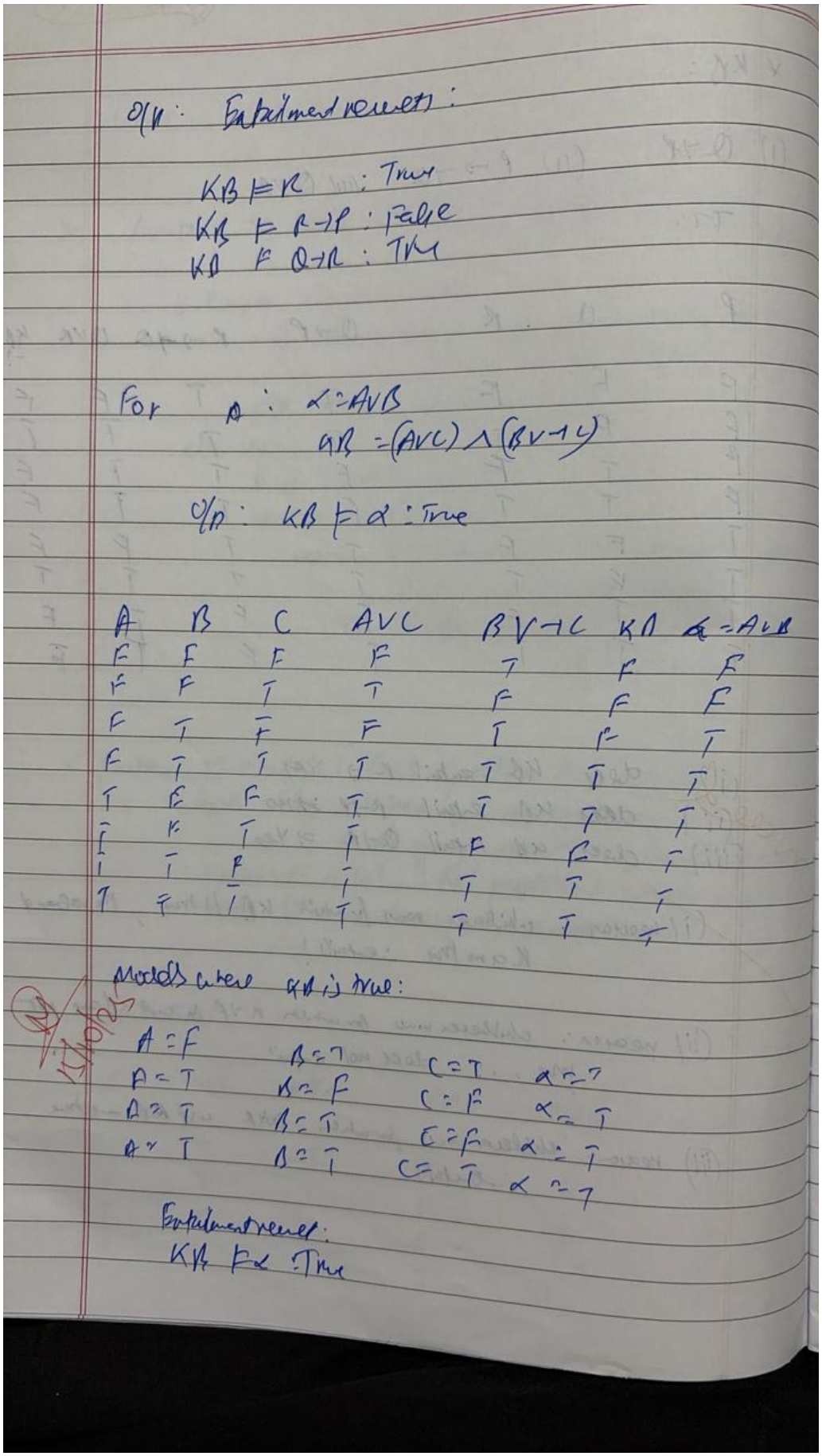
(iii) does KB entail $Q \rightarrow R$ ⇒ Yes

Proof

(i) reason: whichever rows for which KB is true, the values of R are true ∴ entails!

(ii) reason: whichever rows for which $R \rightarrow P$ is true KB are not true, ∴ does not entail

(iii) reason: whichever rows for which $Q \vee R$ and KB are true ∴ entails



Q(i): Entailment recursion:

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

For Q: α = A∨B
αβ = (A∨C) ∧ (B∨¬C)

O/P: KB ⊨ α : True

A	B	C	A∨C	B∨¬C	KB	α = A∨B
F	F	F	F	T	F	F
F	F	T	T	F	F	F
F	T	F	F	T	F	T
F	T	T	T	T	T	T
T	F	F	T	T	T	T
T	F	T	T	T	T	T
T	T	F	T	T	F	T
T	T	T	T	T	T	T

Models where KB is true:

A = F B = T C = T α = T
A = T B = F C = F α = T
A = T B = T C = F α = T
A = T B = T C = T α = T

Entailment recursion:
KB ⊨ α : True

Code

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

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

def is_entailed(KB_formula, alpha_formula, variables):
    truth_combinations = generate_truth_table(variables)
    print(f"{' '.join(variables)} | KB Result | Alpha Result")
    print("-" * (len(variables) * 2 + 15))
    for combination in truth_combinations:
        truth_assignment = dict(zip(variables, combination))
        KB_value = evaluate_formula(KB_formula, truth_assignment)
        alpha_value = evaluate_formula(alpha_formula, truth_assignment)
        result_str = " ".join(["T" if value else "F" for value in combination])
        print(f"{result_str} | {'T' if KB_value else 'F'}         | {'T' if alpha_value else 'F'}")
        if KB_value and not alpha_value:
            return False
    return True

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

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

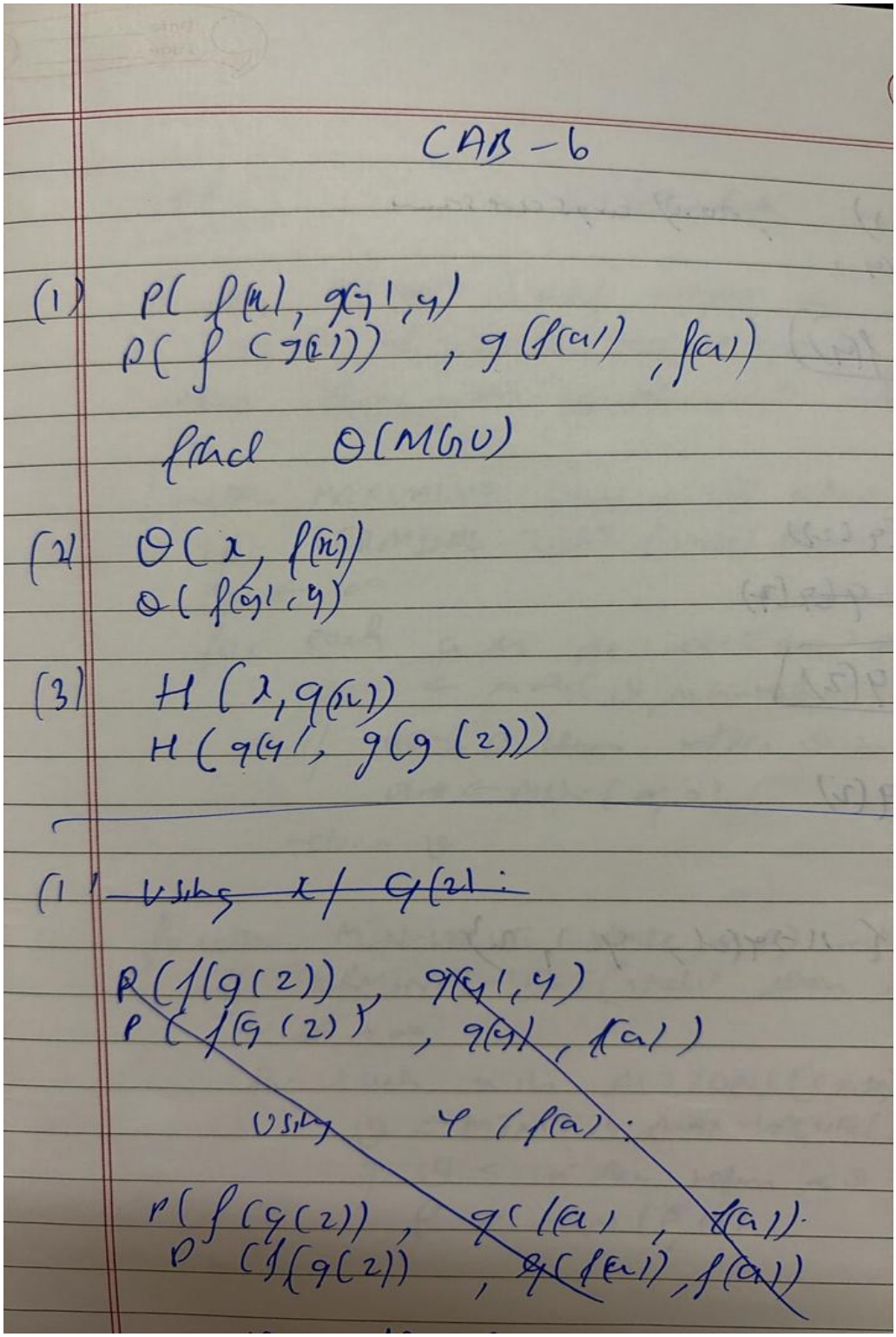
Output

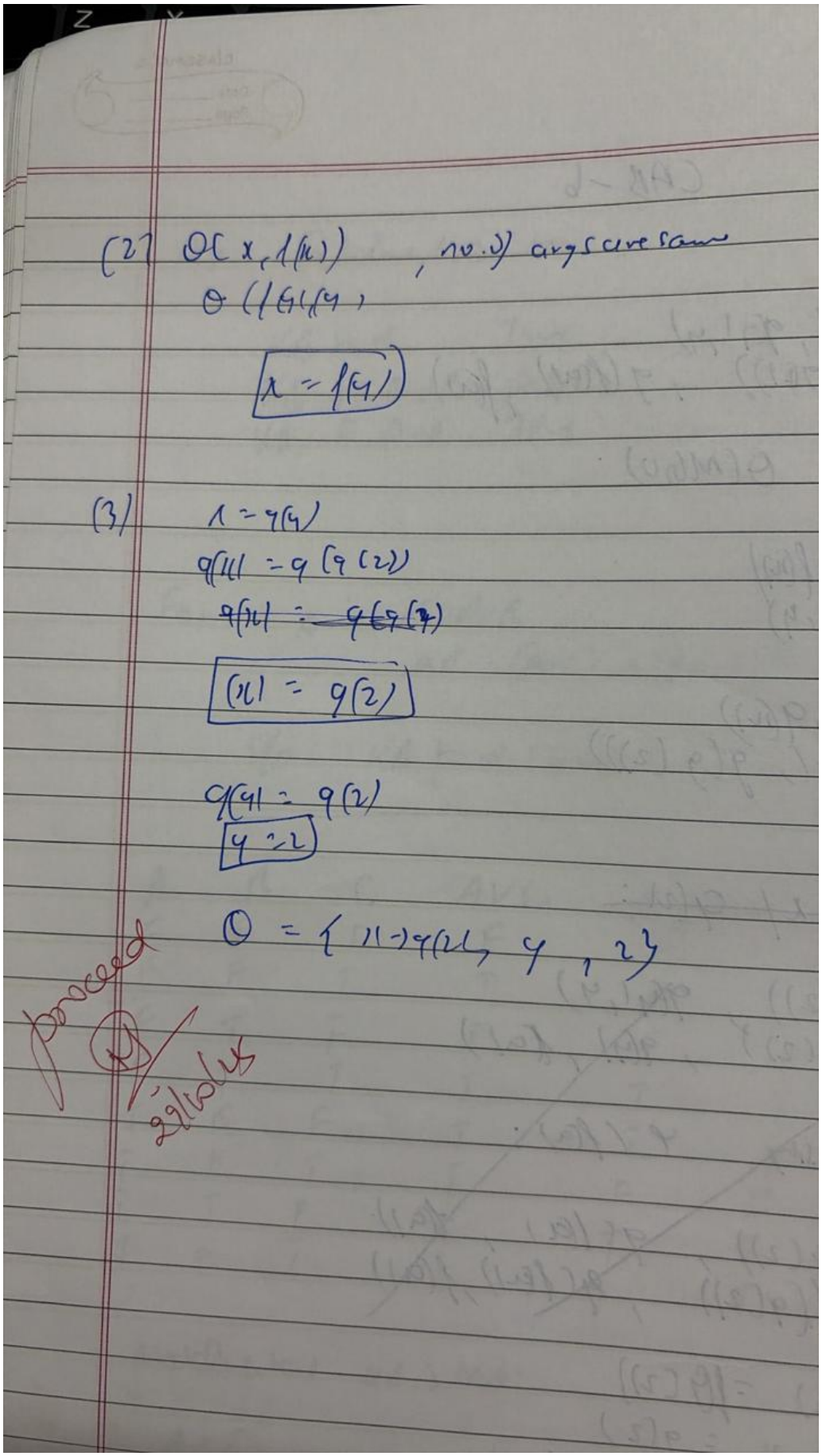
```
A B C | KB Result | Alpha Result
---------------------
F F F | F         | F
F F T | F         | F
F T F | F         | T
F T T | T         | T
T F F | T         | T
T F T | F         | T
T T F | T         | T
T T T | T         | T

The knowledge base entails alpha.
```

Program 7

Implement unification in first order logic

Algorithm

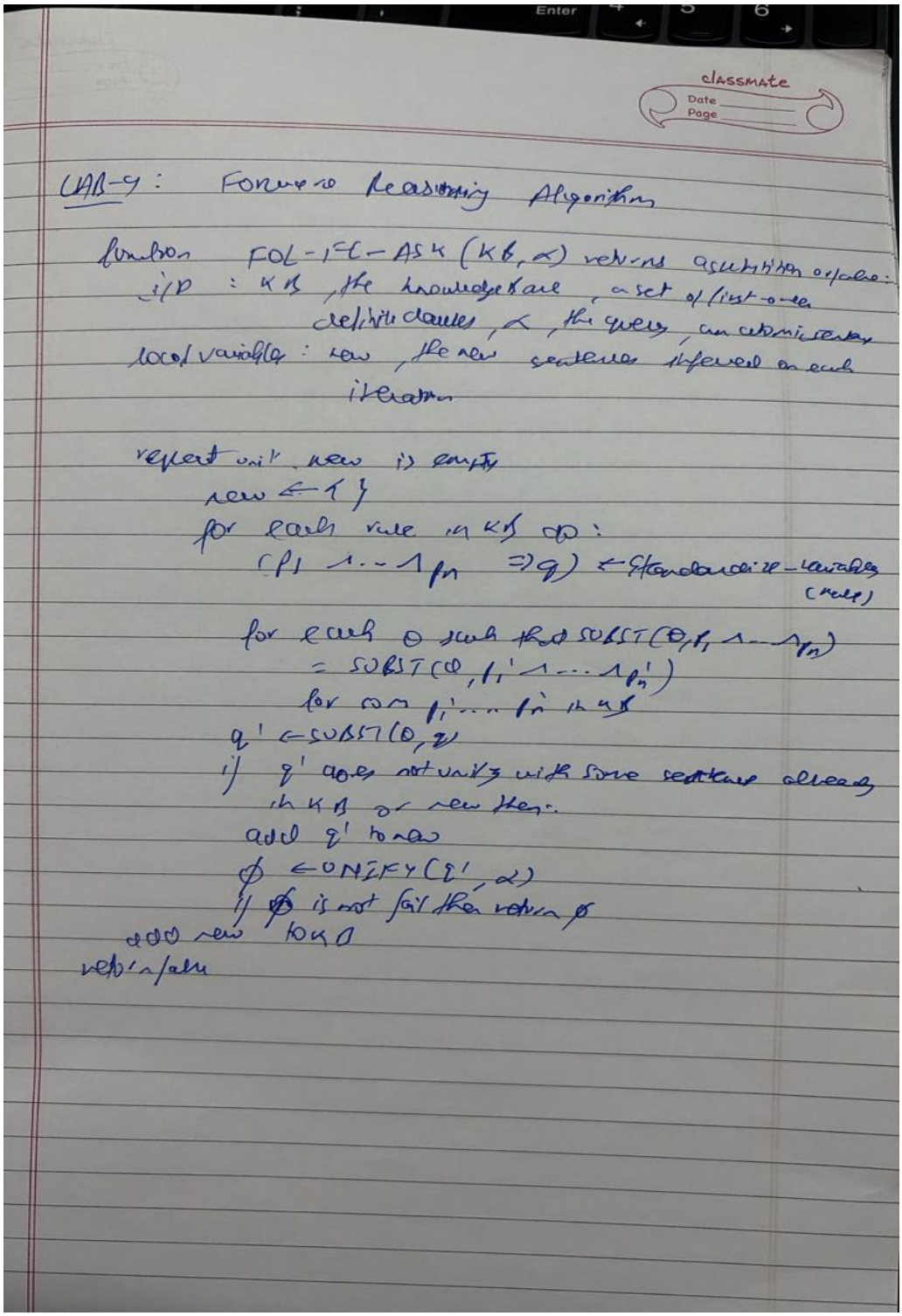



(2)
(3)
proceed
Syllabus

Program 8

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

Algorithm



Code

```
import re

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

    if pattern_pred != fact_pred:
        return None  # predicate mismatch

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

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

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


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


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

rules = [
    (["American(p)", "Weapon(q)", "Sells(p,q,r)", "Hostile(r)"], "Criminal(p)"),
```

```
    (["Missile(x)"], "Weapon(x)"),
    (["Enemy(x, America)"], "Hostile(x)"),
    (["Missile(x)", "Owns(A, x)"], "Sells(Robert, x, A)")
]

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

goal = "Criminal(Robert)"

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

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

                    break
            else:

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

                new_fact = apply_substitution(conclusion, combined)

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

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

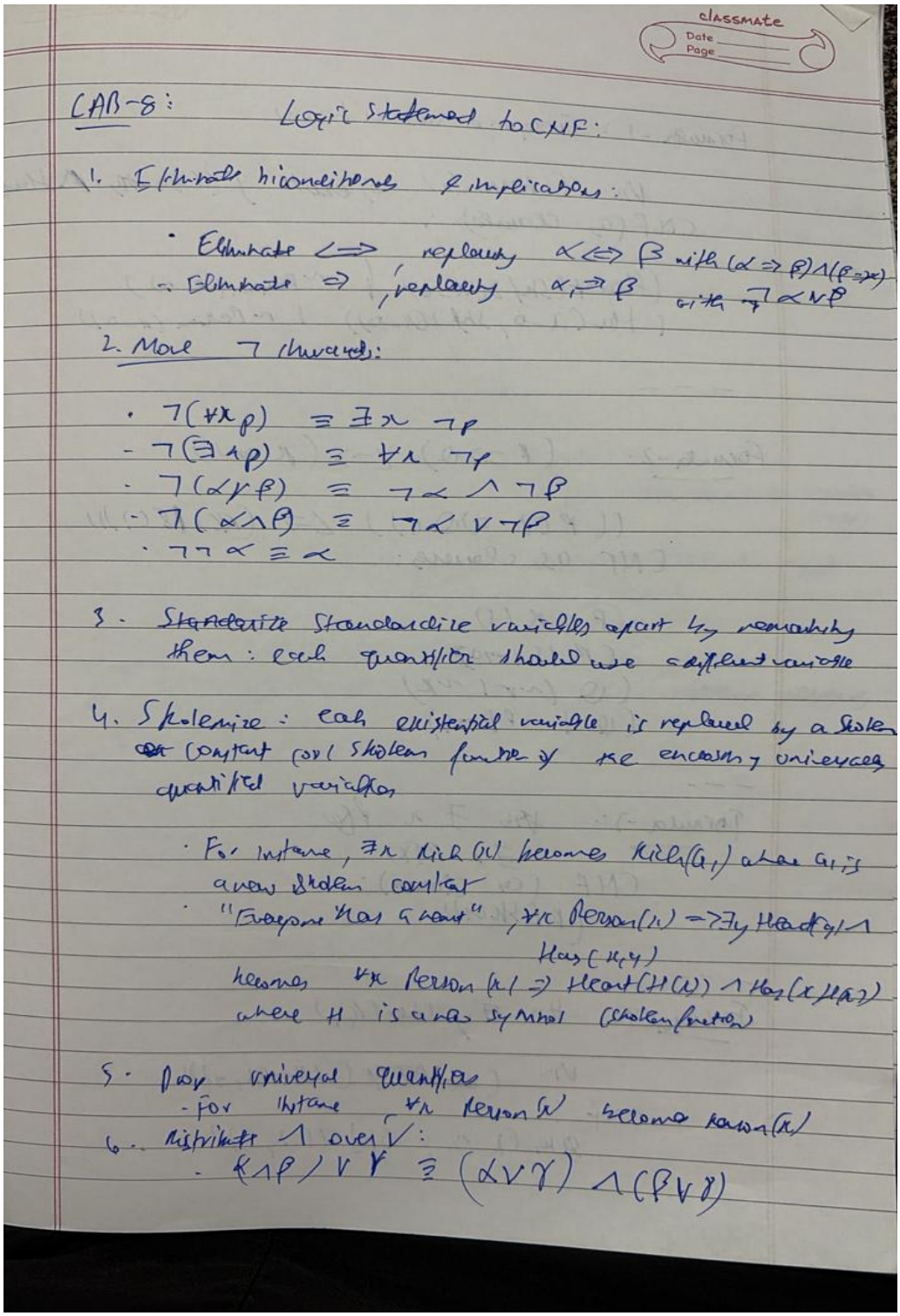
Output

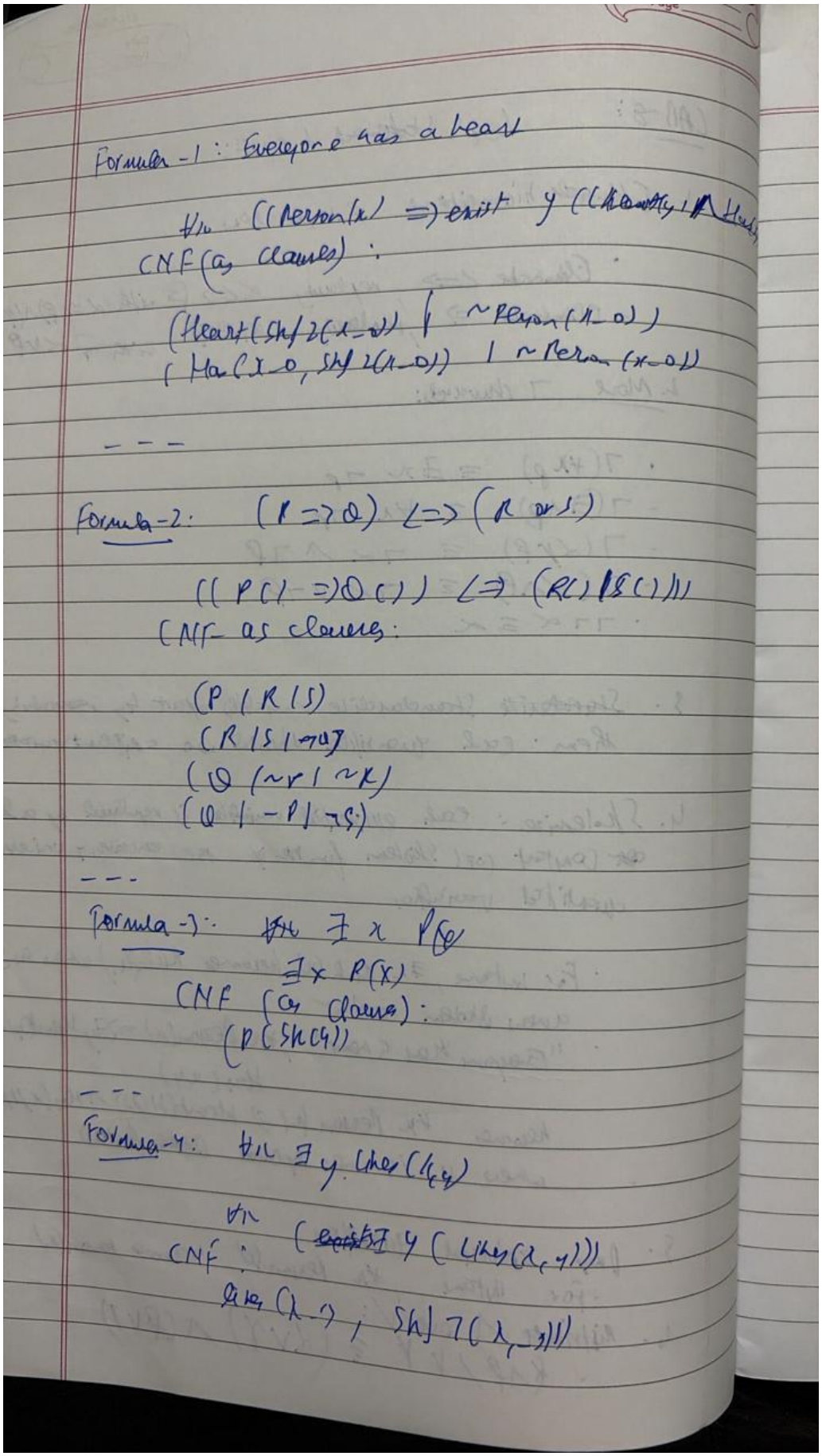
```
Inferred: Weapon(T1)
Inferred: Hostile(A)
Inferred: Sells(Robert, T1, A)
Inferred: Criminal(Robert)
Goal achieved: True
```

Program 9

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

Algorithm





Formula-1 : Everyone has a heart

∀x ((Person(x) ⇒ exist y (Heart(y) ∧ Has(x,y))

CNF (as clauses) :

(Heart(Sk1(x)) | ~Person(x))

(Has(x, Sk1(x)) | ~Person(x))

Formula-2 : (P ⇒ Q) <⇒ (P ∨ S)

((P(x) ⇒ Q(x)) <⇒ (R(x) | S(x)))

CNF as clauses :

(P | R | S)

(R | S | ~Q)

(Q | ~P | ~R)

(Q | ~P | ~S)

Formula-3 : ~~∀x~~ ∃x P(x)

∃x P(x)

CNF (as clause) :

(P(Sk(4)))

Formula-4 : ∀x ∃y Likes(x,y)

∀x (~~exist~~ ∃y (Likes(x,y)))

CNF :

(Likes(x, Sk1(x)))

Code

```
from copy import deepcopy

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

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

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

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

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

def unify(lit1, lit2):
    """Small unifier for patterns like Food(x) and Food(Apple)."""
    if "(" not in lit1 or "(" not in lit2:
        return None
    pred1, args1 = lit1.split("(")
    pred2, args2 = lit2.split("(")
    args1 = args1[:-1].split(",")
```

```
    args2 = args2[:-1].split(",")
    if pred1 != pred2 or len(args1) != len(args2):
        return None
    subs = {}
    for a, b in zip(args1, args2):
        if a == b:
            continue
        if a.islower():
            subs[a] = b
        elif b.islower():
            subs[b] = a
        else:
            return None
    return subs

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

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

    steps = []
    new = []
    while True:
        pairs = [(clauses[i], clauses[j]) for i in range(len(clauses))
```

```
            for j in range(i + 1, len(clauses))]
        for (ci, cj) in pairs:
            for r, subs, pair in resolve(ci, cj):
                if not r:
                    steps.append({
                        "parents": (ci, cj),
                        "resolvent": r,
                        "subs": subs
                    })
                    print_tree(steps)
                    print("\n☑ Empty clause derived — query proven.")
                    return True
                if r not in clauses and r not in new:
                    new.append(r)
                    steps.append({
                        "parents": (ci, cj),
                        "resolvent": r,
                        "subs": subs
                    })
        if all(r in clauses for r in new):
            print_step("No New Clauses", "Query cannot be proven ✗")
            print_tree(steps)
            return False
        clauses.extend(new)

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

        print(f"  Resolve {p1} and {p2}")
        if subs_text:
            print(subs_text)
        if r:
            print(f"  ⇒ {r}")
        else:
            print("  ⇒ {} (empty clause)")
        print("-"*45)

def main():
    print_step("Knowledge Base in CNF", KB)
    print_step("Negated Query", [negate(q) for q in QUERY])
```

```
    proven = resolution(KB, QUERY)
    if proven:
        print("\n☑ Query Proven by Resolution: John likes peanuts.")
    else:
        print("\n❌ Query cannot be proven from KB.")

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

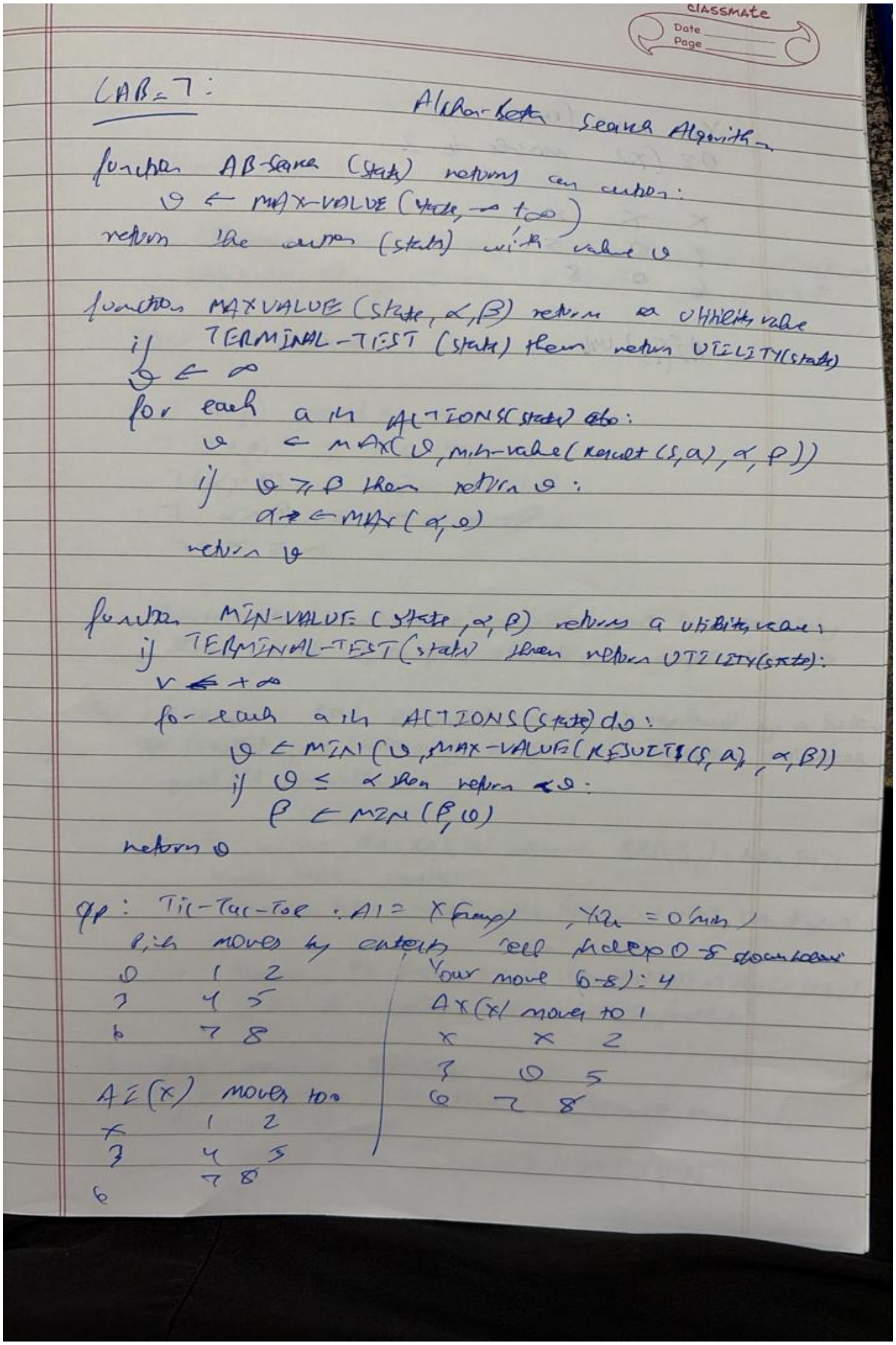
Output

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

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

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

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

Program 10

Implement Alpha-Beta Pruning

Algorithm



LAB-7: Alpha-Beta Search Algorithm

function AB-Search (state) returns an action:
  v ← MAX-VALUE (state, -∞, +∞)
return the action (state) with value v

function MAXVALUE (state, α, β) returns a utility value
  if TERMINAL-TEST (state) then return UTILITY(state)
  v ← ∞
  for each a in ACTIONS(state) do:
    v ← MAX(v, min-value(Result(s,a), α, β))
    if v ≥ β then return v:
      α ← MAX(α, v)
    return v

function MIN-VALUE (state, α, β) returns a utility value:
  if TERMINAL-TEST(state) then return UTILITY(state):
  v ← +∞
  for each a in ACTIONS(state) do:
    v ← MIN(v, MAX-VALUE(RESULTS(s, a), α, β))
    if v ≤ α then return v:
      β ← MIN(β, v)
  return v

o/p: Tic-Tac-Toe : AI = X (max), You = O (min)
  Pick moves by entering cell index 0-8 shown below

0 1 2
3 4 5
6 7 8

AI(X) moves to 0
X 1 2
3 4 5
6 7 8

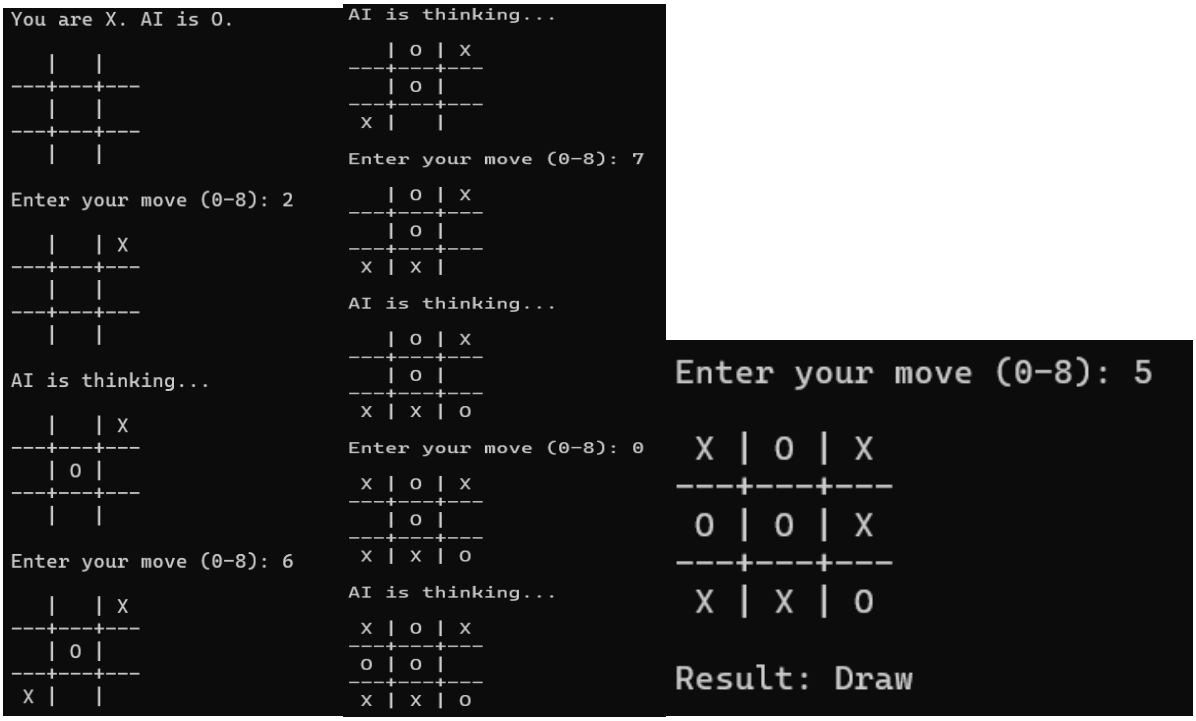
Your move (0-8): 4
AI(X) moves to 1
X X 2
3 O 5
6 7 8

Code

```
def unify(a, b):
    """Very simple unification for small terms like ('line', [X,O,X])"""
    if a == b:
        return {}
    if isinstance(a, str) and a.islower():  # variable
        return {a: b}
    if isinstance(b, str) and b.islower():
        return {b: a}
    if isinstance(a, tuple) and isinstance(b, tuple):
        if a[0] != b[0] or len(a[1]) != len(b[1]):
            return None
        subs = {}
        for x, y in zip(a[1], b[1]):
            s = unify(x, y)
            if s is None:
                return None
            subs.update(s)
        return subs
    return None


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

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

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

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

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

    moves = [i for i,c in enumerate(board) if c == '_']
    best_move = None
    if player == 'X':
        max_eval = -float('inf')
        for m in moves:
            new_board = board[:]
            new_board[m] = 'X'
            eval_, _ = alpha_beta(new_board, 'O', alpha, beta)
            if eval_ > max_eval:
                max_eval, best_move = eval_, m
            alpha = max(alpha, eval_)
            if beta <= alpha: break
        return max_eval, best_move
    else:
        min_eval = float('inf')
        for m in moves:
            new_board = board[:]
            new_board[m] = 'O'
            eval_, _ = alpha_beta(new_board, 'X', alpha, beta)
            if eval_ < min_eval:
                min_eval, best_move = eval_, m
            beta = min(beta, eval_)
            if beta <= alpha: break
        return min_eval, best_move

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

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

Output


You are X. AI is O.
Enter your move (0-8): 2
AI is thinking...
Enter your move (0-8): 6
AI is thinking...
Enter your move (0-8): 7
AI is thinking...
Enter your move (0-8): 0
AI is thinking...
Enter your move (0-8): 5
Result: Draw