VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

Subramanya J (1BM23CS343)

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

B.M.S. COLLEGE OF ENGINEERING
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BENGALURU-560019
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B.M.S. College of Engineering,
Bull Temple Road, Bangalore 560019
(Affiliated To Visvesvaraya Technological University, Belgaum)
Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Subramanya J (1BM23CS343),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

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

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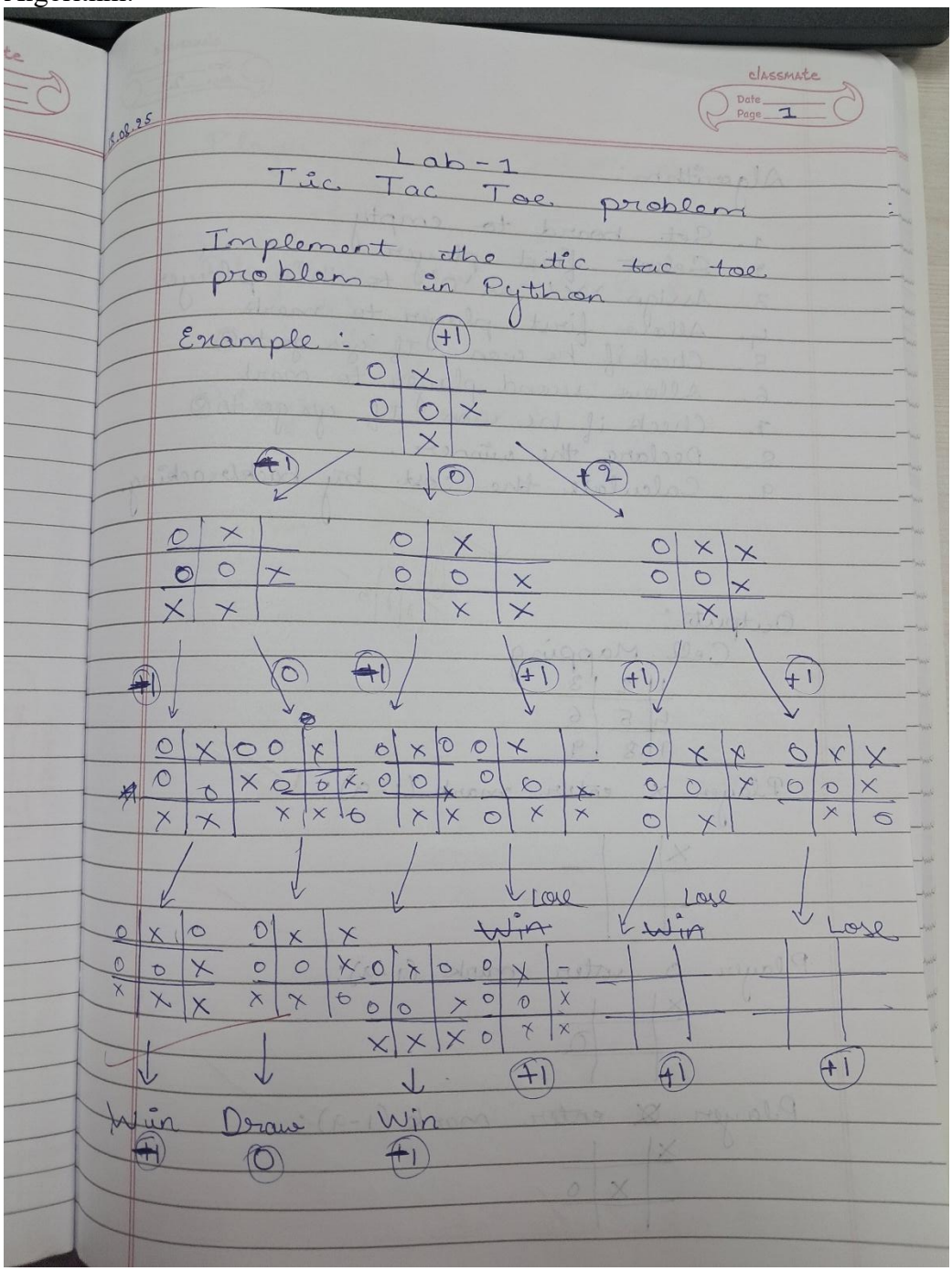
Github Link:
https://github.com/SubramanyaJ/23CS5PCAIN

Program 1
Implement Tic –Tac –Toe Game
Implement Vacuum Cleaner agent

Algorithm:



Algorithm:

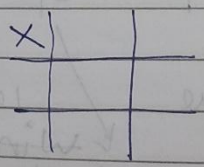
1. Set board to empty
2. Select first player.
3. Assign 'X' or 'O' to this player.
4. Allow first player to mark
5. Check if he won. If yes go to (8)
6. Allow second player to mark
7. Check if he won. If yes go to (8)
8. Declare the winner.
9. Calculate the cost by backtracking.

Output:

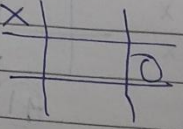
Cell Mapping

1	2	3
4	5	6
7	8	9

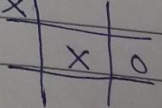
Player X enter mark (1-9):



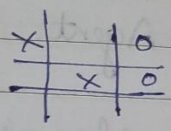
Player O enter mark (1-9):



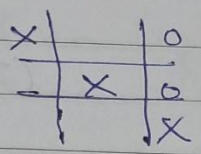
Player X enter mark (1-9):



Player O enter mark (1-9):



Player X enter mark (1-9):



Player X won!

O/P

18/8/25

Lab-2

Vacuum Cleaner Agent

Implement the vacuum cleaner agent problem in Python

Example / Algorithm : (Two Rooms)

1. Initialize the Rooms
2. Place the cleaner in a room
3. Check if the room is dirty.
4. If dirty, suck the dirt.
5. Else, move to adjacent room
6. Repeat ③ → ④ → ⑤
7. If all rooms are clean, end program.

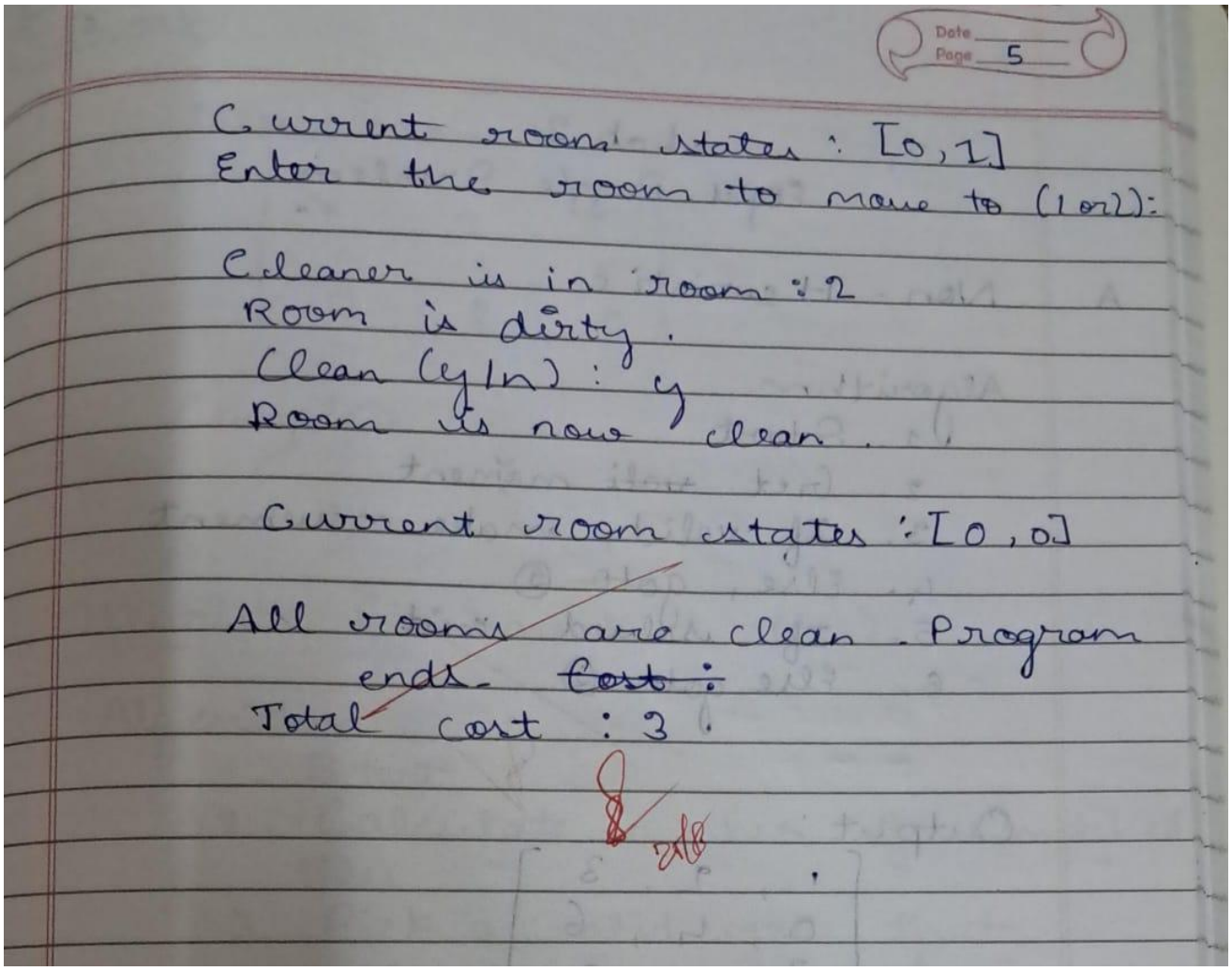
Output :

Initial states : [1, 1]
Cleaner in room 1

Cleaner is in room 1
Room is dirty
Clean? (y/n) : y
Room is now clean

Current room states : [0, 1]
Enter the room number to move to (1 or 2): 1

Cleaner is in room: 1
Room is already



Code:

```
def print_board(board):
    for row in board:
        print(" | ".join(row))
        print("-" * 9)

def print_cell_mapping():
    mapping = [
        "1 | 2 | 3",
        "- - - - - - -",
        "4 | 5 | 6",
        "- - - - - - -",
        "7 | 8 | 9"
    ]
    print("\nCell Mapping:")
    for line in mapping:
        print(line)
```

```
    print()

def check_winner(board):
    for i in range(3):
        if board[i][0] == board[i][1] == board[i][2] != " ":
            return board[i][0]
        if board[0][i] == board[1][i] == board[2][i] != " ":
            return board[0][i]

    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):
    return all(cell != " " for row in board for cell in row)

def tic_tac_toe():
    board = [[" " for _ in range(3)] for _ in range(3)]
    current_player = "X"
    print_cell_mapping()

    while True:
        print_board(board)
        move = int(input(f"Player {current_player}, enter the cell number (1-9): ")) - 1
        row, col = divmod(move, 3)

        if 0 <= move < 9 and board[row][col] == " ":
            board[row][col] = current_player
        else:
            print("Invalid move! Try again.")
            continue

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

        if is_board_full(board):
            print_board(board)
            print("It's a draw!")
            break
        current_player = "O" if current_player == "X" else "X"

tic_tac_toe()
```

Output :

```
Cell Mapping:
1 | 2 | 3
- - - - - - -
4 | 5 | 6
- - - - - - -
7 | 8 | 9

  |   |
---------
  |   |
---------
  |   |
---------
Player X, enter the cell number (1-9): 1
X |   |
---------
  |   |
---------
  |   |
---------
Player O, enter the cell number (1-9): 2
X | O |
---------
  |   |
---------
  |   |
---------
Player X, enter the cell number (1-9): 5
X | O |
---------
  | X |
---------
  |   |
---------
Player O, enter the cell number (1-9): 3
X | O | O
---------
  | X |
---------
  |   |
---------
Player X, enter the cell number (1-9): 9
X | O | O
---------
  | X |
---------
```

```
  |   | X
---------
Player X wins!
```

Code :

```
import random

rooms = [1, 1]
print(f"Initial room states: {rooms}")

cleaner_location = random.randint(0, 1)
print(f"Cleaner starts in room: {cleaner_location + 1}")

cleaned_count = 0
cost_count = 0

while cleaned_count < 2:
    print(f"\nCleaner is in room: {cleaner_location + 1}")

    if rooms[cleaner_location]:
        print("Room is dirty.")
        clean_confirm = input("Clean? (y/n): ")

        if clean_confirm == 'y':
            rooms[cleaner_location] = 0
            cleaned_count += 1
            cost_count += 1
            print("Room is now clean.")
        else:
            print("Room not cleaned.")

    else:
        print("Room is already clean.")

    print(f"Current room states: {rooms}")
    print(f"Current cost: {cost_count}")

    if cleaned_count < 2:
        while 1 == 1:
          move_to = int(input("Enter the room number to move to (1 or 2): ")) - 1
          if move_to in [0, 1]:
            cleaner_location = move_to
            cost_count += 1
            break
          else:
            print("Invalid room number. Please enter 1 or 2.")
```

```
print("\nAll rooms are clean. Program ends.")
print(f"Total cost: {cost_count}")
```

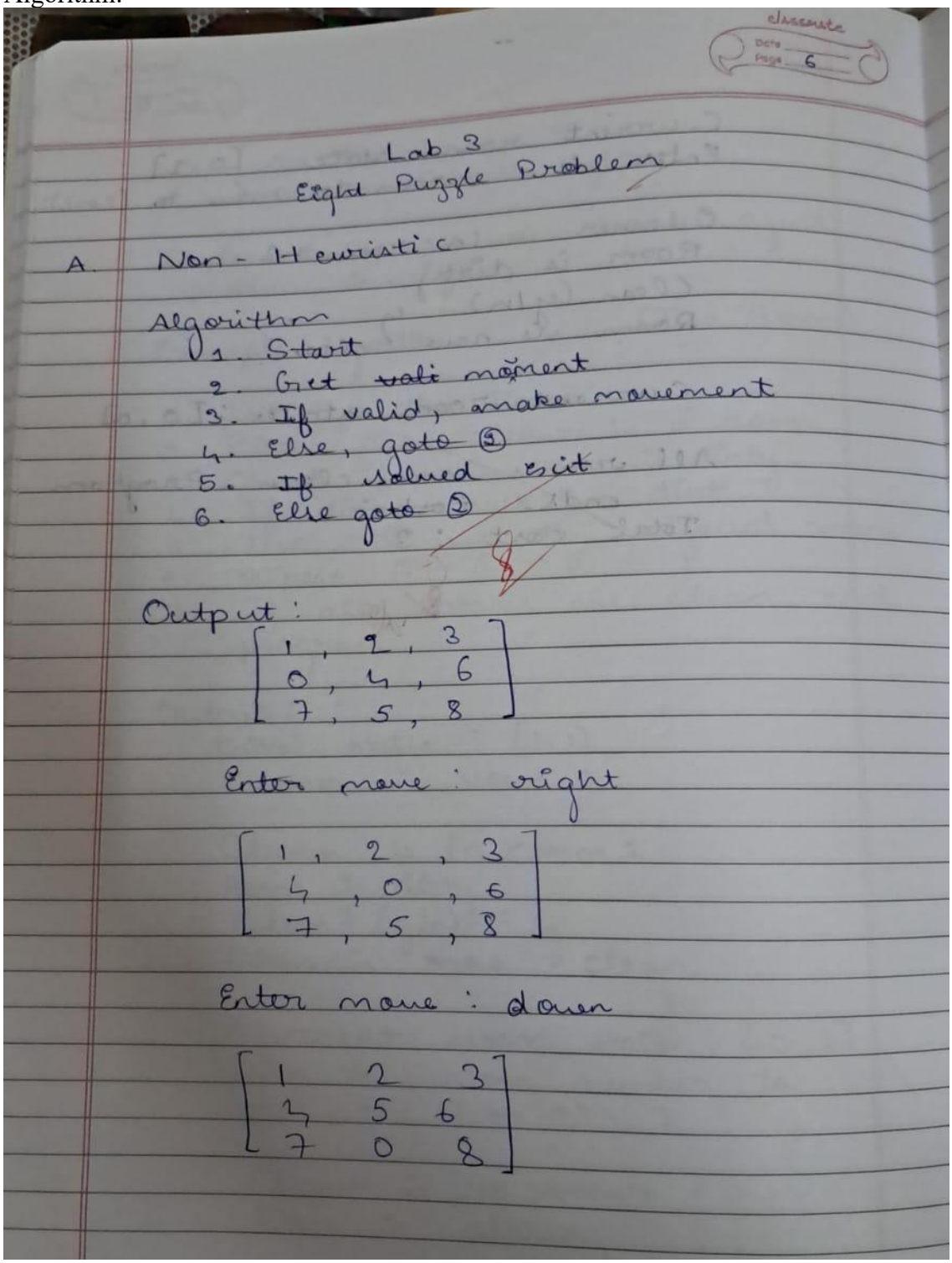
Output :

```
Initial room states: [1, 1]
Cleaner starts in room: 2

Cleaner is in room: 2
Room is dirty.
Clean? (y/n): y
Room is now clean.
Current room states: [1, 0]
Current cost: 1
Enter the room number to move to (1 or 2): 1

Cleaner is in room: 1
Room is dirty.
Clean? (y/n): y
Room is now clean.
Current room states: [0, 0]
Current cost: 3

All rooms are clean. Program ends.
Total cost: 3
```

Program 2

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

Algorithm:



Lab 3
Eight Puzzle Problem

A. Non - Heuristic

Algorithm
1. Start
2. Get ~~vali~~ movement
3. If valid, make movement
4. Else, goto (2)
5. If solved exit
6. Else goto (2)

Output :

$$\begin{bmatrix} 1 & 2 & 3 \\ 0 & 4 & 6 \\ 7 & 5 & 8 \end{bmatrix}$$

Enter move : right

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 0 & 6 \\ 7 & 5 & 8 \end{bmatrix}$$

Enter move : down

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 0 & 8 \end{bmatrix}$$

Enter move : right

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 0 \end{bmatrix}$$

Complete.

Heuristic (Mismatched tiles)

Algorithm

1. Start
2. Calculate number of mismatched tiles
3. Pick a valid move that minimizes number of mismatched tiles.
4. Repeat ③ till program ends.
5. Terminate

Complexity:

$$O(b^d)$$

b → branching factor
d → depth

Output:

Initial state :

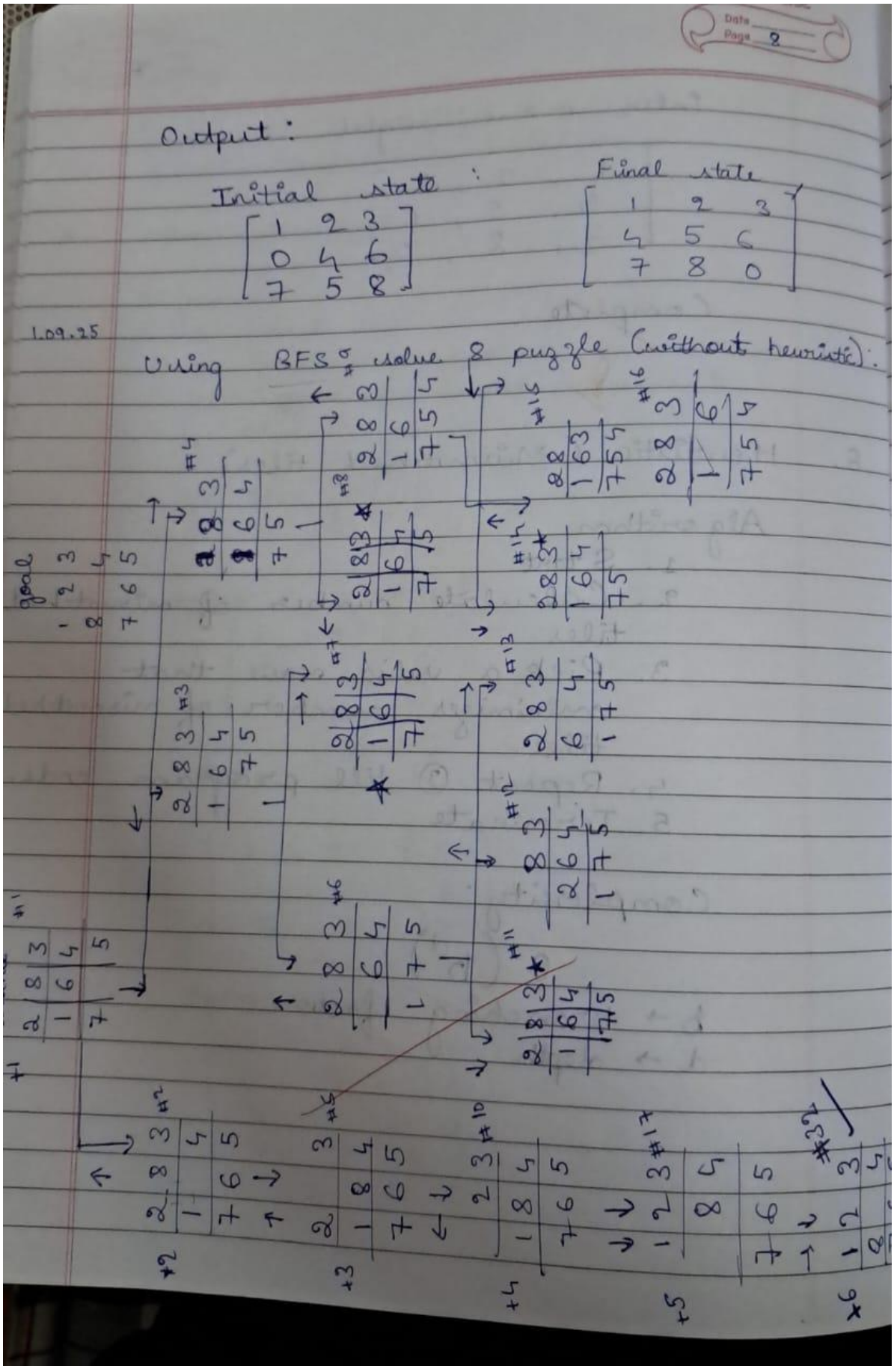
$$\begin{bmatrix} 1 & 2 & 3 \\ 0 & 4 & 6 \\ 7 & 5 & 8 \end{bmatrix}$$

Final state

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 0 \end{bmatrix}$$

1.09.25

Using BFS to solve 8 puzzle (without heuristic):



classmate
Date
Page 9

~~Using DFS:~~

initial

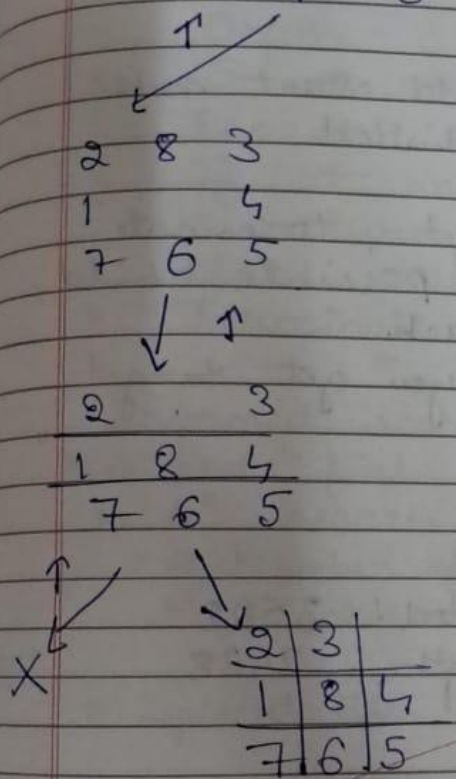
2	8	3
1	6	4
7		5

final

2	8	3
1	6	4
7	6	5

final

2	3	
1	8	4
7	6	5



Algorithm: 01.04 BFS

1. Start
2. Initialize first state to input.
3. Initialize queue and add start node to it.
4. While queue not empty, remove the node.
5. If this is target node, return
6. Else, add children to queue.

1.09.25

7) Repeat from step 2 till you get answers.
8) Terminate

Algorithm DFS

1) Start
2) Initialize stack, add start node
3) Mark node as visited
4) Pop top node
5) If this is target, terminate
6) Else, for each possible child, push onto stack
7) Repeat (2) till you get target
8) Terminate

Output [DFS]

Total states visited: 3528
Final path length: 3438
Final state:

1 2 3
8 4
7 6 5

Output [BFS]

Total states visited: 62
Final path length: 6
Final state:

1 2 3
8 4
7 6 5

2.25

Iterative Deepening Depth First Search

Algorithm

1. Start.
2. Depth = 0 initialize
3. Start at root
4. Repeat : Run DLS to current depth
5. If at any point target found, return length
6. Else, report failure
7. Terminate

×

Informed search strategies:

× 1) Best first search
2) A* search
   a) Number of misplaced tiles
   b) Manhattan distance

2.25

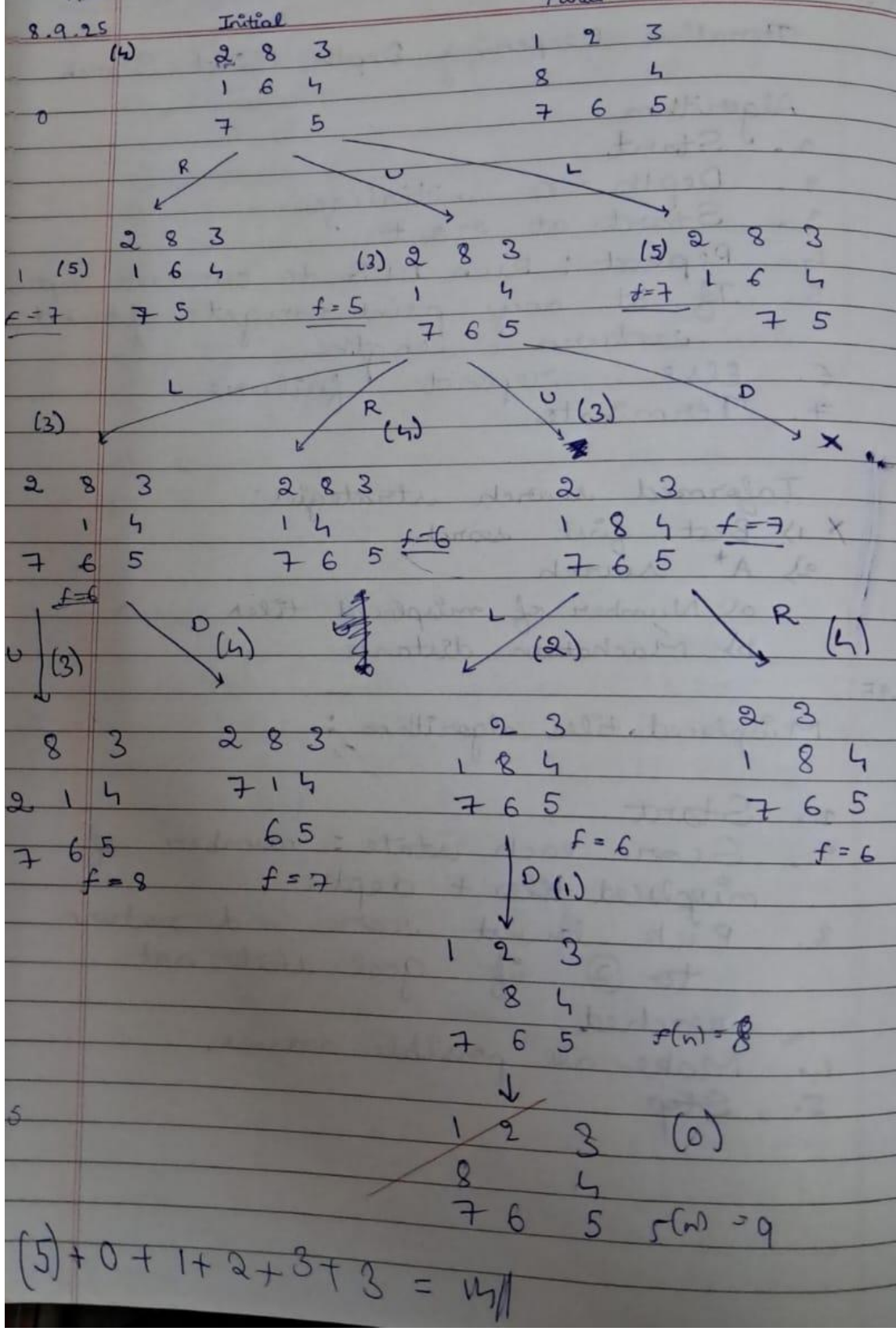
Misplaced tiles algorithm:

1. Start
2. Score each state : number of misplaced tiles + depth
3. Pick lowest score and return to (2) if goal state not reached.
4. Make all possible moves.
5. Stop

Misplaced Tiles

8.9.25

Initial



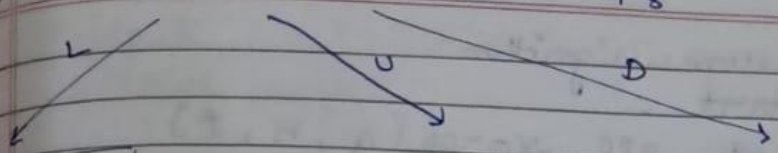
Initial

1	5	8
3	2	
4	6	7

→

Final

1	2	3
4	5	6
7	8	



1	5	8
3	2	
4	6	7

→

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

$f(n) = h(n) + g(n)$

Level No of moves

1	2	3	4	5	6	7	8	
0	1	3	1	1	2	2	3	=13

1	5	8
3	2	
4	6	7

D → U → R ↓

1	5	
3	2	8
4	6	7

$g(n) = 12$

$f(n) = 13$

1	5	8
3	2	
4	6	7

$g(n) = 14$

$f(n) = 15$

1	5	8
3	2	7
4	6	

$g(n) = 14$

$f(n) = 15$

Level 1

↓ R

Level 2

1		5
3	2	8
4	6	7

$g(n) = 13$

$f(n) = 15$

U →

1	2	5
3		8
4	6	7

$g(n) = 12$

$f(n) = 15$

Code:
Eight Puzzle

```
def swap(arr, x1, y1, x2, y2):
    arr[x1][y1], arr[x2][y2] = arr[x2][y2], arr[x1][y1]

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

zero_pos = [1, 0]

def print_puzzle(arr):
    for row in arr:
        print(row)
    print("-" * 10)

moves = {
    'up': (-1, 0),
    'down': (1, 0),
    'left': (0, -1),
    'right': (0, 1)
}

while final != arr:
    print_puzzle(arr)
    move = input("Enter move (up, down, left, right): ").lower()

    dx, dy = moves[move]
    new_x, new_y = zero_pos[0] + dx, zero_pos[1] + dy

    if 0 <= new_x < 3 and 0 <= new_y < 3:
      swap(arr, zero_pos[0], zero_pos[1], new_x, new_y)
      zero_pos[0], zero_pos[1] = new_x, new_y
    else:
      print("Invalid move.")
print("Complete")
```

Output :

```
[1, 2, 3]
[0, 4, 6]
[7, 5, 8]
----------
Enter move (up, down, left, right): right
[1, 2, 3]
[4, 0, 6]
[7, 5, 8]
----------
Enter move (up, down, left, right): down
```

```
[1, 2, 3]
[4, 5, 6]
[7, 0, 8]
----------
Enter move (up, down, left, right): right
Complete
```

Eight puzzle with heuristic

```
import copy
def swap(arr, x1, y1, x2, y2):
    arr[x1][y1], arr[x2][y2] = arr[x2][y2], arr[x1][y1]

def get_zero_pos(arr):
    for r in range(len(arr)):
        for c in range(len(arr[r])):
            if arr[r][c] == 0:
                return [r, c]
    return None
def print_puzzle(arr):
    for row in arr:
        print(row)
    print("-" * 10)

def count_mismatched_tiles(current_arr, final_arr):
    count = 0
    for r in range(len(current_arr)):
        for c in range(len(current_arr[r])):
            if current_arr[r][c] != final_arr[r][c] and current_arr[r][c] != 0:
                count += 1
    return count

def solve_puzzle_heuristic(initial_arr, final_arr):
    open_list = [(initial_arr, [initial_arr], get_zero_pos(initial_arr))]
    closed_set = set()
    moves = {'up': (-1, 0), 'down': (1, 0), 'left': (0, -1), 'right': (0, 1)}
    while open_list:
        open_list.sort(key=lambda item: count_mismatched_tiles(item[0], final_arr))
        current_arr, path, zero_pos = open_list.pop(0)
        if current_arr == final_arr:
            return path
        current_tuple = tuple(tuple(row) for row in current_arr)
        if current_tuple in closed_set:
            continue
        closed_set.add(current_tuple)
        for move, (dx, dy) in moves.items():
            new_x, new_y = zero_pos[0] + dx, zero_pos[1] + dy
            if 0 <= new_x < 3 and 0 <= new_y < 3:
```

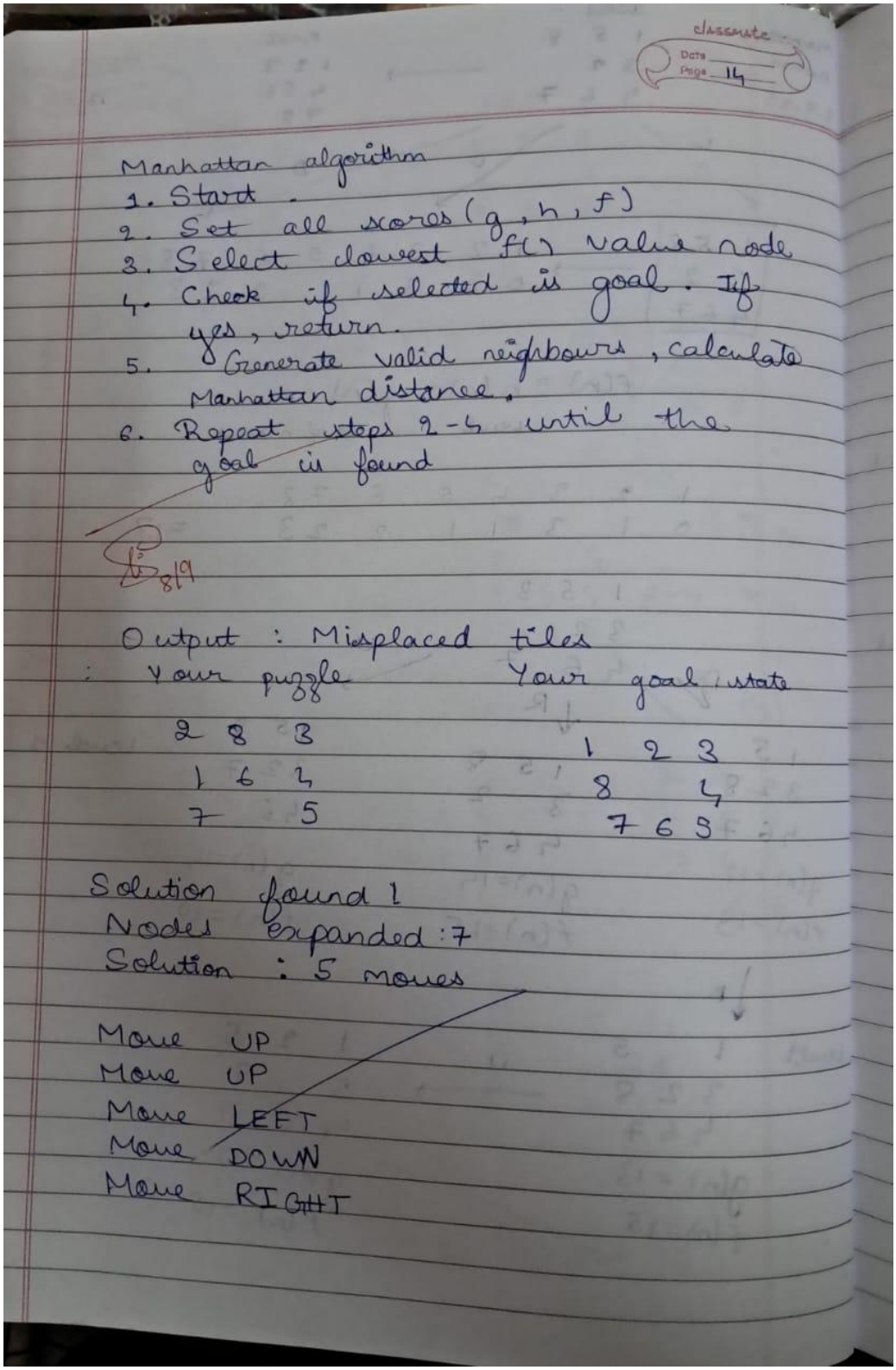
```
            new_arr = copy.deepcopy(current_arr)
            swap(new_arr, zero_pos[0], zero_pos[1], new_x, new_y)
            new_path = path + [new_arr]
            new_zero_pos = [new_x, new_y]
            open_list.append((new_arr, new_path, new_zero_pos))
    return None

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

print("Initial State:")
print_puzzle(initial_state)

solution_path = solve_puzzle_heuristic(initial_state, final_state)

if solution_path:
    print("Solution Found:")
    for step in solution_path:
        print_puzzle(step)
    print("Complete")
else:
    print("No solution exists for this puzzle.")
```

Output :

```
Initial State:
[1, 2, 3]
[0, 4, 6]
[7, 5, 8]
----------
Solution Found:
[1, 2, 3]
[0, 4, 6]
[7, 5, 8]
----------
[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]
----------
Complete
```

Program 3

Implement A* search algorithm



Manhattan algorithm

1. Start.
2. Set all scores (g, h, f)
3. Select lowest f() value node
4. Check if selected is goal. If yes, return.
5. Generate valid neighbours, calculate Manhattan distance.
6. Repeat steps 2-5 until the goal is found

8!/9

Output : Misplaced tiles

Your puzzle	Your goal state
2 8 3	1 2 3
1 6 4	8 4
7 5	7 6 5

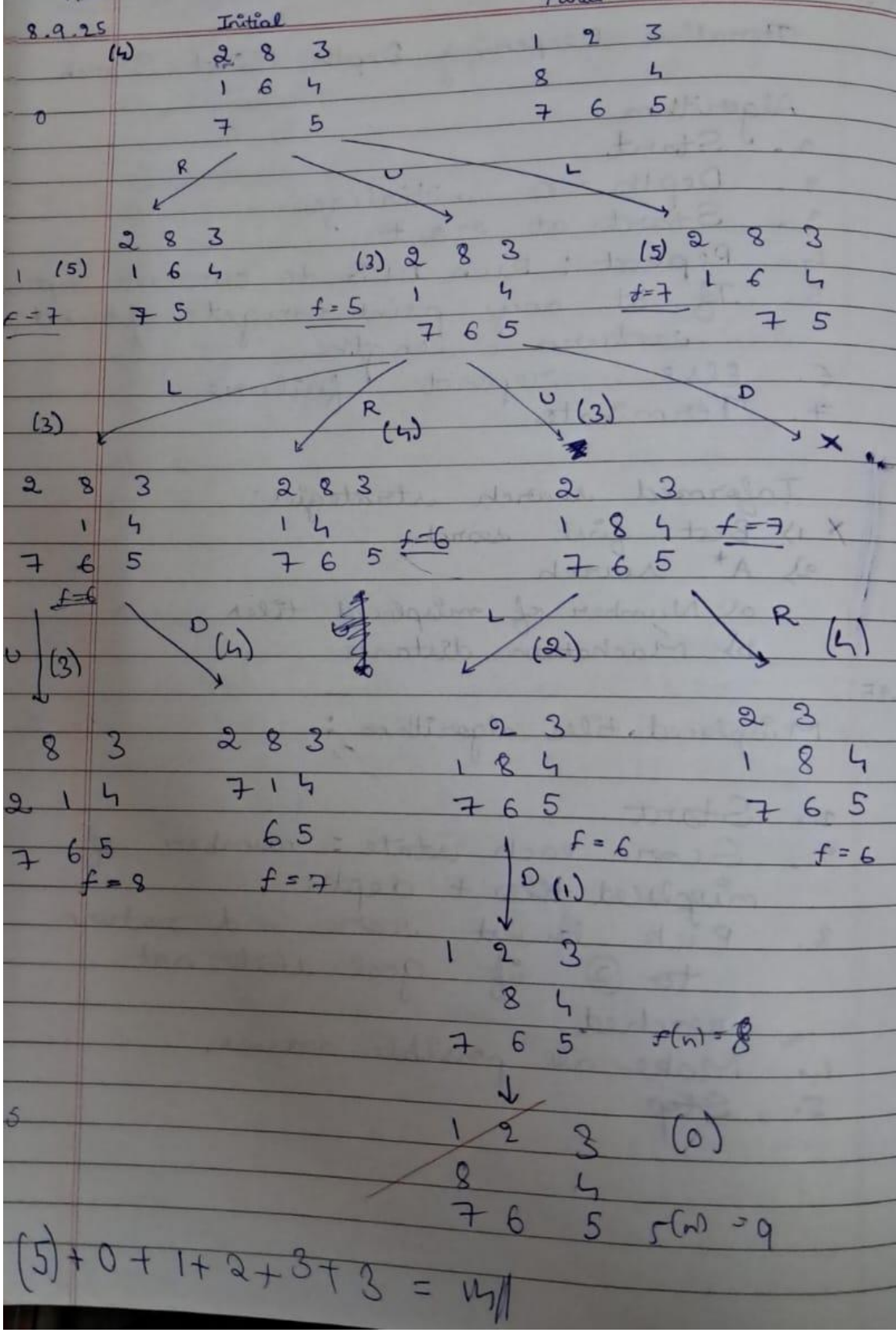
Solution found !
Nodes expanded : 7
Solution : 5 moves

Move UP
Move UP
Move LEFT
Move DOWN
Move RIGHT

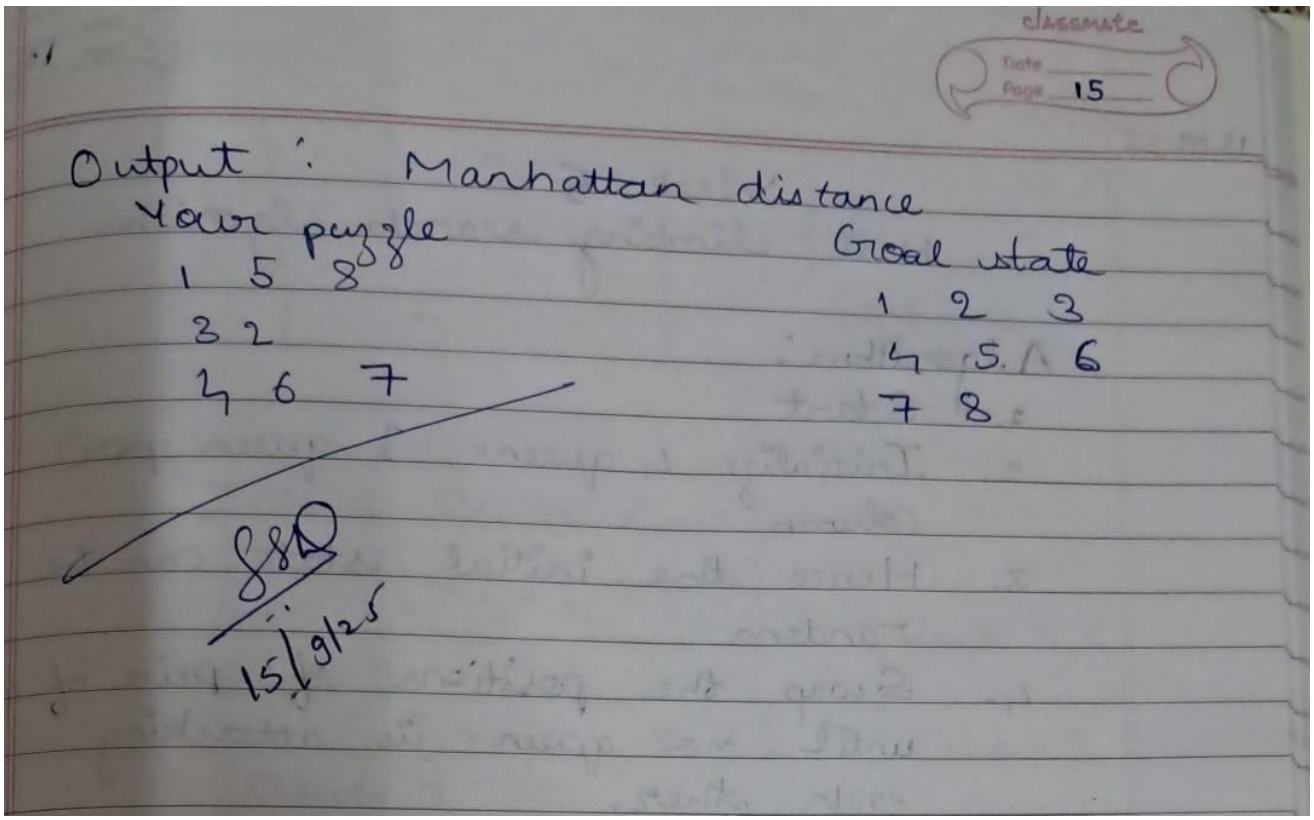
Misplaced Tiles

8.9.25

Initial



(5) + 0 + 1 + 2 + 3 + 3 = 14//



Code :

```
def find_empty(board):
    """Find position of empty tile (0)"""
    for i in range(3):
        for j in range(3):
            if board[i][j] == 0:
                return i, j
    return 0, 0

def is_goal(board, goal_board):
    """Check if current state is goal state"""
    return board == goal_board

def copy_board(board):
    """Create a copy of the board"""
    new_board = []
    for i in range(3):
        row = []
        for j in range(3):
            row.append(board[i][j])
        new_board.append(row)
    return new_board
```

```
def get_neighbors(board):
    """Get all possible next states"""
    neighbors = []
    empty_row, empty_col = find_empty(board)

    # Try all 4 directions: up, down, left, right
    directions = [(-1, 0, "UP"), (1, 0, "DOWN"), (0, -1, "LEFT"), (0, 1, "RIGHT")]

    for dr, dc, move_name in directions:
        new_row = empty_row + dr
        new_col = empty_col + dc

        # Check if move is within bounds
        if 0 <= new_row < 3 and 0 <= new_col < 3:
            # Create new board by copying current board
            new_board = copy_board(board)

            # Swap empty tile with adjacent tile
            new_board[empty_row][empty_col] = new_board[new_row][new_col]
            new_board[new_row][new_col] = 0

            neighbors.append((new_board, move_name))

    return neighbors

def misplaced_tiles_heuristic(board, goal_board):
    """Count number of tiles in wrong position"""
    count = 0

    for i in range(3):
        for j in range(3):
            if board[i][j] != 0 and board[i][j] != goal_board[i][j]:
                count += 1

    return count

def manhattan_distance_heuristic(board, goal_board):
    """Calculate Manhattan distance for each tile"""
    # Goal positions for each number
    goal_positions = {}
    for i in range(3):
        for j in range(3):
            goal_positions[goal_board[i][j]] = (i, j)

    total_distance = 0

    for i in range(3):
```

```
        for j in range(3):
            if board[i][j] != 0:  # Don't calculate for empty tile
                goal_row, goal_col = goal_positions[board[i][j]]
                distance = abs(i - goal_row) + abs(j - goal_col)
                total_distance += distance

    return total_distance

def print_board(board):
    """Print the board nicely"""
    print(" ┌─────────────┐ ")
    for row in board:
        print(" │ ", end="")
        for cell in row:
            if cell == 0:
                print("   ", end="")
            else:
                print(f" {cell} ", end="")
        print(" │ ")
    print(" └─────────────┘ ")

def board_to_string(board):
    """Convert board to string for comparison"""
    result = ""
    for row in board:
        for cell in row:
            result += str(cell)
    return result

def find_min_f_cost(open_list):
    """Find node with minimum f cost in open list"""
    min_f = float('inf')
    min_index = -1

    for i in range(len(open_list)):
        if open_list[i]['f_cost'] < min_f:
            min_f = open_list[i]['f_cost']
            min_index = i

    return min_index

def reconstruct_path(node):
    """Reconstruct path from goal to start"""
    path = []
    current = node

    while current['parent'] is not None:
```

```
        path.append({'board': current['board'], 'move': current['move']})
        current = current['parent']

    path.reverse()
    return path

def a_star_solver(start_board, goal_board, heuristic_type):
    """A* algorithm implementation"""

    # Choose heuristic function
    if heuristic_type == 1:
        heuristic_func = misplaced_tiles_heuristic
        heuristic_name = "Misplaced Tiles"
    else:
        heuristic_func = manhattan_distance_heuristic
        heuristic_name = "Manhattan Distance"

    print(f"\nUsing {heuristic_name} heuristic")
    print("="*40)

    # Check if already solved
    if is_goal(start_board, goal_board):
        print("Puzzle already solved!")
        return

    # Initialize open and closed lists
    open_list = []
    closed_list = []

    # Create start node
    start_node = {
        'board': start_board,
        'g_cost': 0,
        'h_cost': heuristic_func(start_board, goal_board),
        'f_cost': 0,
        'parent': None,
        'move': "START"
    }
    start_node['f_cost'] = start_node['g_cost'] + start_node['h_cost']

    open_list.append(start_node)
    nodes_expanded = 0

    while len(open_list) > 0:
        # Find node with minimum f cost
        current_index = find_min_f_cost(open_list)
        current_node = open_list.pop(current_index)
```

```
closed_list.append(current_node)
nodes_expanded += 1

# Check if goal reached
if is_goal(current_node['board'], goal_board):
    print(f"Solution found! Nodes expanded: {nodes_expanded}")
    print(f"Solution length: {current_node['g_cost']} moves\n")

    # Reconstruct and print path
    path = reconstruct_path(current_node)

    print("Solution path:")
    print("Initial state:")
    print_board(start_board)

    for step, state in enumerate(path):
        print(f"\nStep {step + 1}: Move {state['move']}")
        print_board(state['board'])

    return

# Get neighbors
neighbors = get_neighbors(current_node['board'])

for neighbor_board, move in neighbors:
    # Check if neighbor is in closed list
    neighbor_string = board_to_string(neighbor_board)
    in_closed = False

    for closed_node in closed_list:
        if board_to_string(closed_node['board']) == neighbor_string:
            in_closed = True
            break

    if in_closed:
        continue

    # Calculate costs
    g_cost = current_node['g_cost'] + 1
    h_cost = heuristic_func(neighbor_board, goal_board)
    f_cost = g_cost + h_cost

    # Check if neighbor is in open list with better cost
    in_open = False
    for open_node in open_list:
        if board_to_string(open_node['board']) == neighbor_string:
            if g_cost < open_node['g_cost']:
```

```
                    open_node['g_cost'] = g_cost
                    open_node['f_cost'] = f_cost
                    open_node['parent'] = current_node
                    open_node['move'] = move
                in_open = True
                break

        # Add to open list if not already there
        if not in_open:
            neighbor_node = {
                'board': neighbor_board,
                'g_cost': g_cost,
                'h_cost': h_cost,
                'f_cost': f_cost,
                'parent': current_node,
                'move': move
            }
            open_list.append(neighbor_node)

    print("No solution found!")

def get_puzzle_input():
    """Get puzzle input from user"""
    print("Enter your 3x3 puzzle:")
    print("Use 0 for empty tile")
    print("Enter each row (3 numbers separated by spaces):")

    board = []
    for i in range(3):
        while True:
            try:
                row_input = input(f"Row {i+1}: ").strip()
                row = list(map(int, row_input.split()))

                if len(row) != 3:
                    print("Please enter exactly 3 numbers")
                    continue

                # Check if numbers are valid (0-8)
                valid = True
                for num in row:
                    if num < 0 or num > 8:
                        print("Numbers must be between 0 and 8")
                        valid = False
                        break

                if valid:
```

```
                board.append(row)
                break

            except ValueError:
                print("Please enter valid integers")

    return board

def main():
    """Main function"""
    print("="*50)
    print("     A* SLIDING PUZZLE SOLVER")
    print("="*50)

    # Get puzzle input
    puzzle = get_puzzle_input()

    print("\nYour puzzle:")
    print_board(puzzle)

    # Get goal state input
    print("\nEnter your 3x3 goal state:")
    goal_puzzle = get_puzzle_input()

    print("\nYour goal state:")
    print_board(goal_puzzle)

    # Choose heuristic
    print("\nChoose heuristic:")
    print("1. Misplaced Tiles")
    print("2. Manhattan Distance")

    while True:
        try:
            choice = int(input("Enter choice (1 or 2): "))
            if choice in [1, 2]:
                break
            else:
                print("Please enter 1 or 2")
        except ValueError:
            print("Please enter a valid number")

    # Solve puzzle
    a_star_solver(puzzle, goal_puzzle, choice)

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

Output:
Enter your 3x3 puzzle:

Start state:
2 8 3
1 6 4
7 5
Total states visited: 7
Solution found!
Moves: U U L D R
Number of moves: 5

Move 1: U
2 8 3
1 4
7 6 5
g(n) = 1, h(n) = 3, f(n) = g(n) + h(n) = 4
Move 2: U
2 3
1 8 4
7 6 5
g(n) = 2, h(n) = 3, f(n) = g(n) + h(n) = 5
Move 3: L
 2 3
1 8 4
7 6 5
g(n) = 3, h(n) = 2, f(n) = g(n) + h(n) = 5
Move 4: D
1 2 3
 8 4
7 6 5
g(n) = 4, h(n) = 1, f(n) = g(n) + h(n) = 5
Move 5: R
1 2 3
27
8 4
7 6 5
g(n) = 5, h(n) = 0, f(n) = g(n) + h(n) = 5

Output 2:
Start state:
1 2 3
6 7 8
4 5
Total states visited: 21
Solution found!

Moves: L U L D R R U L D R
Number of moves: 10

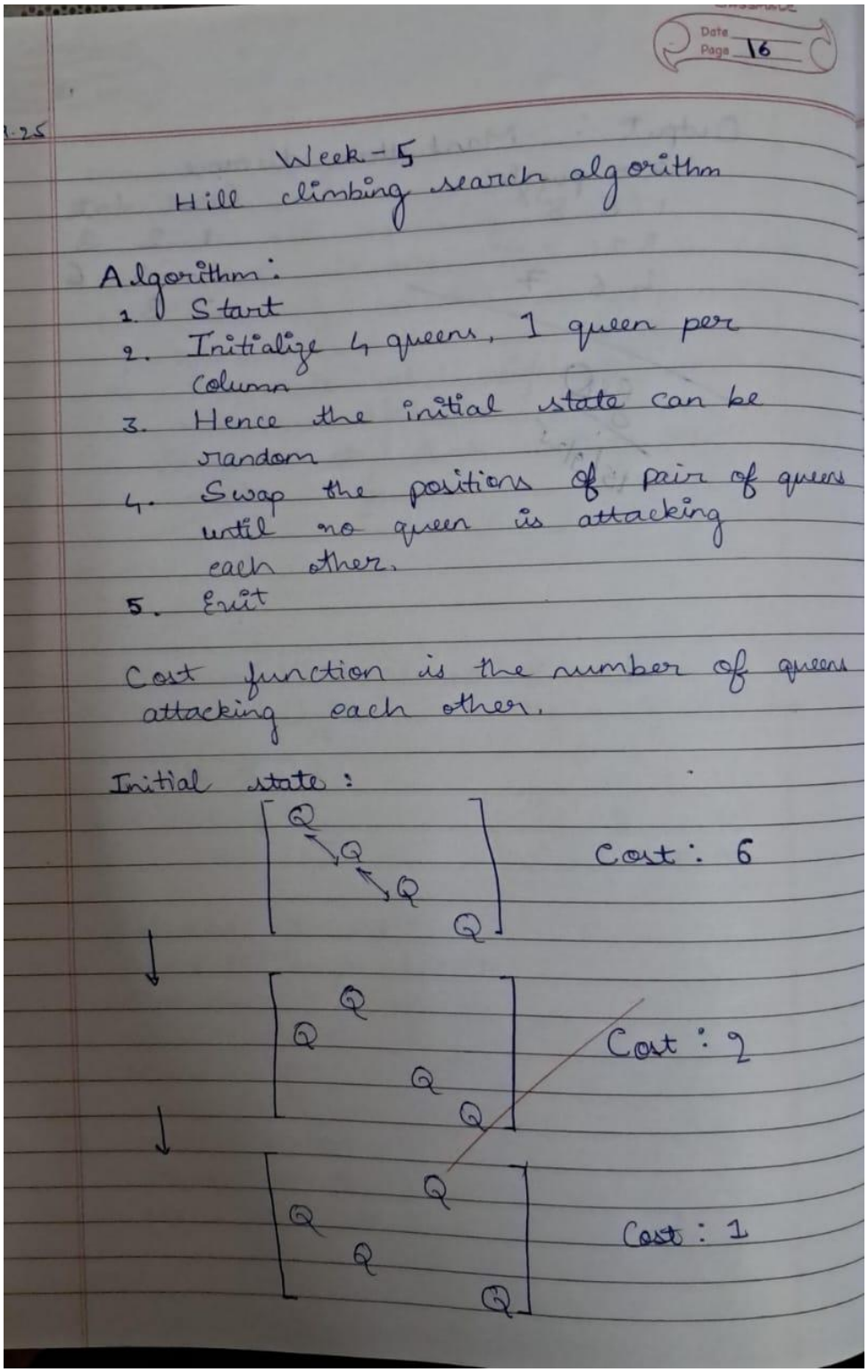
Move 1: L
1 2 3
6 7 8
4 5
g(n) = 1, h(n) = 9, f(n) = g(n) + h(n) = 10
Move 2: U
1 2 3
6 8
4 7 5
30
g(n) = 2, h(n) = 8, f(n) = g(n) + h(n) = 10
Move 3: L
1 2 3
 6 8
4 7 5
g(n) = 3, h(n) = 7, f(n) = g(n) + h(n) = 10
Move 4: D
1 2 3
4 6 8
 7 5
g(n) = 4, h(n) = 6, f(n) = g(n) + h(n) = 10
Move 5: R
1 2 3
4 6 8
7 5
g(n) = 5, h(n) = 5, f(n) = g(n) + h(n) = 10
Move 6: R
1 2 3
4 6 8
7 5
g(n) = 6, h(n) = 4, f(n) = g(n) + h(n) = 10
Move 7: U
1 2 3
4 6
7 5 8
g(n) = 7, h(n) = 3, f(n) = g(n) + h(n) = 10
Move 8: L
1 2 3
4 6
7 5 8
g(n) = 8, h(n) = 2, f(n) = g(n) + h(n) = 10
31
Move 9: D
1 2 3

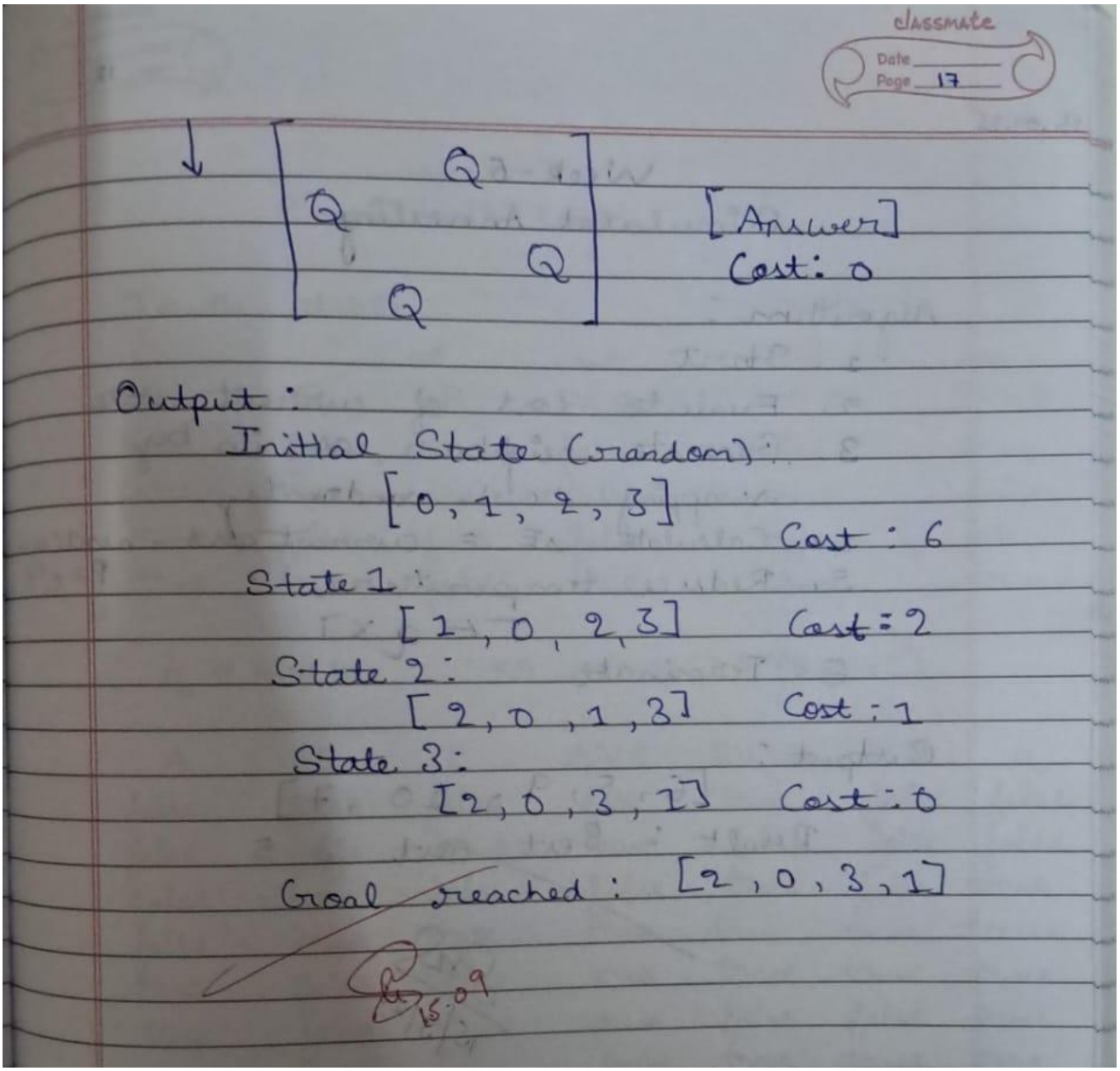
4 5 6
7 8
g(n) = 9, h(n) = 1, f(n) = g(n) + h(n) = 10
Move 10: R
1 2 3
4 5 6
7 8
g(n) = 10, h(n) = 0, f(n) = g(n) + h(n) = 10

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Observation:





Code :

```
import random

def calculate_cost(state):
    """Calculates the number of attacking queen pairs."""
    n = len(state)
    cost = 0
    for i in range(n):
        for j in range(i + 1, n):
            # Check for attacks in the same row or on diagonals
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                cost += 1
```

```
    return cost

def generate_random_state(n=4):
    """Generates a random initial state."""
    return [random.randint(0, n - 1) for _ in range(n)]

def generate_neighbours(state):
    """Generates all neighbours by swapping column positions."""
    n = len(state)
    neighbours = []
    for i in range(n):
        for j in range(i + 1, n):
            neighbour = list(state)
            neighbour[i], neighbour[j] = neighbour[j], neighbour[i]
            neighbours.append(neighbour)
    return neighbours

def hill_climbing_search():
    """Performs hill-climbing search for the 4-Queens problem."""
    current_state = generate_random_state()
    current_cost = calculate_cost(current_state)

    print("Initial State:", current_state, "Cost:", current_cost)

    while current_cost > 0:
        neighbours = generate_neighbours(current_state)
        best_neighbour = None
        best_neighbour_cost = current_cost

        for neighbour in neighbours:
            neighbour_cost = calculate_cost(neighbour)
            if neighbour_cost < best_neighbour_cost:
                best_neighbour_cost = neighbour_cost
                best_neighbour = neighbour

        if best_neighbour_cost < current_cost:
            current_state = best_neighbour
            current_cost = best_neighbour_cost
            print("Chosen Neighbour:", current_state, "Cost:", current_cost)
        else:
            print("No neighbour has a lower cost. Stopping.")
            break

    if current_cost == 0:
        print("Goal reached! Solution:", current_state)

# Run the hill-climbing search
```

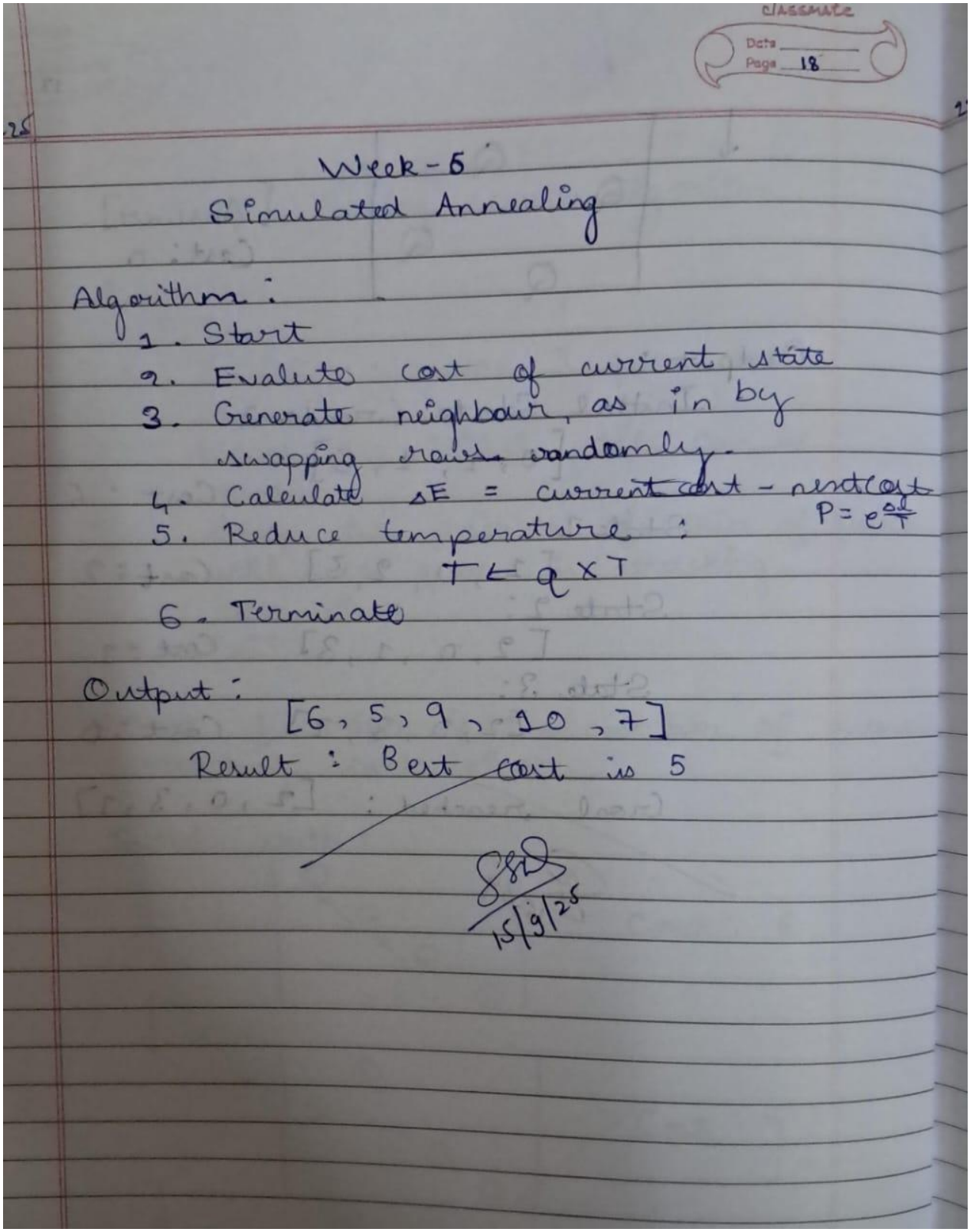
hill_climbing_search()

Output :
Initial State: [0, 1, 2, 3] Cost: 6
Chosen Neighbour: [1, 0, 2, 3] Cost: 2
Chosen Neighbour: [2, 0, 1, 3] Cost: 1
Chosen Neighbour: [2, 0, 3, 1] Cost: 0
Goal reached! Solution: [2, 0, 3, 1]

Program 5

Simulated Annealing to Solve 8-Queens problem

Observation:



Week-5

Simulated Annealing

Algorithm:

1. Start
2. Evaluate cost of current state
3. Generate neighbour, as in by swapping rows randomly.
4. Calculate δE = current cost - next cost
   $P = e^{\frac{\delta E}{T}}$
5. Reduce temperature:
   $T \leftarrow q \times T$
6. Terminate

Output:

[6, 5, 9, 10, 7]

Result: Best cost is 5

15/9/25

Code :

```
import random
import math

# 1. Implement State Representation and Initialization
def random_state():
    """Generates a random initial state, ensuring at least one 0."""
    state = [random.randint(0, 7) for _ in range(8)]
    # Ensure at least one 0 in the state
    if 0 not in state:
        state[random.randint(0, 7)] = 0
    return state

# 2. Implement Cost Function
def cost_function(state):
    """Calculates the number of attacking queen pairs."""
    attacks = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            # Check for same row
            if state[i] == state[j]:
                attacks += 1
            # Check for diagonals
            elif abs(state[i] - state[j]) == abs(i - j):
                attacks += 1
    return attacks

# 3. Implement Neighbor Generation
def get_neighbor(state):
    """Generates a random neighbor state."""
    neighbor = list(state)
    col = random.randint(0, 7)
    row = random.randint(0, 7)
    neighbor[col] = row
    return neighbor

# 4. Implement Simulated Annealing
def simulated_annealing(initial_state, initial_temperature=100, cooling_rate=0.95):
    """Performs simulated annealing."""
    current_state = list(initial_state)
    current_cost = cost_function(current_state)
    best_state = list(current_state)
    best_cost = current_cost
    temperature = initial_temperature

    # Added a counter to limit the number of iterations if delta_e never reaches around 1
```

```
    iterations = 0
    max_iterations = 10000 # Set a reasonable limit

    while temperature > 0 and current_cost > 0 and iterations < max_iterations:
        next_state = get_neighbor(current_state)
        next_cost = cost_function(next_state)

        delta_e = current_cost - next_cost

        # Stop when delta_e is around 1 (e.g., between 0.5 and 1.5)
        if 0.5 <= delta_e <= 1.5:
            #print(f"\nStopping condition met: delta_e is around {delta_e:.2f}") # Commented out for
cleaner output during multiple runs
            break


        if delta_e > 0:
            current_state = list(next_state)
            current_cost = next_cost
            if current_cost < best_cost:
                best_state = list(current_state)
                best_cost = current_cost
        else:
            acceptance_probability = math.exp(delta_e / temperature)
            if random.random() < acceptance_probability:
                current_state = list(next_state)
                current_cost = next_cost

        temperature *= cooling_rate
        iterations += 1

        # Show intermediate updates (commented out for cleaner output during multiple runs)
        # print(f"Temperature: {temperature:.4f}, Current Cost: {current_cost}")


    #if iterations == max_iterations: # Commented out as we are running multiple times
        #print("\nStopped due to reaching maximum iterations.")


    return best_state, best_cost

# 5. Run and Output - Modified to run multiple times
num_runs = 5 # Number of times to run the algorithm
overall_best_state = None
overall_best_cost = float('inf')

print(f"Running Simulated Annealing {num_runs} times...")
```

```
for run in range(num_runs):
    print(f"\n--- Run {run + 1} ---")
    initial_state = random_state()
    best_state, best_cost = simulated_annealing(initial_state)

    print(f"Run {run + 1} Best State Found: {best_state}")
    print(f"Run {run + 1} Best Cost Found: {best_cost}")

    if best_cost < overall_best_cost:
        overall_best_cost = best_cost
        overall_best_state = list(best_state)

    if overall_best_cost == 0:
        print("\nSolution with cost 0 found!")
        break # Stop if a solution with cost 0 is found

print("\n--- Overall Results ---")
print(f"Overall Best State Found: {overall_best_state}")
print(f"Overall Best Cost Found: {overall_best_cost}")

if overall_best_cost == 0:
    print("A solution with cost 0 was found in one of the runs.")
else:
    print("Could not find a solution with cost 0 in the given number of runs.")
```

Output :

```
Running Simulated Annealing 5 times...

--- Run 1 ---
Run 1 Best State Found: [6, 4, 1, 4, 0, 0, 3, 2]
Run 1 Best Cost Found: 5

--- Run 2 ---
Run 2 Best State Found: [1, 1, 0, 0, 4, 4, 7, 1]
Run 2 Best Cost Found: 9

--- Run 3 ---
Run 3 Best State Found: [5, 1, 6, 1, 3, 5, 2, 0]
Run 3 Best Cost Found: 5

--- Run 4 ---
Run 4 Best State Found: [0, 0, 1, 4, 7, 0, 7, 0]
Run 4 Best Cost Found: 10

--- Run 5 ---
```

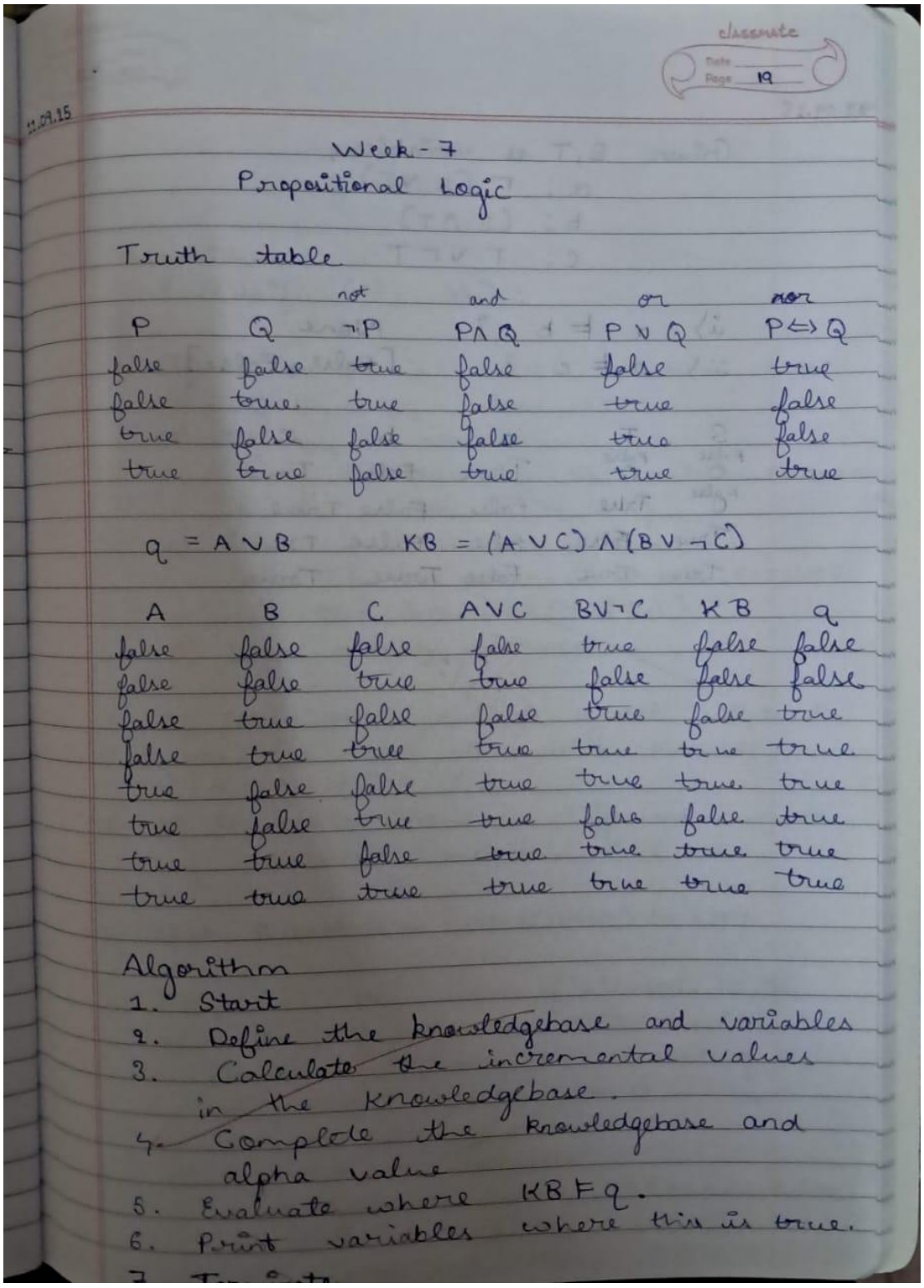
Run 5 Best State Found: [0, 3, 3, 7, 2, 7, 3, 6]
Run 5 Best Cost Found: 5

--- Overall Results ---
Overall Best State Found: [6, 4, 1, 4, 0, 0, 3, 2]
Overall Best Cost Found: 5
Could not find a solution with cost 0 in the given number of runs.

Program 6

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

Observation:



Week - 7

Propositional Logic

Truth table

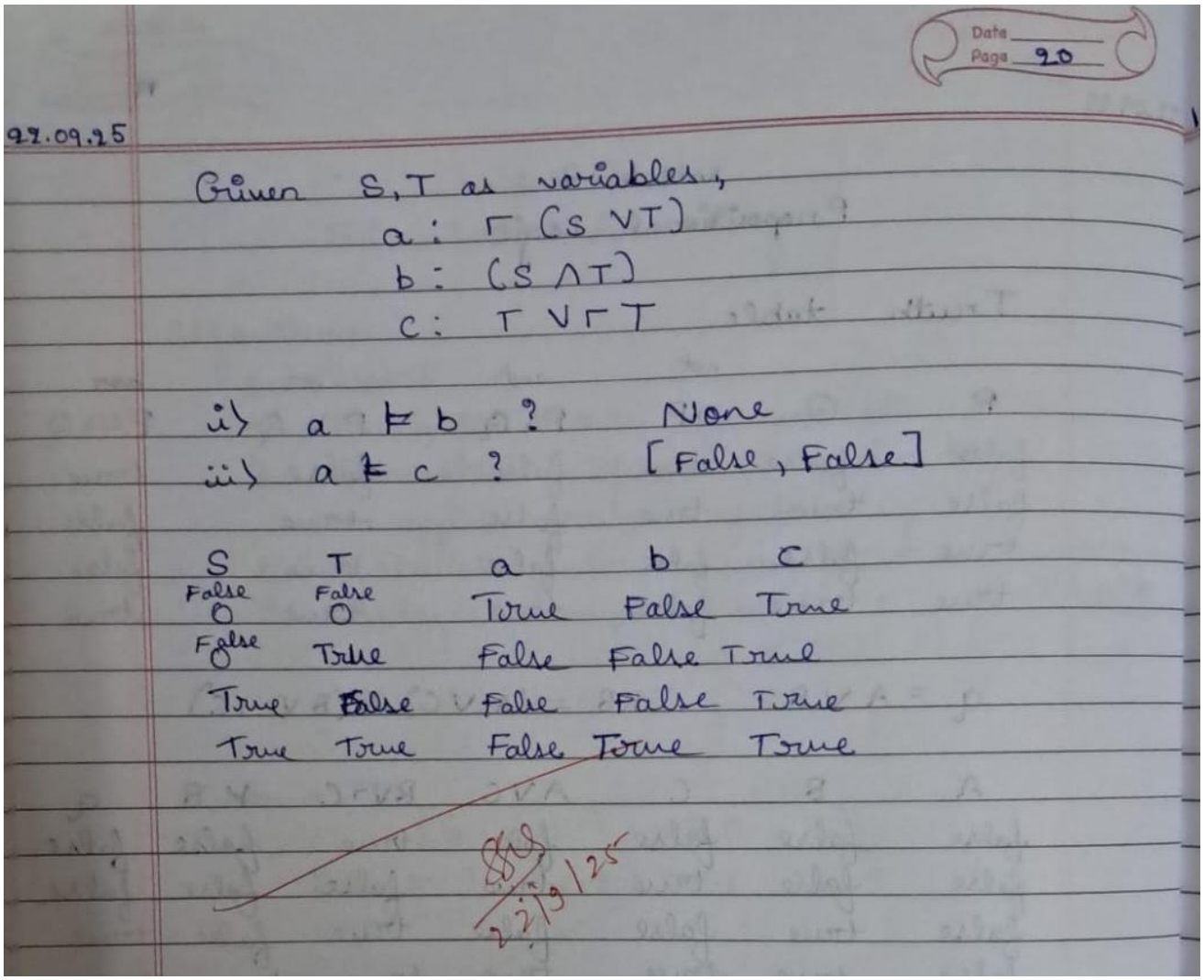
		not	and	or	nor
P	Q	¬P	P∧Q	P∨Q	P⇔Q
false	false	true	false	false	true
false	true	true	false	true	false
true	false	false	false	true	false
true	true	false	true	true	true

q = A ∨ B KB = (A ∨ C) ∧ (B ∨ ¬C)

A	B	C	A∨C	B∨¬C	KB	q
false	false	false	false	true	false	false
false	false	true	true	false	false	false
false	true	false	false	true	false	true
false	true	true	true	true	true	true
true	false	false	true	true	true	true
true	false	true	true	false	false	true
true	true	false	true	true	true	true
true	true	true	true	true	true	true

Algorithm

1. Start
2. Define the knowledgebase and variables
3. Calculate the incremental values in the knowledgebase.
4. Complete the knowledgebase and alpha value
5. Evaluate where KB ⊨ q.
6. Print variables where this is true.
7. To find



Code:

```
from itertools import product
import pandas as pd

def KB(combo):
  a,b,c = combo
  return ((a or c) and (b or not c))

def alpha(combo):
  a, b, c = combo
  return a or b


n = 3
binary = [list(i) for i in product([False, True], repeat=n)]
base = [KB(x) for x in binary]
alpha_values = [alpha(x) for x in binary]
```

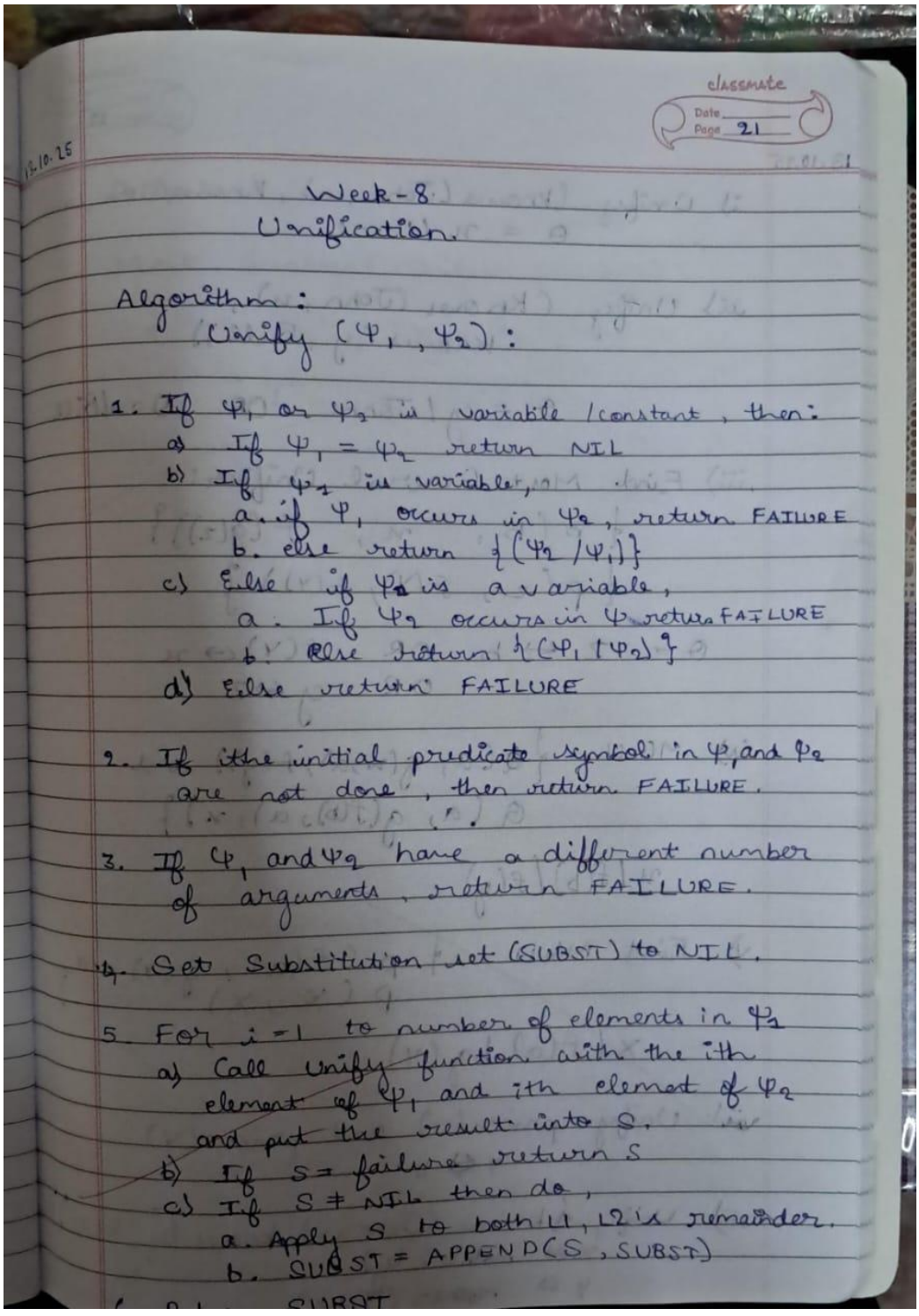
```
result = [(base[i] and alpha_values[i]) for i in range(2**n)]


df = pd.DataFrame(binary, columns=[f"V{i+1}" for i in range(n)])

df['KB'] = base
df['Alpha'] = alpha_values
df['Final'] = result
df
for index, row in df[df['Final'] == True].iterrows():
  print(row['V1'], row['V2'], row['V3'])
```

Output :
False True True
True False False
True True False
True True True

Program 7

Implement unification in first order logic

Observation:



Week-8

Unification.

Algorithm:

Unify (Ψ_1, Ψ_2):

1. If Ψ_1 or Ψ_2 is variable / constant, then:
   a) If $\Psi_1 = \Psi_2$ return NIL
   b) If Ψ_1 is variable,
      a. 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 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 done, then return FAILURE.

3. If Ψ_1 and Ψ_2 have a different number of arguments, return FAILURE.

4. Set Substitution set (SUBST) to NIL.

5. For i = 1 to number of elements in Ψ_2
   a) Call unify function with the ith element of Ψ_1 and ith element of Ψ_2 and put the result into S.
   b) If S = failure return S
   c) If S ≠ NIL then do,
      a. Apply S to both L1, L2 i.e remainder.
      b. SUBST = APPEND(S, SUBST)

SUBST

13.10.25

i) Unify {Knows(John, x), Knows(John, Jane)}
θ = x / Jane

ii) Unify (Knows(John, x), Knows(y, Bill))

θ = y / John OR θ = x / Bill

iii) Find Most General Unifier:
{p(b, x, f(g(z))}
{p(z, f(y), f(y))}

θ = z ↔ b OR f(y) ↔ x
OR y ↔ z

iv) MGU {Q(a, g(x,a), f(y)) and
Q(a, g(f(b), a), x)}

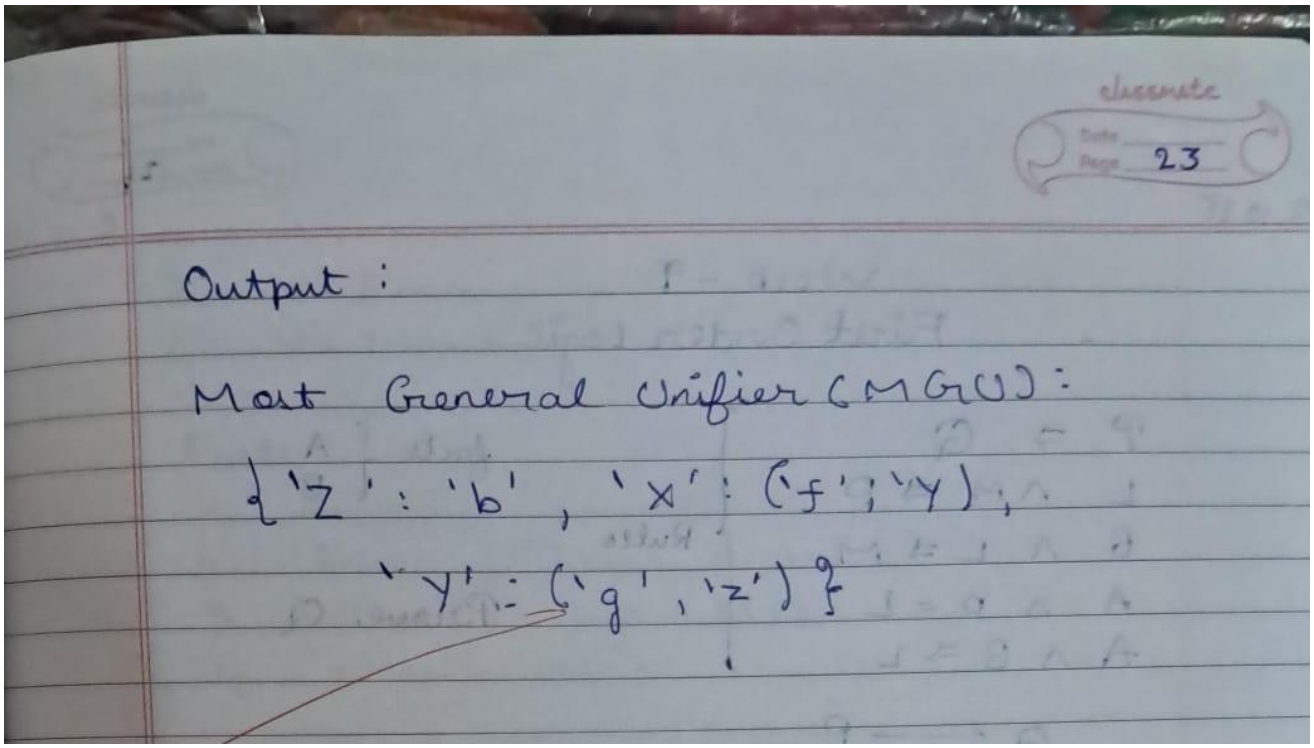
x / f(b) / f(y)

v) Find MGU {p(f(a), g(y)) and
p(x, x)}

x / f(a) / g(y)

vi) Unify prime(11) and prime(y)
y ↔ 11

vii) Unify {knows(John, x), knows(y, Bill)}
x ↔ mother(y)
y ↔ mother(John)



Code :

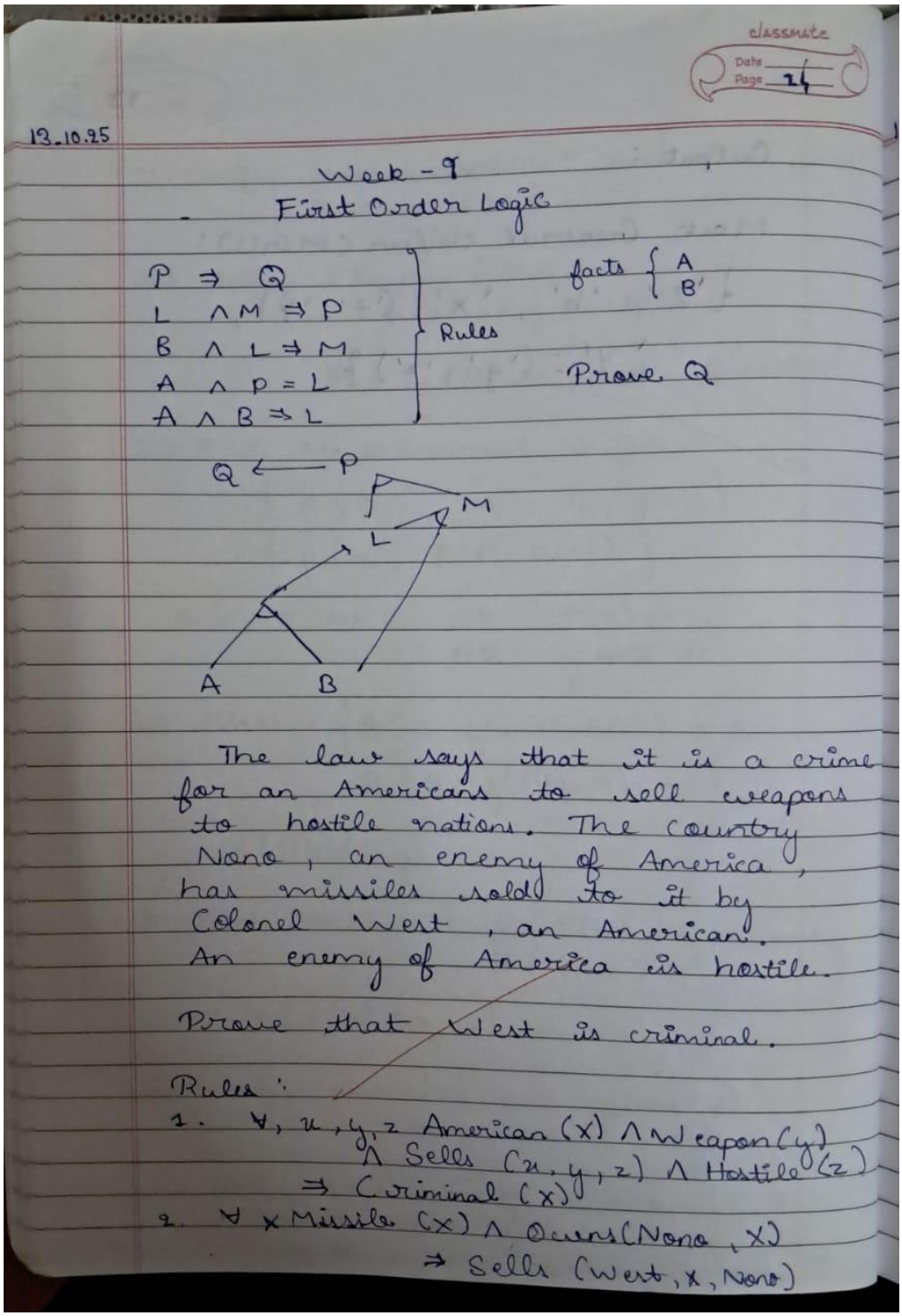
```
class UnificationError(Exception):
    pass

def occurs_check(var, term):
    """Check if a variable occurs in a term (to prevent infinite recursion)."""
    if var == term:
        return True
    if isinstance(term, tuple):  # Term is a compound (function term)
        return any(occurs_check(var, subterm) for subterm in term)
    return False

def unify(term1, term2, substitutions=None):
    """Try to unify two terms, return the MGU (Most General Unifier)."""
    if substitutions is None:
        substitutions = {}

    # If both terms are equal, no further substitution is needed
    if term1 == term2:
        return substitutions

    # If term1 is a variable, we substitute it with term2
    elif isinstance(term1, str) and term1.isupper():
        # If term1 is already substituted, recurse
        if term1 in substitutions:
            return unify(substitutions[term1], term2, substitutions)
```

```
        elif occurs_check(term1, term2):
            raise UnificationError(f"Occurs check fails: {term1} in {term2}")
        else:
            substitutions[term1] = term2
            return substitutions

    # If term2 is a variable, we substitute it with term1
    elif isinstance(term2, str) and term2.isupper():
        # If term2 is already substituted, recurse
        if term2 in substitutions:
            return unify(term1, substitutions[term2], substitutions)
        elif occurs_check(term2, term1):
            raise UnificationError(f"Occurs check fails: {term2} in {term1}")
        else:
            substitutions[term2] = term1
            return substitutions

    # If both terms are compound (i.e., functions), unify their parts recursively
    elif isinstance(term1, tuple) and isinstance(term2, tuple):
        # Ensure that both terms have the same "functor" and number of arguments
        # if len(term1) != len(term2):
        #     raise UnificationError(f"Function arity mismatch: {term1} vs {term2}")

        for subterm1, subterm2 in zip(term1, term2):
            substitutions = unify(subterm1, subterm2, substitutions)

        return substitutions

    else:
        raise UnificationError(f"Cannot unify: {term1} with {term2}")

# Define the terms as tuples
term1 = ('p', 'b', 'X', ('f', ('g', 'Z')))
term2 = ('p', 'Z', ('f', 'Y'), ('f', 'Y'))

try:
    # Find the MGU
    result = unify(term1, term2)
    print("Most General Unifier (MGU):")
    print(result)
except UnificationError as e:
    print(f"Unification failed: {e}")

    Output :
    Most General Unifier (MGU):
    {'Z': 'b', 'X': ('f', 'Y'), 'Y': ('g', 'Z')}
```

Program 8

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

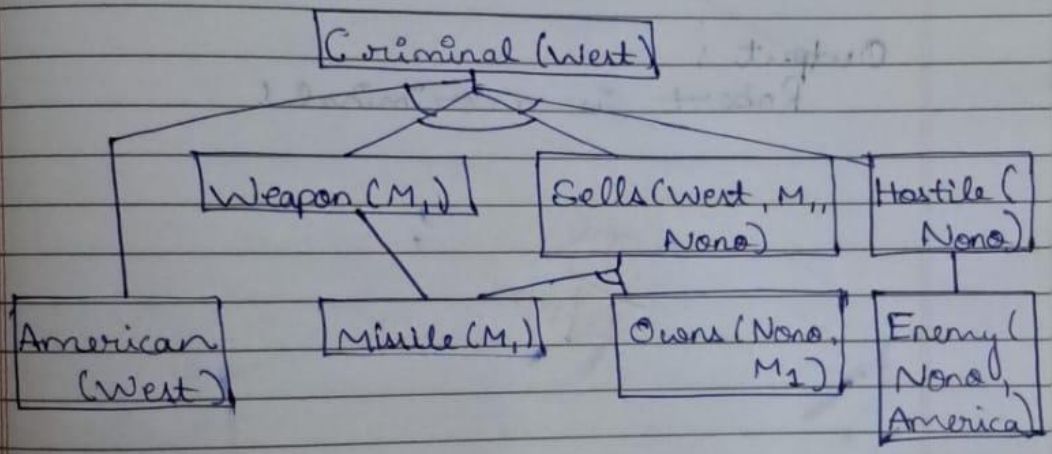
Observation :



3. $\forall x$ Enemy (x, America) $\Rightarrow$ Hostile (x)
4. $\forall x$ Missile (x) $\Rightarrow$ Weapon (x)

Facts :

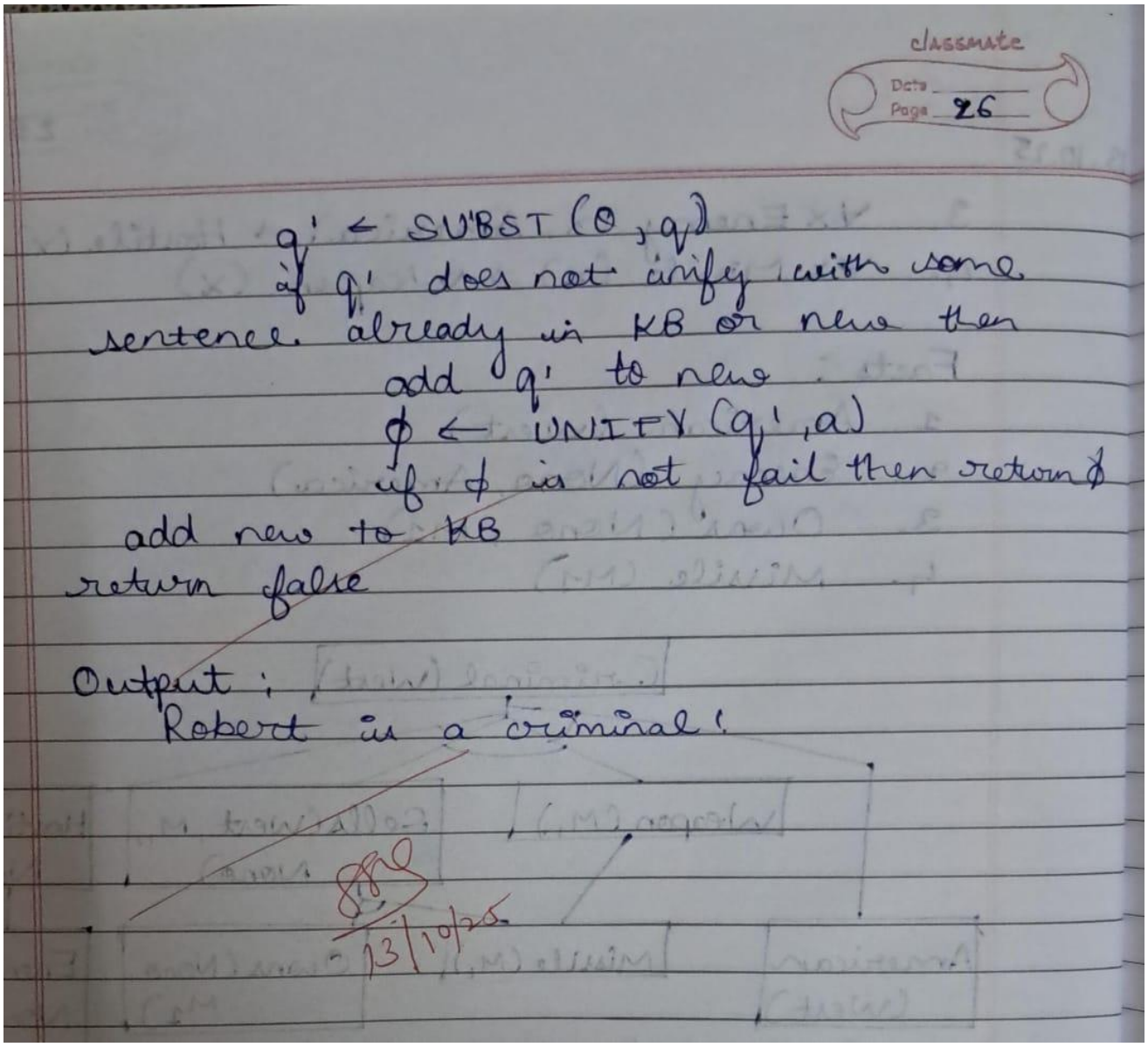
1. American (West)
2. Enemy (Nono, America)
3. Owns (Nono, M_1)
4. Missile (M_1)



Algorithm :

function FOL-FC-ASK (KB, q) return a sub of false
inputs : KB, q
local variables : new, new sentences inferred on each iteration

repeat until new empty
new $\leftarrow$ {}
for each rule in KB do
$(p_1 \wedge \dots \wedge p_n \Rightarrow q) \leftarrow$ STANDARDIZE (rule)
for each θ such SUBST ($\theta, p_1 \wedge \dots \wedge p_n$)
= SUBST ($\theta, p_1' \wedge \dots \wedge p_n'$)
for some $p_1' \dots p_n'$ in KB



Code :

```
def FOL_FC_ASK(KB, alpha):
    # Initialize the new sentences to be inferred in this iteration
    new = set()

    while new:  # Repeat until new is empty
        new = set()  # Clear new sentences on each iteration

        # For each rule in KB
        for rule in KB:
            # Standardize the rule variables to avoid conflicts
            standardized_rule = standardize_variables(rule)
            p1_to_pn, q = standardized_rule  # Premises (p1, ..., pn) and conclusion (q)
```

```
            # For each substitution θ such that Subst(θ, p1, ..., pn) matches the premises
            for theta in get_matching_substitutions(p1_to_pn, KB):
                q_prime = apply_substitution(theta, q)

                # If q_prime does not unify with some sentence already in KB or new
                if not any(unify(q_prime, sentence) != 'FAILURE' for sentence in KB.union(new)):
                    new.add(q_prime)  # Add q_prime to new

                    # Unify q_prime with the query (alpha)
                    phi = unify(q_prime, alpha)
                    if phi != 'FAILURE':
                        return phi  # Return the substitution if it unifies

        # Add newly inferred sentences to the knowledge base
        KB.update(new)

    return False  # Return false if no substitution is found


def standardize_variables(rule):
    """
    Standardize variables in the rule to avoid variable conflicts.
    Rule is assumed to be a tuple (premises, conclusion).
    """
    premises, conclusion = rule
    # Apply standardization logic here (for simplicity, assume no conflict in this case)
    return (premises, conclusion)


def get_matching_substitutions(premises, KB):
    """
    Get matching substitutions for the premises in the KB.
    This is a placeholder to represent how substitutions would be found.
    """
    # Implement substitution matching here
    return []  # This should return a list of valid substitutions


def apply_substitution(theta, expression):
    """
    Apply a substitution θ to an expression.
    This function will replace variables in expression with their corresponding terms from θ.
    """
    if isinstance(expression, str) and expression.startswith('?'):
        return theta.get(expression, expression)  # Apply substitution to variable
    elif isinstance(expression, tuple):
        return tuple(apply_substitution(theta, arg) for arg in expression)
```

```
    return expression


def unify(psi1, psi2, subst=None):
    """Unification algorithm (simplified)"""
    if subst is None:
        subst = {}

    def apply_subst(s_map, expr):
        if isinstance(expr, str) and expr.startswith('?'):
            return s_map.get(expr, expr)
        elif isinstance(expr, tuple):
            return tuple(apply_subst(s_map, arg) for arg in expr)
        return expr

    def is_variable(expr):
        return isinstance(expr, str) and expr.startswith('?')

    _psi1 = apply_subst(subst, psi1)
    _psi2 = apply_subst(subst, psi2)

    if is_variable(_psi1) or is_variable(_psi2) or not isinstance(_psi1, tuple) or not isinstance(_psi2,
tuple):
        if _psi1 == _psi2:
            return subst
        elif is_variable(_psi1):
            if _psi1 in str(_psi2):
                return 'FAILURE'
            return {**subst, _psi1: _psi2}
        elif is_variable(_psi2):
            if _psi2 in str(_psi1):
                return 'FAILURE'
            return {**subst, _psi2: _psi1}
        else:
            return 'FAILURE'

    if _psi1[0] != _psi2[0] or len(_psi1) != len(_psi2):
        return 'FAILURE'

    for arg1, arg2 in zip(_psi1[1:], _psi2[1:]):
        s = unify(arg1, arg2, subst)
        if s == 'FAILURE':
            return 'FAILURE'
        subst = s

    return subst
```

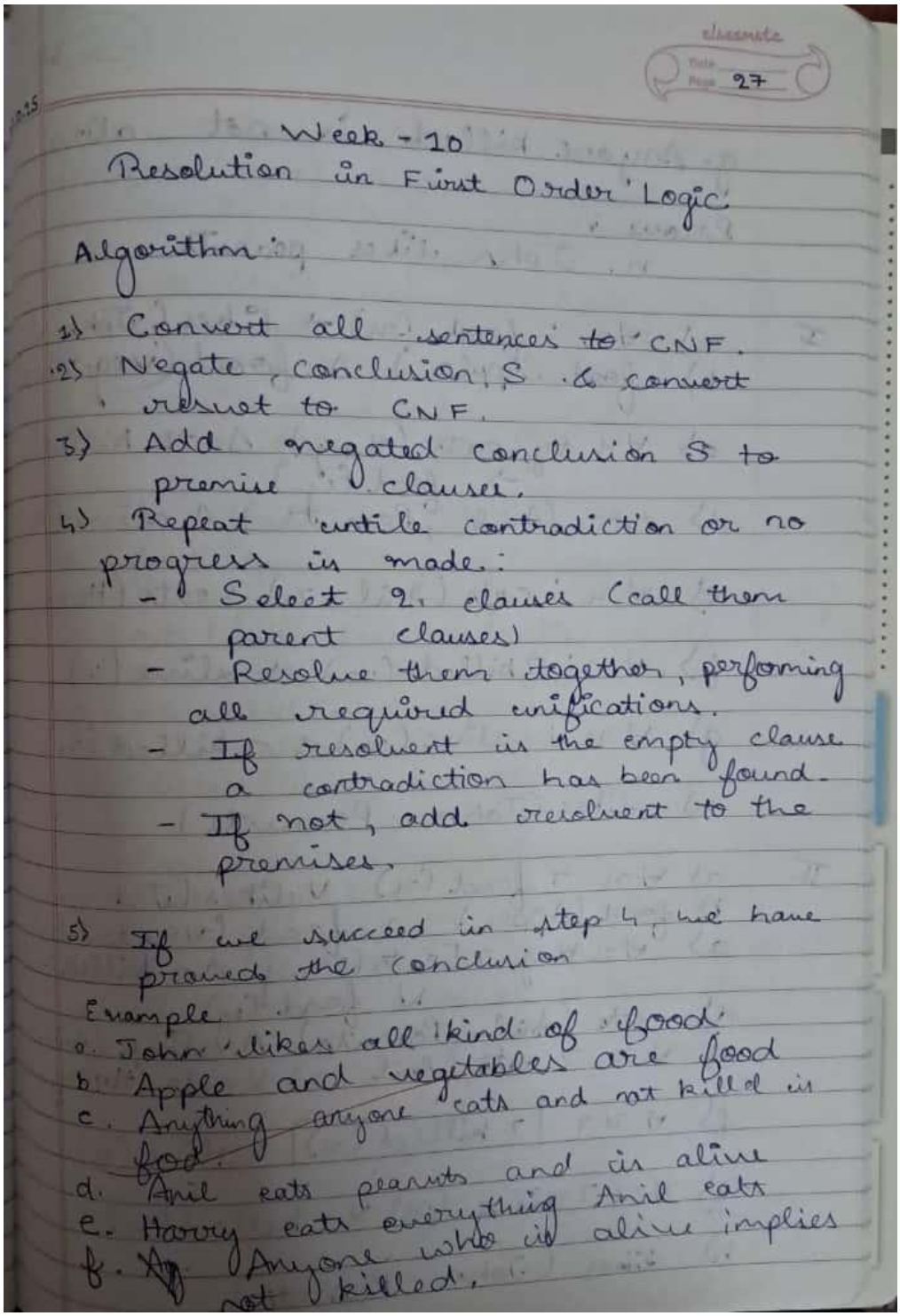
```
# Knowledge Base (KB)
KB = set()

# Adding facts to KB:
KB.add(('american', 'Robert'))  # Robert is an American
KB.add(('hostile_nation', 'Country_A'))  # Country A is a hostile nation
KB.add(('sell_weapons', 'Robert', 'Country_A'))  # Robert sold weapons to Country A

# Adding the rule (the law):
KB.add((('american(x)', 'hostile_nation(y)', 'sell_weapons(x, y)'),
        'criminal(x)'))

# Goal: Prove that Robert is a criminal
goal = 'criminal(Robert)'

# Calling FOL_FC_ASK to prove the goal
result = FOL_FC_ASK(KB, goal)

if result != 'FAILURE':
    print("Robert is a criminal!")
else:
    print("Robert is not a criminal.")
```

Output :
Robert is a criminal!

Program 9

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

Observation :



Week - 10

Resolution in First Order Logic

Algorithm:

1) Convert all sentences to CNF.
2) Negate conclusion S & convert result to CNF.
3) Add negated conclusion S to premise clauses.
4) Repeat until contradiction or no progress is made:
   - Select 2 clauses (call them parent clauses)
   - Resolve them together, performing all required unifications.
   - If resolvent is the empty clause a contradiction has been found.
   - If not, add resolvent to the premises.
5) If we succeed in step 4, we have proved the conclusion

Example

a. John likes all kind of food.
b. Apple and vegetables are food
c. Anything anyone eats and not killed is food.
d. Anil eats peanuts and is alive
e. Harry eats everything Anil eats
f. Anyone who is alive implies not killed.

g. Anyone killed is not alive

Prove :
n. John likes peanuts

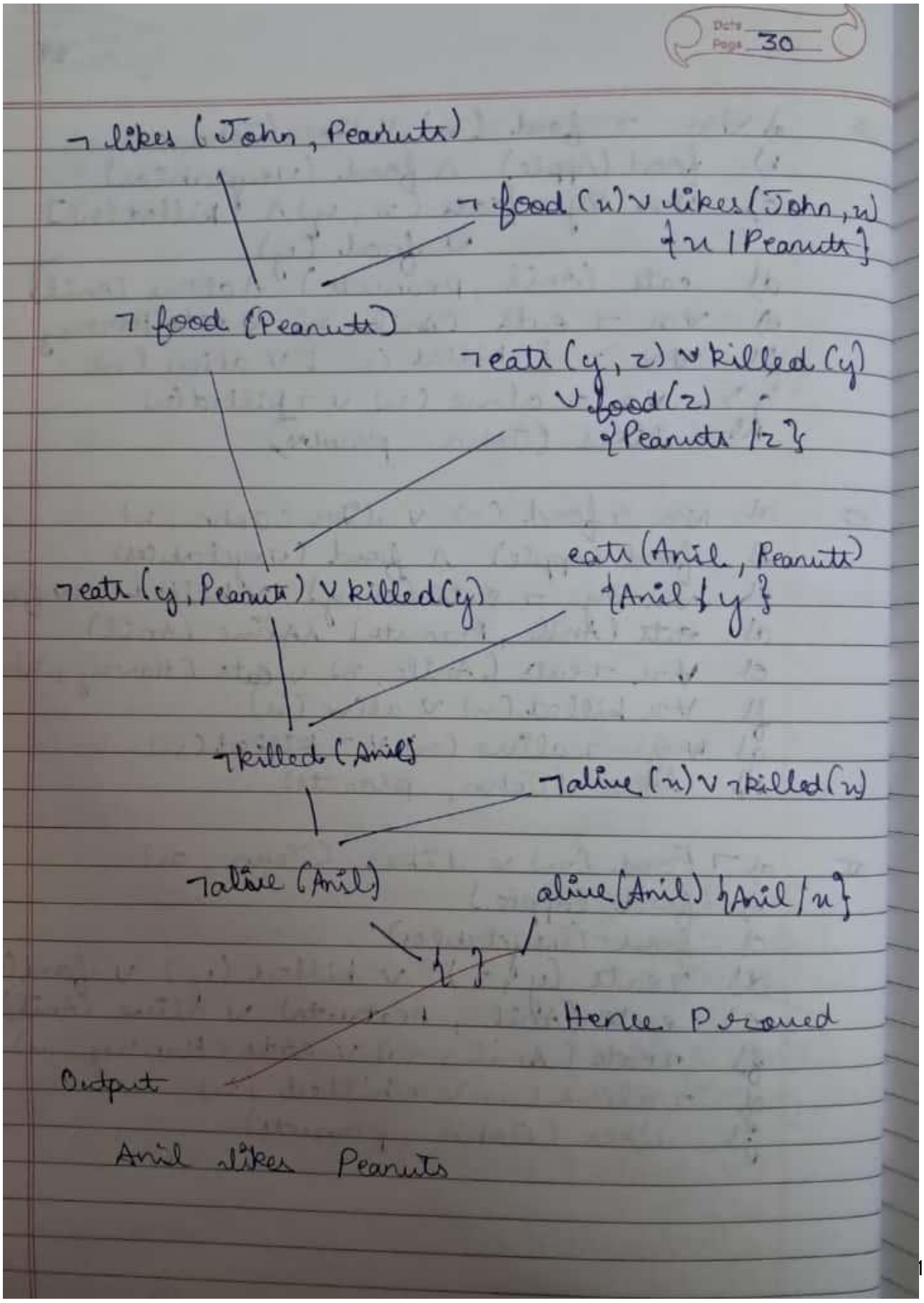
I
a) $\forall x : food(x) \rightarrow likes(John, x)$
b) $food(Apple) \wedge food(vegetables)$
c) $\forall x \forall y : eats(x, y) \wedge \neg killed(x) \rightarrow food(y)$
d) $eats(Anil, Peanuts) \wedge alive(Anil)$
e) $\forall x : eats(Anil, x) \rightarrow eats(Harry, x)$
f) $\forall x : \neg killed(x) \rightarrow alive(x)$
g) $\forall x : alive(x) \rightarrow \neg killed(x)$
h) $likes(John, Peanuts)$

II
a) $\forall x \neg food(x) \vee likes(John, x)$
b) $food(Apple) \wedge food(vegetables)$
c) $\forall x \forall y \neg [eats(x, y) \wedge \neg killed(x)] \vee food(y)$
d) $eats(Anil, Peanuts) \wedge alive(Anil)$
e) $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$
f) $\forall x \neg [\neg killed(x)] \vee alive(x)$
g) $\forall x \neg alive(x) \vee \neg killed(x)$
h) $likes(John, Peanuts)$

a) $\forall x \neg food(x) \vee likes(John, x)$
b) $food(Apple) \wedge food(Vegetables)$
c) $\forall x \forall y \neg [eats(x, y) \wedge \neg killed(x)] \vee food(y)$
d) $eats(Anil, Peanuts) \wedge alive(Anil)$
e) $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$
f) $\forall x \neg [\neg killed(x)] \vee alive(x)$
g) $\forall x \neg alive(x) \vee \neg killed(x)$
h) $likes(John, peanuts)$

a) $\forall x \neg food(x) \vee likes(John, x)$
b) $food(Apple) \wedge food(Vegetables)$
c) $\forall x \forall y \neg eats(x, y) \vee killed(x) \vee food(y)$
d) $eats(Anil, Peanuts) \wedge alive(Anil)$
e) $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$
f) $\forall x killed(x) \vee alive(x)$
g) $\forall x \neg alive(x) \vee \neg killed(x)$
h) $likes(John, peanuts)$

a) $\neg Food(x) \vee likes(John, x)$
b) $food(Apple)$
c) $food(Vegetables)$
d) $\neg eats(y, z) \vee killed(y) \vee food(z)$
e) $eats(Anil, Peanuts) \vee alive(Anil)$
f) $\neg eats(Anil, w) \vee eats(Harry, w)$
g) $\neg alive(x) \vee \neg killed(x)$
i) $likes(John, peanuts)$


¬ likes (John, Peanuts)
¬ food (x) ∨ likes (John, x)
{x / Peanuts}
¬ food (Peanuts)
¬ eats (y, z) ∨ killed (y)
∨ food (z)
{Peanuts / z}
¬ eats (y, Peanuts) ∨ killed (y)
eats (Anil, Peanuts)
{Anil / y}
¬ killed (Anil)
¬ alive (x) ∨ ¬ killed (x)
¬ alive (Anil)
alive (Anil) {Anil / x}
{ }
Hence Proved
Output
Anil likes Peanuts

Code :

```
from itertools import combinations

def unify(x, y, theta=None):
    if theta is None:
        theta = {}
    if x == y:
        return theta
    elif isinstance(x, str) and x.islower():
        return unify_var(x, y, theta)
    elif isinstance(y, str) and y.islower():
        return unify_var(y, x, theta)
    elif isinstance(x, tuple) and isinstance(y, tuple) and len(x) == len(y):
        return unify(x[1:], y[1:], unify(x[0], y[0], theta))
    else:
        return None

def unify_var(var, x, theta):
    if var in theta:
        return unify(theta[var], x, theta)
    elif x in theta:
        return unify(var, theta[x], theta)
    else:
        theta[var] = x
        return theta

def negate(predicate):
    if isinstance(predicate, tuple) and predicate[0] == 'not':
        return predicate[1]
    else:
        return ('not', predicate)

def substitute_predicate(predicate, theta):
    if isinstance(predicate, str):
        return theta.get(predicate, predicate)
    elif isinstance(predicate, tuple):
        return (predicate[0],) + tuple(theta.get(arg, arg) for arg in predicate[1:])
    return predicate

def substitute(clause, theta):
    return {substitute_predicate(p, theta) for p in clause}

def resolve(clause1, clause2):
    resolvents = []
    for p1 in clause1:
        for p2 in clause2:
```

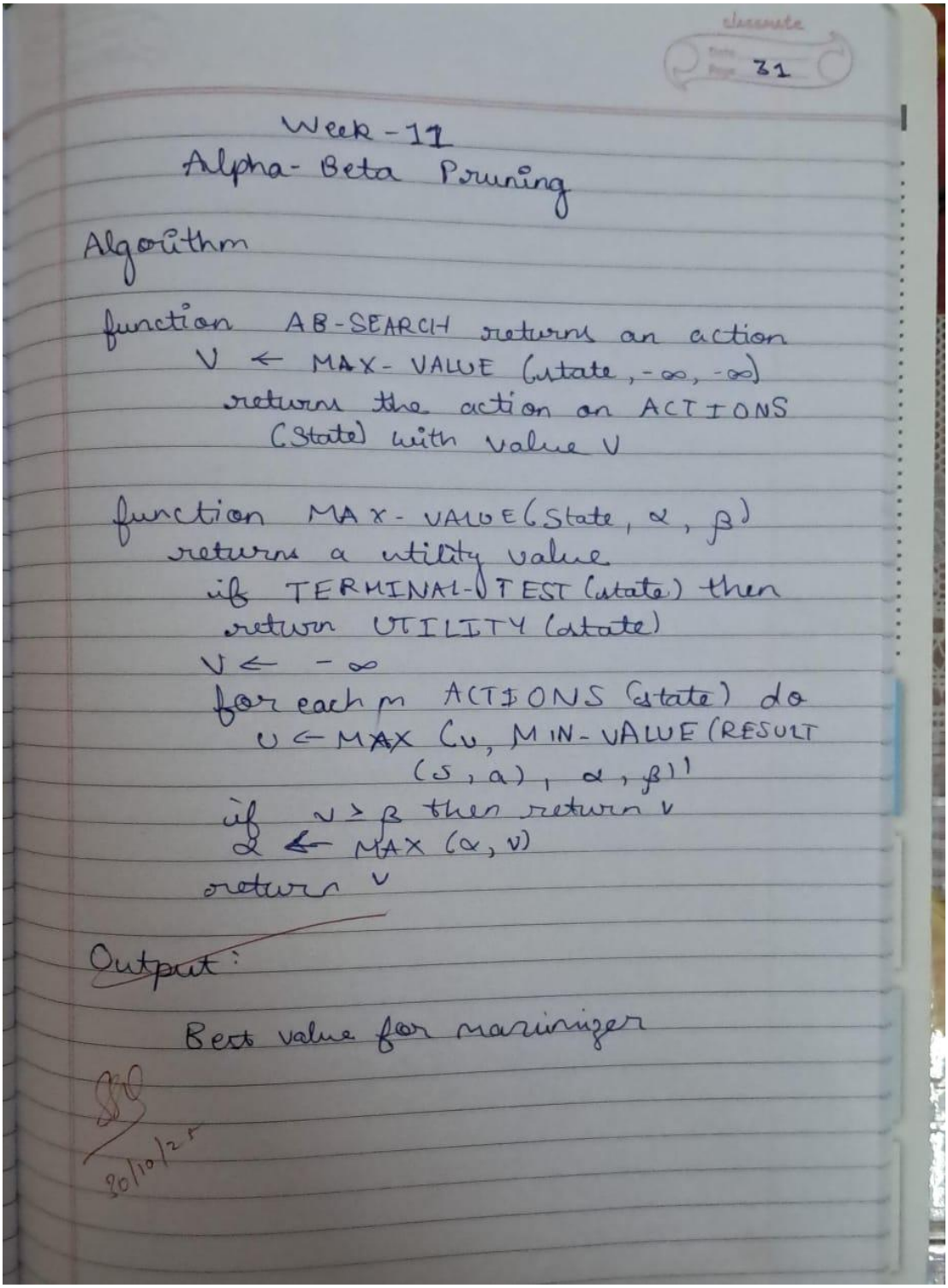
```
            theta = unify(p1, negate(p2))
            if theta is not None:
                new_clause = (substitute(clause1, theta) | substitute(clause2, theta)) - {p1, p2}
                resolvents.append(frozenset(new_clause))
    return resolvents

def resolution(kb, query):
    negated_query = frozenset({negate(query)})
    clauses = kb | {negated_query}
    new = set()

    while True:
        pairs = list(combinations(clauses, 2))
        for (ci, cj) in pairs:
            resolvents = resolve(ci, cj)
            if frozenset() in resolvents:
                return True
            new |= set(resolvents)
        if new.issubset(clauses):
            return False
        clauses |= new

# Knowledge Base
kb = {
    frozenset({('not', ('Food', 'x')), ('Likes', 'John', 'x')}),  # a
    frozenset({('Food', 'Apple')}),  # b
    frozenset({('Food', 'Vegetables')}),  # b
    frozenset({('not', ('Eats', 'x', 'y')), ('Killed', 'x'), ('Food', 'y')}),  # c
    frozenset({('Eats', 'Anil', 'Peanuts')}),  # d
    frozenset({('Alive', 'Anil')}),  # d
    frozenset({('not', ('Eats', 'Anil', 'x')), ('Eats', 'Harry', 'x')}),  # e
    frozenset({('not', ('Alive', 'x')), ('not', ('Killed', 'x'))}),  # f
    frozenset({('Killed', 'x'), ('Alive', 'x')}),  # g
}
query = ('Likes', 'John', 'Peanuts')

# Run resolution
result = resolution(kb, query)

if result:
    print("Proved by resolution: John likes peanuts.")
else:
    print("Cannot prove that John likes peanuts.")
```

Output :

Proved by resolution: John likes peanuts.

Program 10
Implement Alpha-Beta Pruning

Observation :



Week - 11
Alpha- Beta Pruning

Algorithm

function AB-SEARCH returns an action
V ← MAX-VALUE (state, -∞, -∞)
returns the action on ACTIONS (State) with value V

function MAX-VALUE (State, α, β)
returns a utility value
if TERMINAL-TEST (state) then
return UTILITY (state)
V ← -∞
for each a 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

Output:

Best value for maximizer

30/10/25

Code :

```
import numpy as np

class Node:
    def __init__(self, value=None, children=None):
        self.value = value
        self.children = children if children else []

def build_tree_from_array(arr):
    leaves = [Node(value=v) for v in arr.flatten()]
    num_leaves = len(leaves)


    while num_leaves > 1:
        new_level = []
        for i in range(0, num_leaves, 2):
            if i + 1 < num_leaves:
                new_level.append(Node(None, [leaves[i], leaves[i + 1]]))
            else:
                new_level.append(leaves[i])
        leaves = new_level
        num_leaves = len(leaves)

    return leaves[0]

def alpha_beta_pruning(node, depth, alpha, beta, maximizing_player):
    if not node.children or depth == 0:
        return node.value

    if maximizing_player:
        max_eval = float('-inf')
        for child in node.children:
            eval = alpha_beta_pruning(child, depth - 1, alpha, beta, False)
            max_eval = max(max_eval, eval)
            alpha = max(alpha, eval)
            if beta <= alpha:
                print(f"Pruned at MAX node (α={alpha}, β={beta})")
                break
        node.value = max_eval
        return max_eval
    else:
        min_eval = float('inf')
        for child in node.children:
            eval = alpha_beta_pruning(child, depth - 1, alpha, beta, True)
            min_eval = min(min_eval, eval)
            beta = min(beta, eval)
            if beta <= alpha:
```

```
            print(f"Pruned at MIN node (α={alpha}, β={beta})")
            break
        node.value = min_eval
        return min_eval

def print_tree(node, level=0):
    print("  " * level + f"Node Value: {node.value}")
    for child in node.children:
        print_tree(child, level + 1)

if __name__ == "__main__":
    tree_array = np.array([
        [10, 9],
        [14, 18],
        [5, 4],
        [50, 3]
    ])

    root = build_tree_from_array(tree_array)

    print("Game Tree Before Alpha-Beta Pruning:")
    print_tree(root)

    depth = int(np.log2(tree_array.size))
    final_value = alpha_beta_pruning(root, depth, alpha=float('-inf'), beta=float('inf'),
maximizing_player=True)

    print("\nGame Tree After Alpha-Beta Pruning:")
    print_tree(root)

    print(f"\nFinal Value at MAX node: {final_value}")

    Output :
    Game Tree Before Alpha-Beta Pruning:
    Node Value: None
      Node Value: None
        Node Value: None
          Node Value: 10
          Node Value: 9
        Node Value: None
          Node Value: 14
          Node Value: 18
      Node Value: None
        Node Value: None
          Node Value: 5
          Node Value: 4
        Node Value: None
```

```
      Node Value: 50
      Node Value: 3
Pruned at MAX node (α=14, β=10)
Pruned at MIN node (α=10, β=5)

Game Tree After Alpha-Beta Pruning:
Node Value: 10
  Node Value: 10
    Node Value: 10
      Node Value: 10
      Node Value: 9
    Node Value: 14
      Node Value: 14
      Node Value: 18
  Node Value: 5
    Node Value: 5
      Node Value: 5
      Node Value: 4
    Node Value: None
      Node Value: 50
      Node Value: 3

Final Value at MAX node: 10
```