VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

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

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

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Shruti Khandelia (1BM22CS274),** who is a bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

Prof. Saritha A.N Assistant Professor Department of CSE, BMSCE	Dr. Joythi S Nayak Professor & HOD Department of CSE, BMSCE

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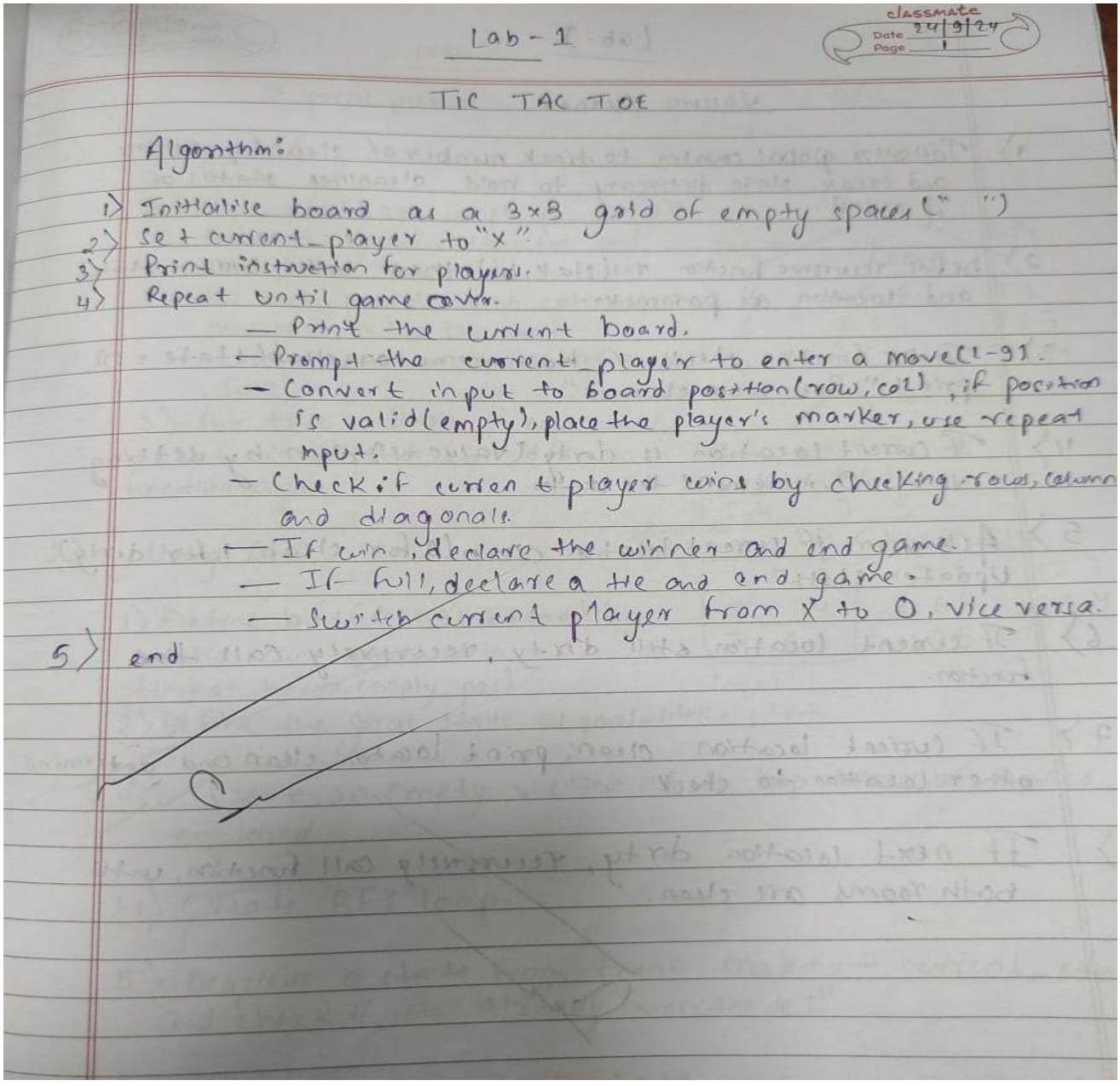
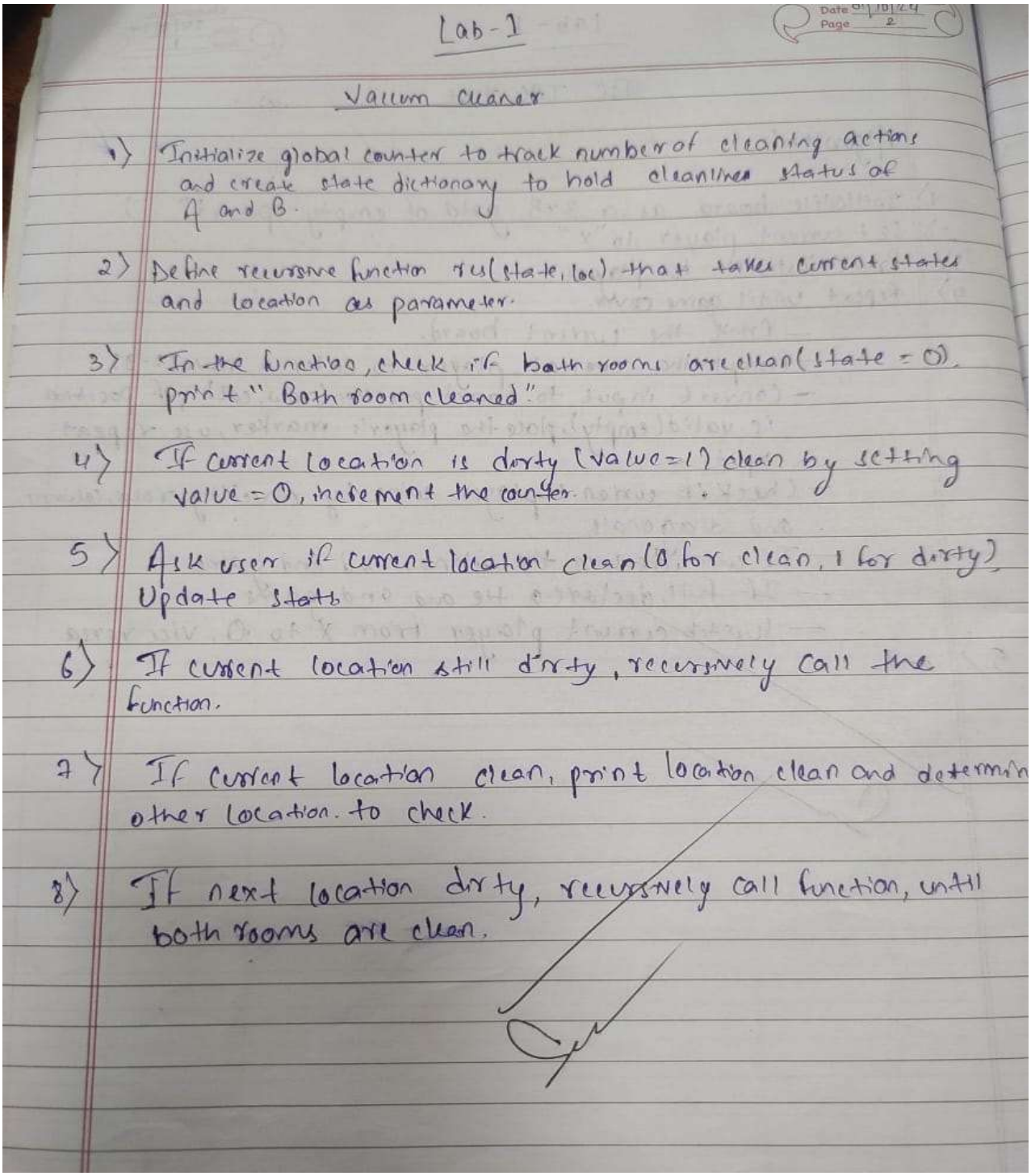
Github Link:
https://github.com/shrutikhandelia/AI

Program 1
Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

Algorithm:





Code:

```
def print_board(board):
    print("\n")
```

```
    for row in board:
        print("|".join(row))
        print("-" * 5)
    print("\n")

def check_winner(board, player):
    for row in board:
        if all([cell == player for cell in row]):
            return True
    for col in range(3):
        if all([board[row][col] == player for row in range(3)]):
            return True
    if board[0][0] == player and board[1][1] == player and board[2][2] ==
player:
        return True
    if board[0][2] == player and board[1][1] == player and board[2][0] ==
player:
        return True
    return False

def is_board_full(board):
    return all([cell != ' ' for row in board for cell in row])

def player_move(board, player):
    while True:
        try:
            move = int(input(f"Player {player}, enter your move (1-9): ")) -
1
            if move < 0 or move >= 9:
                raise ValueError
            row, col = divmod(move, 3)
            if board[row][col] == ' ':
                board[row][col] = player
                break
            else:
                print("This spot is already taken. Try again.")
        except ValueError:
            print("Invalid input. Enter a number between 1 and 9.")

def play_game():
    board = [[' ' for _ in range(3)] for _ in range(3)]
```

```
    current_player = 'X'
    game_over = False
    print("Welcome to Tic Tac Toe!")
    print("Player X goes first.")
    print("Enter a number between 1-9 to make your move (1 is top-left and 9
is bottom-right).")
    print_board(board)
    while not game_over:
        player_move(board, current_player)
        print_board(board)
        if check_winner(board, current_player):
            print(f"Player {current_player} wins!")
            game_over = True
        elif is_board_full(board):
            print("It's a tie!")
            game_over = True
        else:
            current_player = 'O' if current_player == 'X' else 'X'

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

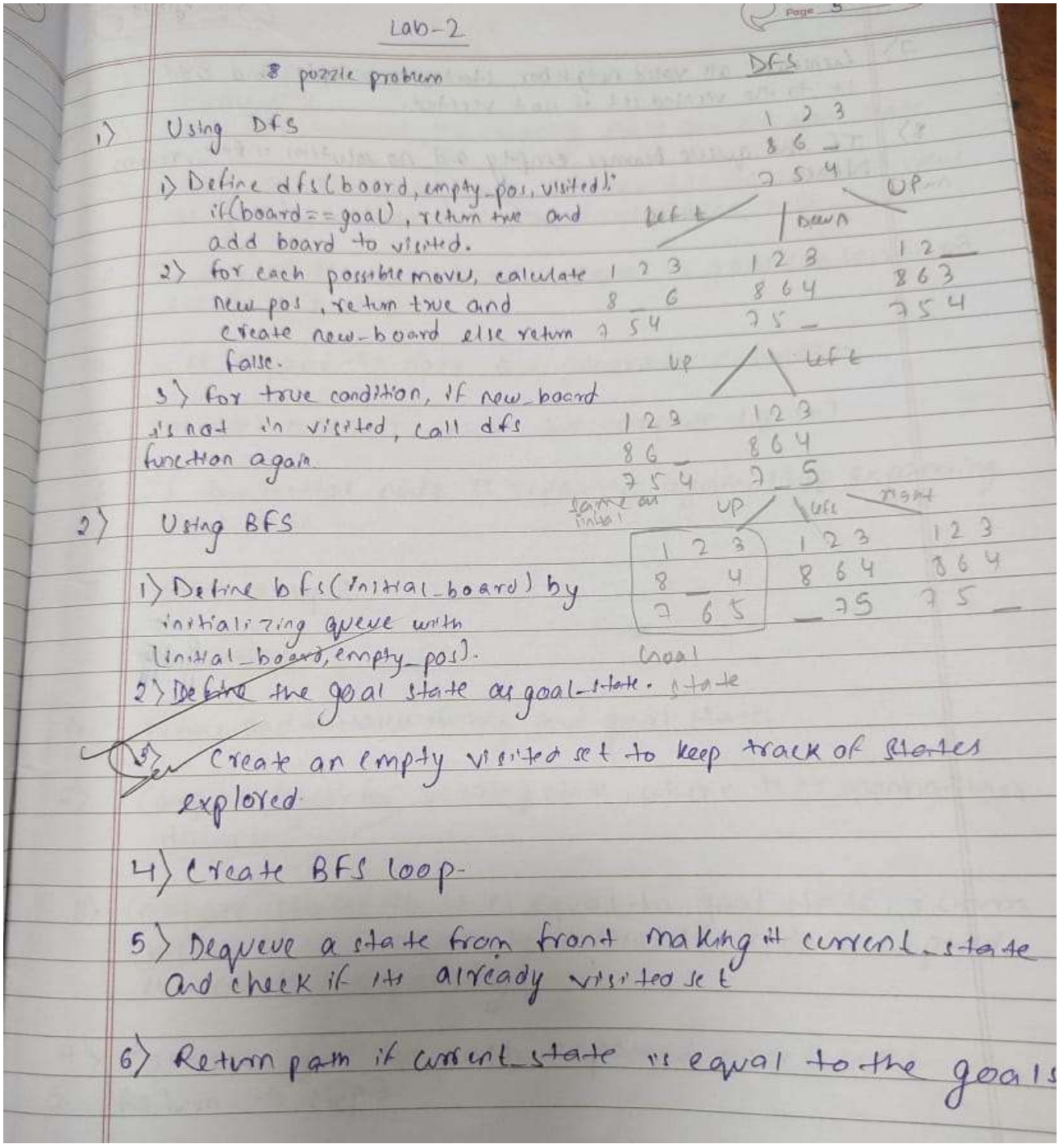
```
Player X, enter your move (1-9): 5

 | |
-----
 |X|
-----
 | |
-----

Player O, enter your move (1-9): 8

 | |
-----
 |X|
-----
 |O|
-----

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

 | |
-----
 |X|X
-----
 |O|
-----

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

 | |O
-----
 |X|X
-----
 |O|
-----

Player X, enter your move (1-9): 4

 | |O
-----
X|X|X
-----
 |O|
-----

Player X wins!
```

```
count = 0
def rec(state, loc):
    global count
    if state['A'] == 0 and state['B'] == 0:
        print("Turning vacuum off")
        return

    if state[loc] == 1:
        state[loc] = 0
        count += 1
        print(f"Cleaned {loc}.")
        next_loc = 'B' if loc == 'A' else 'A'
        state[loc] = int(input(f"Is {loc} clean now? (0 if clean, 1 if
dirty): "))
        if(state[next_loc]!=1):
          state[next_loc]=int(input(f"Is {next_loc} dirty? (0 if clean, 1 if
dirty): "))
    if(state[loc]==1):
       rec(state,loc)
    else:
      next_loc = 'B' if loc == 'A' else 'A'
      dire="left" if loc=="B" else "right"
      print(loc,"is clean")
      print(f"Moving vacuum {dire}")
      if state[next_loc] == 1:
          rec(state, next_loc)

state = {}
state['A'] = int(input("Enter state of A (0 for clean, 1 for dirty): "))
state['B'] = int(input("Enter state of B (0 for clean, 1 for dirty): "))
loc = input("Enter location (A or B): ")
rec(state, loc)
print("Cost:",count)
print(state)
```

Program 2

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

Algorithm:



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7) Generate all valid neighbor state to a tuple and add it to the visited set if not visited.

8) If the queue becomes empty and no solution is found, return None.

1) Algorithm for iterative deepening search:

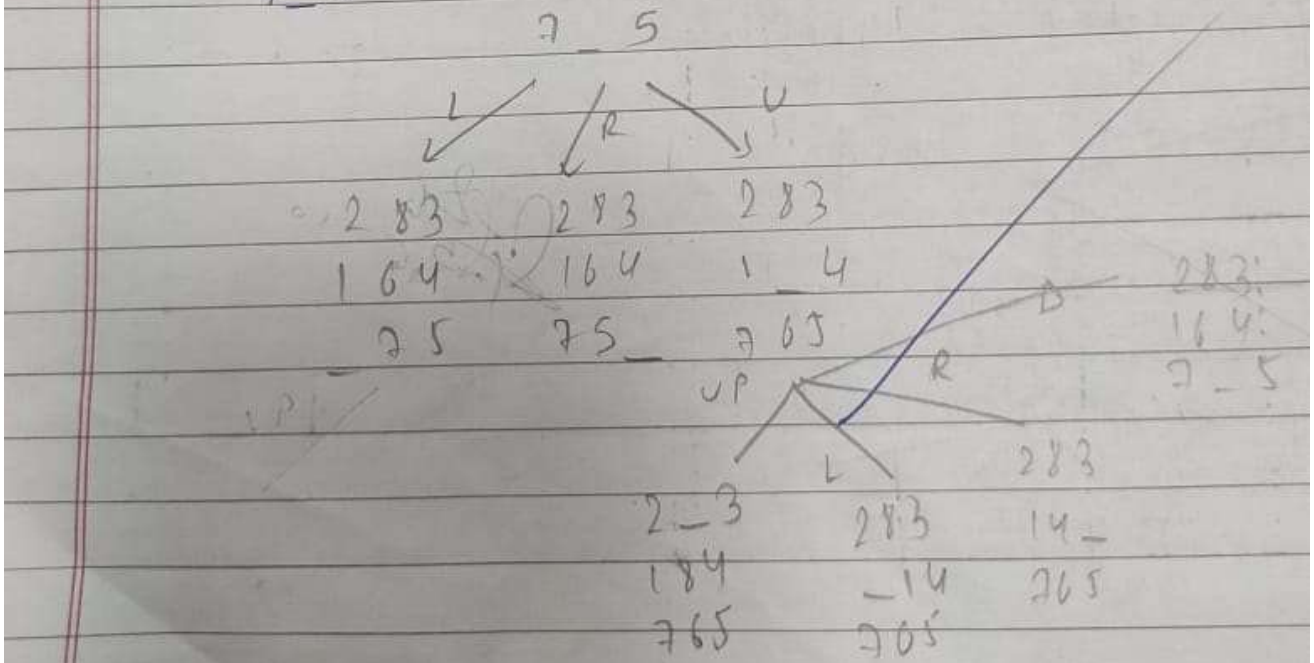
→ Initialize a depth limit to 0
→ Perform a depth-first search up to current limit.
→ If a goal state is found, return the solution.
→ If not found, increment the depth limit by 1.
→ Repeat the DFS with the new depth limit.
→ Continue until a goal state is located or a maximum depth is reached
→ Return the solution or indicate failure if the max depth is reached without finding a goal.

Initial State

2 8 3
1 6 4
7 _ 5

Goal State

2 _ 3
1 8 4
7 6 5



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

def is_goal(state):
    return state == goal_state

def find_blank(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j

def swap(state, i1, j1, i2, j2):
    new_state = [row[:] for row in state]
    new_state[i1][j1], new_state[i2][j2] = new_state[i2][j2],
new_state[i1][j1]
    return new_state

def get_neighbors(state):
    neighbors = []
    i, j = find_blank(state)

    if i > 0:
        neighbors.append(swap(state, i, j, i - 1, j))
    if i < 2:
        neighbors.append(swap(state, i, j, i + 1, j))
    if j > 0:
        neighbors.append(swap(state, i, j, i, j - 1))
    if j < 2:
        neighbors.append(swap(state, i, j, i, j + 1))

    return neighbors

def dfs(state, visited, path):
    state_tuple = tuple(tuple(row) for row in state)

    if state_tuple in visited:
        return None
    visited.add(state_tuple)
```

```
    if is_goal(state):
        return path

    for neighbor in get_neighbors(state):
        result = dfs(neighbor, visited, path + [neighbor])
        if result is not None:
            return result

    return None

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

visited = set()
solution = dfs(initial_state, visited, [])

if solution:
    print("Solution found in", len(solution), "steps:")
    for step in solution:
        for row in step:
            print(row)
        print()
else:
    print("No solution found.")
```

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

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

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

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

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

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

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

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

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

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

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

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

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

```
Solution found in 30 steps:
[1, 0, 3]
[4, 2, 6]
[7, 5, 8]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

```
class PuzzleState:
```

```
    def __init__(self, board, moves=0):
        self.board = board
        self.blank_index = board.index(0)  # Find the index of the
blank space (0)
        self.moves = moves

    def get_possible_moves(self):
        possible_moves = []
        row, col = divmod(self.blank_index, 3)

        # Define possible movements: up, down, left, right
        directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]  #
(row_change, col_change)

        for dr, dc in directions:
            new_row, new_col = row + dr, col + dc
            if 0 <= new_row < 3 and 0 <= new_col < 3:
                new_blank_index = new_row * 3 + new_col
                new_board = self.board[:]
                # Swap the blank with the adjacent tile
                new_board[self.blank_index],
new_board[new_blank_index] = new_board[new_blank_index],
new_board[self.blank_index]
                possible_moves.append(PuzzleState(new_board,
self.moves + 1))

        return possible_moves

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

def depth_limited_search(state, depth, goal_state):
    if state.is_goal(goal_state):
        return state
    if depth == 0:
        return None

    for next_state in state.get_possible_moves():
        result = depth_limited_search(next_state, depth - 1,
goal_state)
        if result is not None:
```

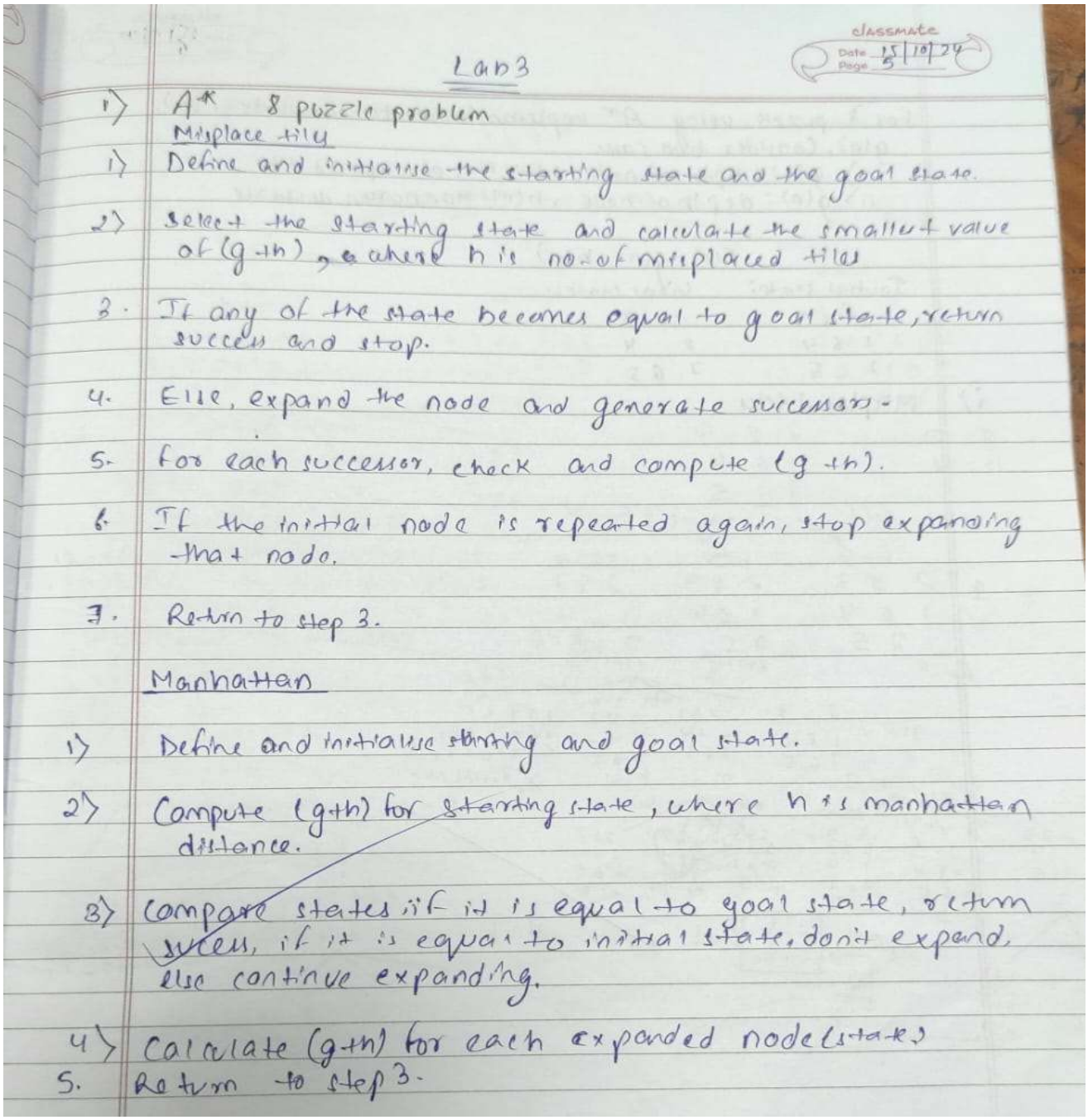
```
            return result

    return None

def iterative_deepening_search(initial_state, goal_state):
    depth = 0
    while True:
        result = depth_limited_search(initial_state, depth,
goal_state)
        if result is not None:
            return result
        depth += 1

# Example Usage
if __name__ == "__main__":
    initial_board = [2, 8, 3, 1, 6, 4, 7, 0, 5]  # Initial state
    goal_state = [2, 0, 3, 1, 8, 4, 7, 6, 5]  # Final state
    initial_state = PuzzleState(initial_board)

    solution = iterative_deepening_search(initial_state, goal_state)

    if solution:
        print("Solution found!")
        print("Moves:", solution.moves)
        print("Final Board State:", solution.board)
    else:
        print("No solution found.")
```

```
Solution found!
Moves: 2
Final Board State: [2, 0, 3, 1, 8, 4, 7, 6, 5]
```

Program 3

Implement A* search algorithm

Algorithm:



Lab 3

1) A* 8 puzzle problem

Misplace tile

1) Define and initialise the starting state and the goal state.
2) Select the starting state and calculate the smallest value of (g+h), where h is no. of misplaced tiles
3. If any of the state becomes equal to goal state, return success and stop.
4. Else, expand the node and generate successors.
5. For each successor, check and compute (g+h).
6. If the initial node is repeated again, stop expanding that node.
7. Return to step 3.

Manhattan

1) Define and initialise starting and goal state.
2) Compute (g+h) for starting state, where h is manhattan distance.
3) Compare states if it is equal to goal state, return success, if it is equal to initial state, don't expand, else continue expanding.
4) Calculate (g+h) for each expanded node(state)
5. Return to step 3.

For 8-puzzle, using A* implementation to calculate f(n), g(n). Consider two cases.

i) g(n): depth of node, h(n): No. of misplaced tiles

ii) g(n): depth of node, h(n): Manhattan distance

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

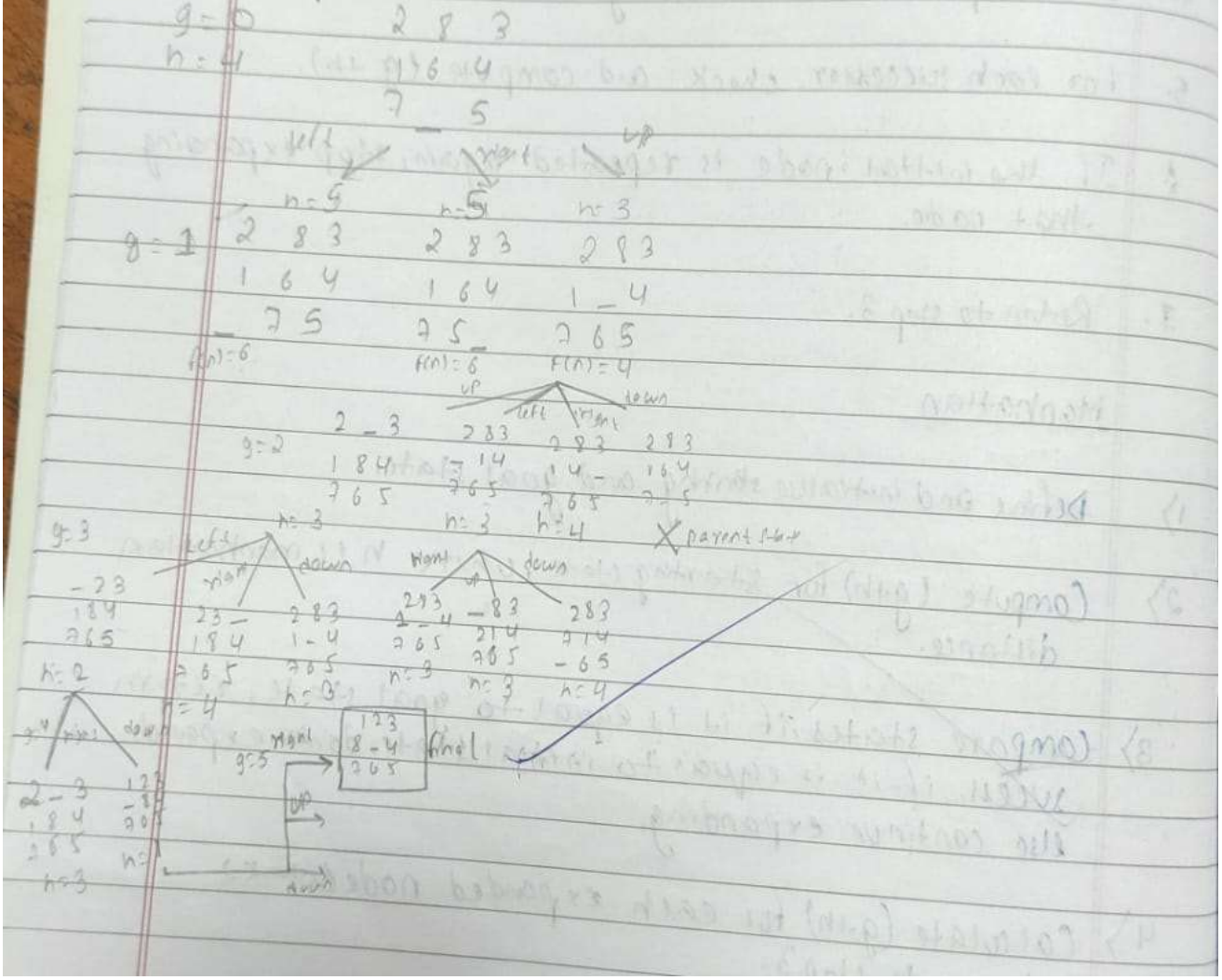
Initial state:

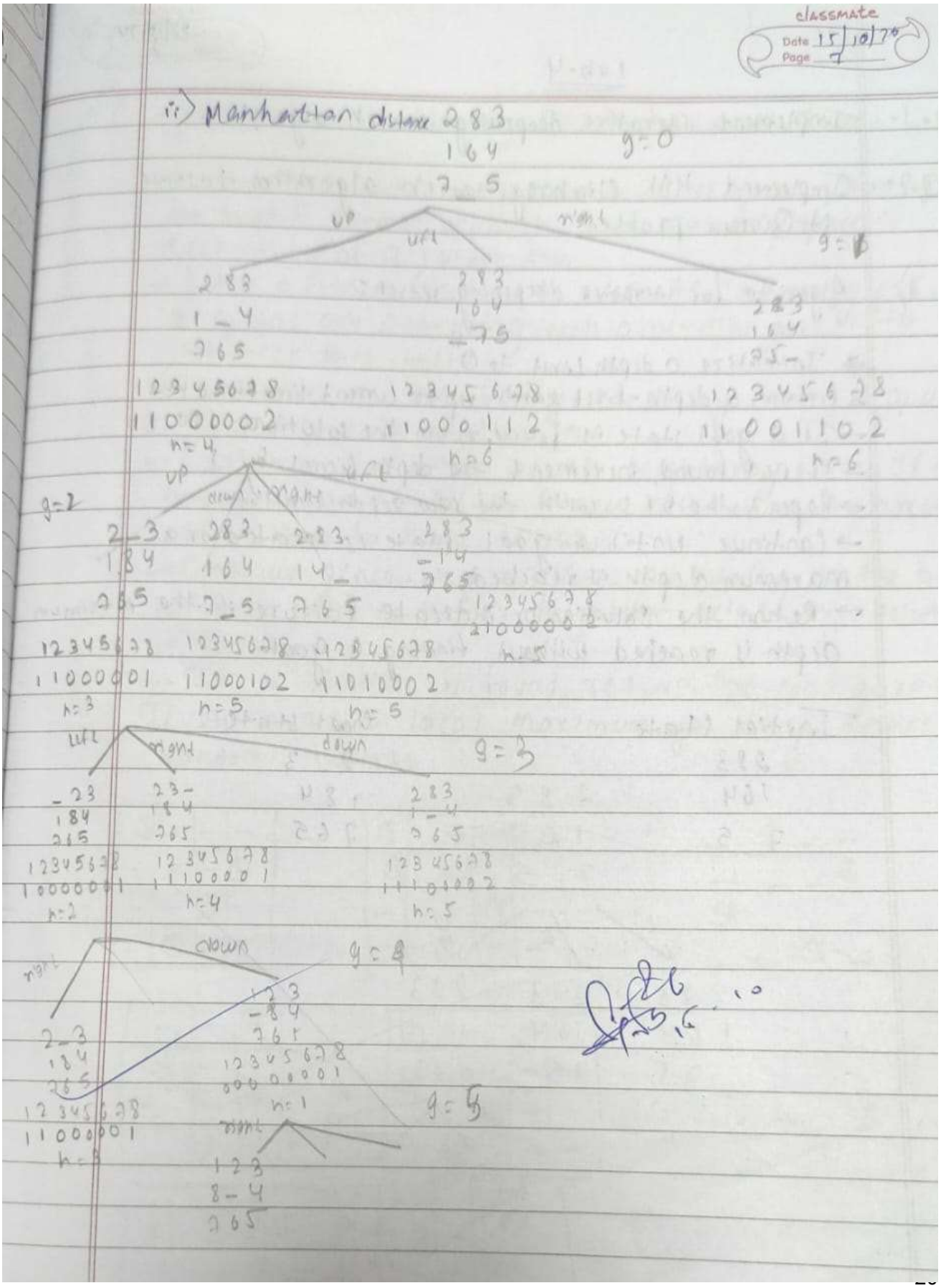
2	8	3
1	6	4
7		5

Goal state:

1	2	3
8		4
7	6	5

i) Misplaced tiles




classmate
Date 15/10/20
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ii) Manhattan distance
g=0
up
left
right
g=1
g=2
up
left
down
right
g=3
left
right
down
g=4
right
down
g=5

```python
import heapq
def manhattan_distance(state, goal):
    distance = 0
    for i in range(3):
        for j in range(3):
            tile = state[i][j]
            if tile != 0:
                for r in range(3):
                    for c in range(3):
                        if goal[r][c] == tile:
                            target_row, target_col = r, c
                            break
                distance += abs(target_row - i) + abs(target_col - j)
    return distance

def findmin(open_list, goal):
    minv = float('inf')
    best_state = None
    for state in open_list:
        h = manhattan_distance(state['state'], goal)
        f = state['g'] + h
        if f < minv:
            minv = f
            best_state = state
    open_list.remove(best_state)
    return best_state

def operation(state):
    next_states = []
    blank_pos = find_blank_position(state['state'])
    for move in ['up', 'down', 'left', 'right']:
        new_state = apply_move(state['state'], blank_pos, move)
        if new_state:
            next_states.append({
                'state': new_state,
                'parent': state,
                'move': move,
                'g': state['g'] + 1
            })
    return next_states
```

```
def find_blank_position(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
    return None

def apply_move(state, blank_pos, move):
    i, j = blank_pos
    new_state = [row[:] for row in state]
    if move == 'up' and i > 0:
        new_state[i][j], new_state[i - 1][j] = new_state[i - 1][j],
new_state[i][j]
    elif move == 'down' and i < 2:
        new_state[i][j], new_state[i + 1][j] = new_state[i + 1][j],
new_state[i][j]
    elif move == 'left' and j > 0:
        new_state[i][j], new_state[i][j - 1] = new_state[i][j - 1],
new_state[i][j]
    elif move == 'right' and j < 2:
        new_state[i][j], new_state[i][j + 1] = new_state[i][j + 1],
new_state[i][j]
    else:
        return None
    return new_state

def print_state(state):
    for row in state:
        print(' '.join(map(str, row)))
initial_state = [[2, 8, 3], [1, 6, 4], [7, 0, 5]]
goal_state = [[1, 2, 3], [8, 0, 4], [7, 6, 5]]

open_list = [{'state': initial_state, 'parent': None, 'move': None,
'g': 0}]
visited_states = []

while open_list:
    best_state = findmin(open_list, goal_state)

    h = manhattan_distance(best_state['state'], goal_state)
    f = best_state['g'] + h
```

```
    print(f"g(n) = {best_state['g']}, h(n) = {h}, f(n) = {f}")
    print_state(best_state['state'])
    print()

    if h == 0:
        print("Goal state reached!")
        break

    visited_states.append(best_state['state'])
    next_states = operation(best_state)

    for state in next_states:
        if state['state'] not in visited_states:
            open_list.append(state)

if h == 0:
    moves = []
    goal_state_reached = best_state
    while goal_state_reached['move'] is not None:
        moves.append(goal_state_reached['move'])
        goal_state_reached = goal_state_reached['parent']
    moves.reverse()
    print("\nMoves to reach the goal state:", moves)
else:
    print("No solution found.")
```

```
g(n) = 0, h(n) = 5, f(n) = 5
2 8 3
1 6 4
7 0 5

g(n) = 1, h(n) = 4, f(n) = 5
2 8 3
1 0 4
7 6 5

g(n) = 2, h(n) = 3, f(n) = 5
2 0 3
1 8 4
7 6 5

g(n) = 3, h(n) = 2, f(n) = 5
0 2 3
1 8 4
7 6 5

g(n) = 4, h(n) = 1, f(n) = 5
1 2 3
0 8 4
7 6 5

g(n) = 5, h(n) = 0, f(n) = 5
1 2 3
8 0 4
7 6 5

Goal state reached!

Moves to reach the goal state: ['up', 'up', 'left', 'down', 'right']
```

```python
import heapq


def find_blank_tile(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
    return None

def count_misplaced_tiles(state, goal):
    misplaced = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != 0 and state[i][j] != goal[i][j]:
                misplaced += 1
    return misplaced


def generate_moves(state):
    moves = []
    x, y = find_blank_tile(state)
    directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]

    for dx, dy in directions:
```

```
        new_x, new_y = x + dx, y + dy
        if 0 <= new_x < 3 and 0 <= new_y < 3:
            new_state = [row[:] for row in state]

            new_state[x][y], new_state[new_x][new_y] =
new_state[new_x][new_y], new_state[x][y]
            moves.append(new_state)
    return moves


def print_state(state):
    for row in state:
        print(row)
    print()

def a_star_8_puzzle(start, goal):

    open_list = []

    heapq.heappush(open_list, (count_misplaced_tiles(start, goal), 0,
start, None))


    visited = set()


    while open_list:

        f_n, g_n, current_state, previous_state =
heapq.heappop(open_list)


        print(f"g(n) = {g_n}, h(n) = {f_n - g_n}, f(n) = {f_n}")
        print_state(current_state)

        if current_state == goal:
            print("Goal state reached!")
            return

        visited.add(tuple(map(tuple, current_state)))
```

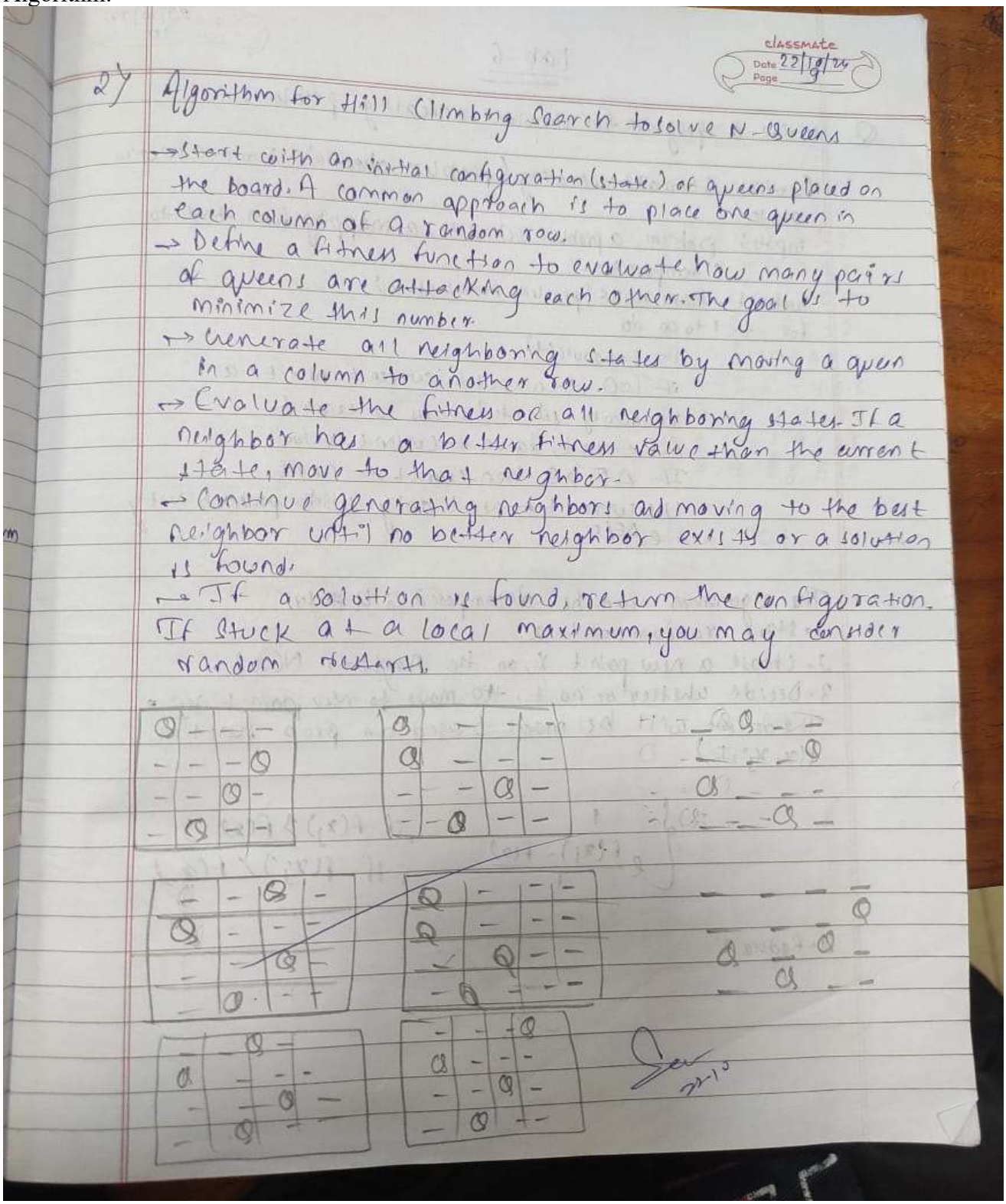
```
        for move in generate_moves(current_state):
            move_tuple = tuple(map(tuple, move))
            if move_tuple not in visited:

                g_move = g_n + 1
                h_move = count_misplaced_tiles(move, goal)
                f_move = g_move + h_move
                heapq.heappush(open_list, (f_move, g_move, move,
current_state))


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

a_star_8_puzzle(start_state, goal_state)
```

```
g(n) = 0, h(n) = 4, f(n) = 4
[2, 8, 3]
[1, 6, 4]
[7, 0, 5]

g(n) = 1, h(n) = 3, f(n) = 4
[2, 8, 3]
[1, 0, 4]
[7, 6, 5]

g(n) = 2, h(n) = 3, f(n) = 5
[2, 0, 3]
[1, 8, 4]
[7, 6, 5]

g(n) = 2, h(n) = 3, f(n) = 5
[2, 8, 3]
[0, 1, 4]
[7, 6, 5]

g(n) = 3, h(n) = 2, f(n) = 5
[0, 2, 3]
[1, 8, 4]
[7, 6, 5]

g(n) = 4, h(n) = 1, f(n) = 5
[1, 2, 3]
[0, 8, 4]
[7, 6, 5]

g(n) = 5, h(n) = 0, f(n) = 5
[1, 2, 3]
[8, 0, 4]
[7, 6, 5]

Goal state reached!
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:



```
import random

class NQueens:
    def __init__(self, n):
        self.n = n
        self.board = self.init_board()

    def init_board(self):
        # Randomly place one queen in each column
        return [random.randint(0, self.n - 1) for _ in range(self.n)]

    def fitness(self, board):
        # Count the number of pairs of queens attacking each other
        conflicts = 0
        for col in range(self.n):
            for other_col in range(col + 1, self.n):
                if board[col] == board[other_col] or abs(board[col] -
board[other_col]) == abs(col - other_col):
                    conflicts += 1
        return conflicts

    def get_neighbors(self, board):
        neighbors = []
        for col in range(self.n):
            for row in range(self.n):
                if row != board[col]:  # Move queen to a different
row in the same column
                    new_board = board[:]
                    new_board[col] = row
                    neighbors.append(new_board)
        return neighbors

    def hill_climbing(self):
        current_board = self.board
        current_fitness = self.fitness(current_board)

        while current_fitness > 0:
            neighbors = self.get_neighbors(current_board)
            next_board = None
            next_fitness = current_fitness
```

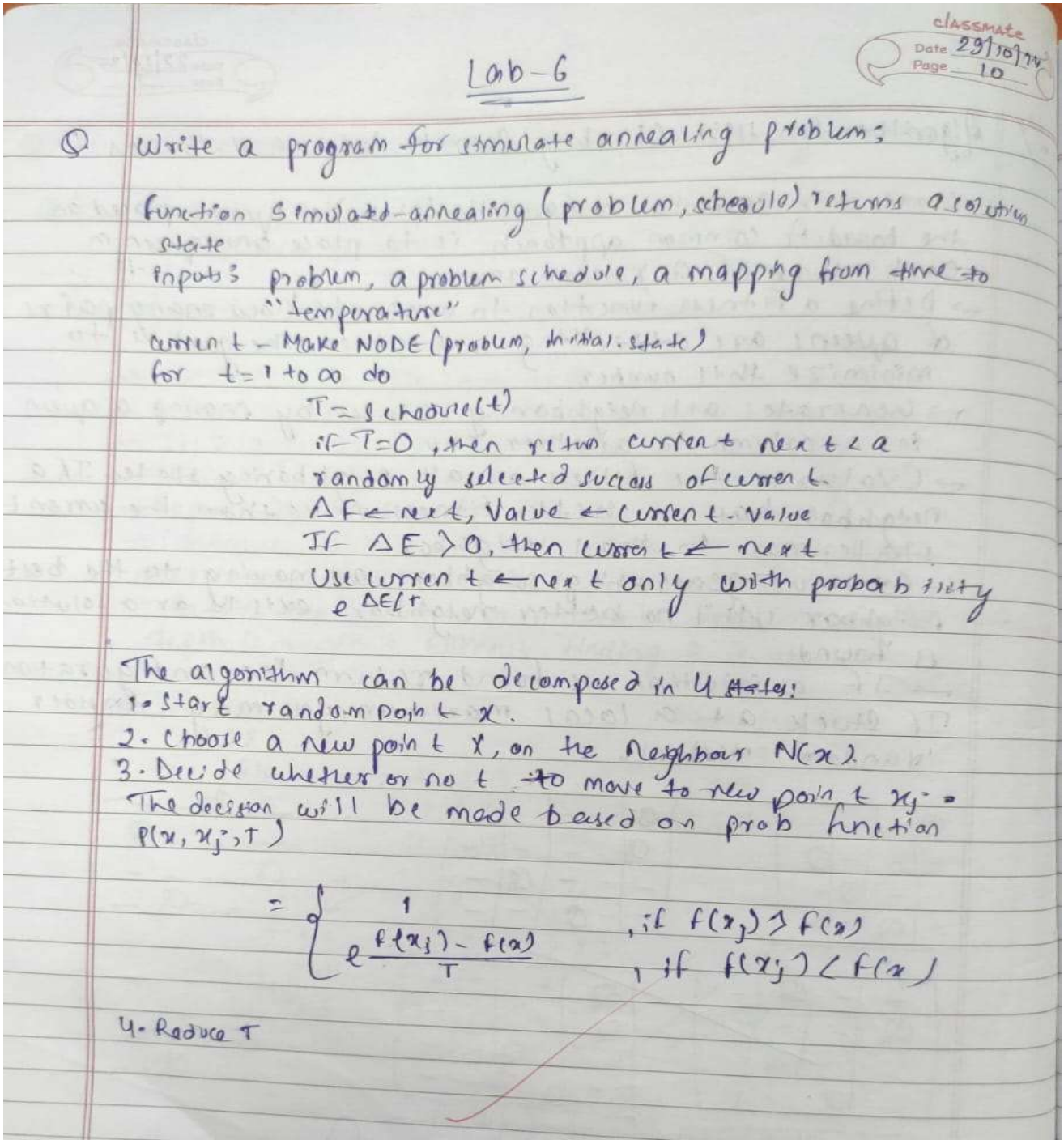
```
            for neighbor in neighbors:
                neighbor_fitness = self.fitness(neighbor)
                if neighbor_fitness < next_fitness:
                    next_fitness = neighbor_fitness
                    next_board = neighbor

            if next_board is None:
                # Stuck at local maximum, can either return or
restart
                print("Stuck at local maximum. Restarting...")
                self.board = self.init_board()
                current_board = self.board
                current_fitness = self.fitness(current_board)
            else:
                current_board = next_board
                current_fitness = next_fitness

        return current_board

# Example usage
if __name__ == "__main__":
    n = 4  # Size of the board (N)
    n_queens_solver = NQueens(n)
    solution = n_queens_solver.hill_climbing()

    print("Solution:")
    for row in solution:
        line = ['Q' if i == row else '.' for i in range(n)]
        print(' '.join(line))
```

```
Solution:
. Q . .
. . . Q
Q . . .
. . Q .
```

Program 5

Simulated Annealing to Solve 8-Queens problem

Algorithm:



Lab-6

Q Write a program for simulate annealing problem:

function Simulated-annealing (problem, schedule) returns a solution state

inputs: problem, a problem schedule, a mapping from time to "temperature"

current ← Make NODE(problem, initial.state)

for t = 1 to ∞ do

T = schedule(t)

if T=0, then return current next ← a randomly selected success of current.

ΔE ← next.Value ← current.Value

If ΔE > 0, then current ← next

Use current ← next only with probability $e^{\Delta E/T}$

The algorithm can be decomposed in 4 steps:

1. Start random point ← x.
2. Choose a new point x, on the neighbour N(x).
3. Decide whether or not to move to new point x_j.

The decision will be made based on prob function $P(x, x_j, T)$

$$= \begin{cases} e^{\frac{f(x_j) - f(x)}{T}} & \text{, if } f(x_j) \geq f(x) \\ 1 & \text{, if } f(x_j) < f(x) \end{cases}$$

4. Reduce T

Date 29/10/24
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Output:

Solution found:

```
_ _ _ _ _ _ Q _
_ _ Q _ _ _ _ _
_ _ _ _ _ _ _ Q
Q _ _ _ _ _ _ _
_ _ _ _ Q _ _ _
_ _ _ Q _ _ _ _
_ _ _ _ Q _ _ _
_ _ _ _ _ Q _ _
```

Conflicts: 6

Output:

Solved sudoku grid:

```
5 3 7 6 7 2 9 3 7
6 3 8 1 9 5 7 3 8
7 9 8 9 6 5 5 6 9
8 9 1 8 6 7 8 3 3
4 4 1 8 4 3 6 1 1
7 1 5 8 2 5 4 5 6
2 6 3 7 2 7 2 8 9
4 1 2 4 1 9 1 2 5
7 7 3 4 8 6 5 7 9
```

Conflicts: 103

```
import random
import math

def print_board(state):
    size = len(state)
    for i in range(size):
        row = ['.'] * size
        row[state[i]] = 'Q'
        print(' '.join(row))
    print()

def calculate_conflicts(state):
    conflicts = 0
    size = len(state)
    for i in range(size):
        for j in range(i + 1, size):
            if state[i] == state[j] or abs(state[i] - state[j]) ==
abs(i - j):
                conflicts += 1
    return conflicts

def random_state(size):
    return [random.randint(0, size - 1) for _ in range(size)]

def neighbor(state):
    new_state = state[:]
    idx = random.randint(0, len(state) - 1)
    new_state[idx] = random.randint(0, len(state) - 1)
    return new_state

def simulated_annealing(size, initial_temp, cooling_rate):
    current_state = random_state(size)
    current_conflicts = calculate_conflicts(current_state)
    temperature = initial_temp

    while temperature > 1:
        new_state = neighbor(current_state)
        new_conflicts = calculate_conflicts(new_state)

        # If new state is better, accept it
        if new_conflicts < current_conflicts:
```

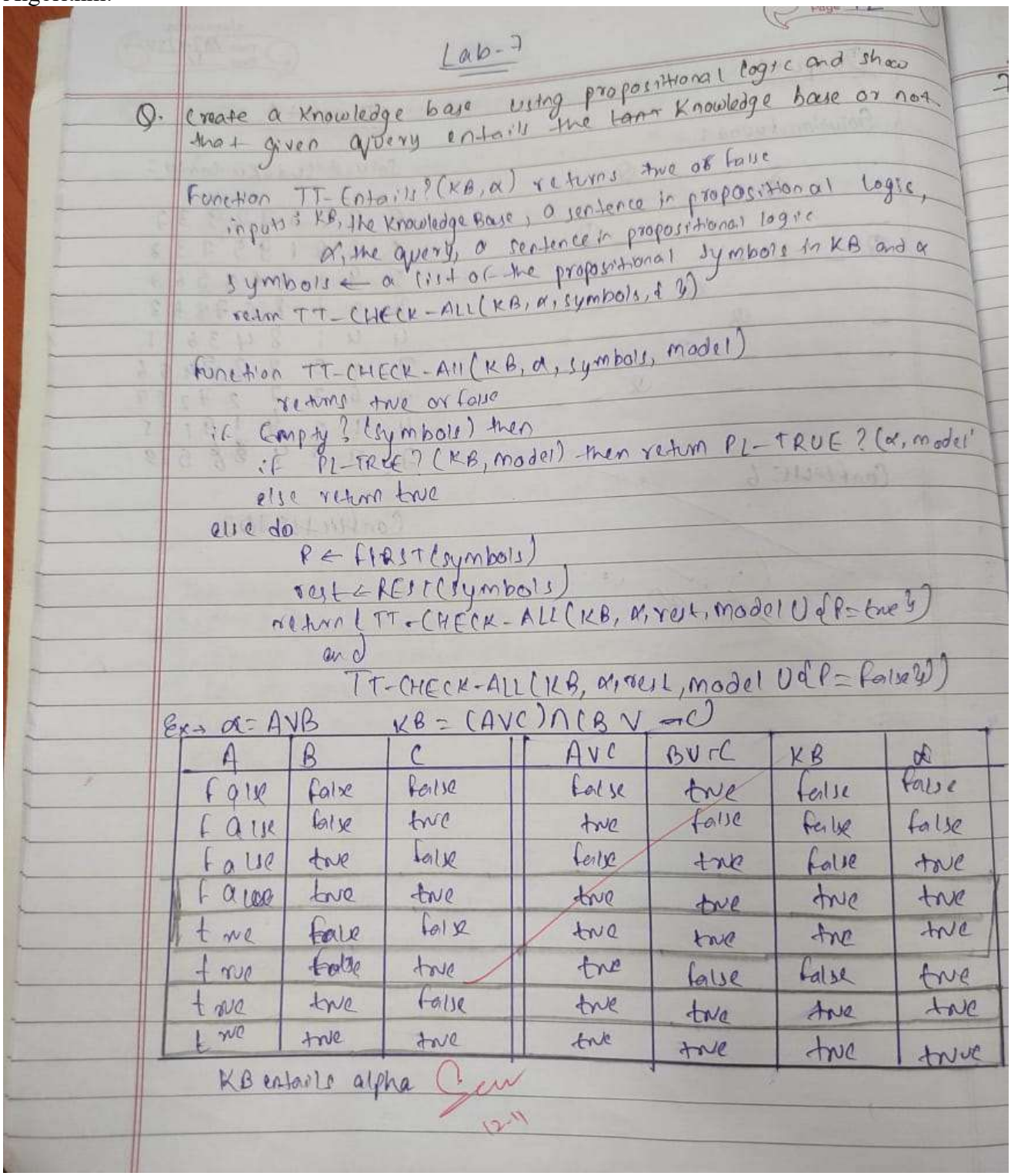
```
            current_state, current_conflicts = new_state,
new_conflicts
        else:
            # Accept with a probability based on temperature
            acceptance_probability = math.exp((current_conflicts -
new_conflicts) / temperature)
            if random.random() < acceptance_probability:
                current_state, current_conflicts = new_state,
new_conflicts

        temperature *= cooling_rate

    return current_state

def main():
    size = 8
    initial_temp = 1000
    cooling_rate = 0.995

    solution = simulated_annealing(size, initial_temp, cooling_rate)
    print("Solution found:")
    print_board(solution)
    print("Conflicts:", calculate_conflicts(solution))

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

```
Solution found:
. . . . . Q .
. . Q . . . .
. . . . . . Q
Q . . . . . .
. . . . Q . .
. . . Q . . .
. . . . Q . .
. . . . . Q .

Conflicts: 6
```

Program 6

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

Algorithm:



Lab-7

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

Function TT-Entails?(KB, α) returns true or false
inputs: KB, the knowledge base, a sentence in propositional logic,
α, the query, a sentence in propositional logic
symbols ← a list of the propositional symbols in KB and α
return TT-CHECK-ALL(KB, α, symbols, {})

function TT-CHECK-ALL(KB, α, symbols, model)
returns true or false
if Empty?(symbols) then
if PL-TRUE?(KB, model) then return PL-TRUE?(α, model)
else return true
else do
P ← FIRST(symbols)
rest ← REST(symbols)
return (TT-CHECK-ALL(KB, α, rest, model ∪ {P=true}))
and
TT-CHECK-ALL(KB, α, rest, model ∪ {P=false}))

Ex→ α = A∨B KB = (A∨C)∧(B∨¬C)

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

KB entails alpha

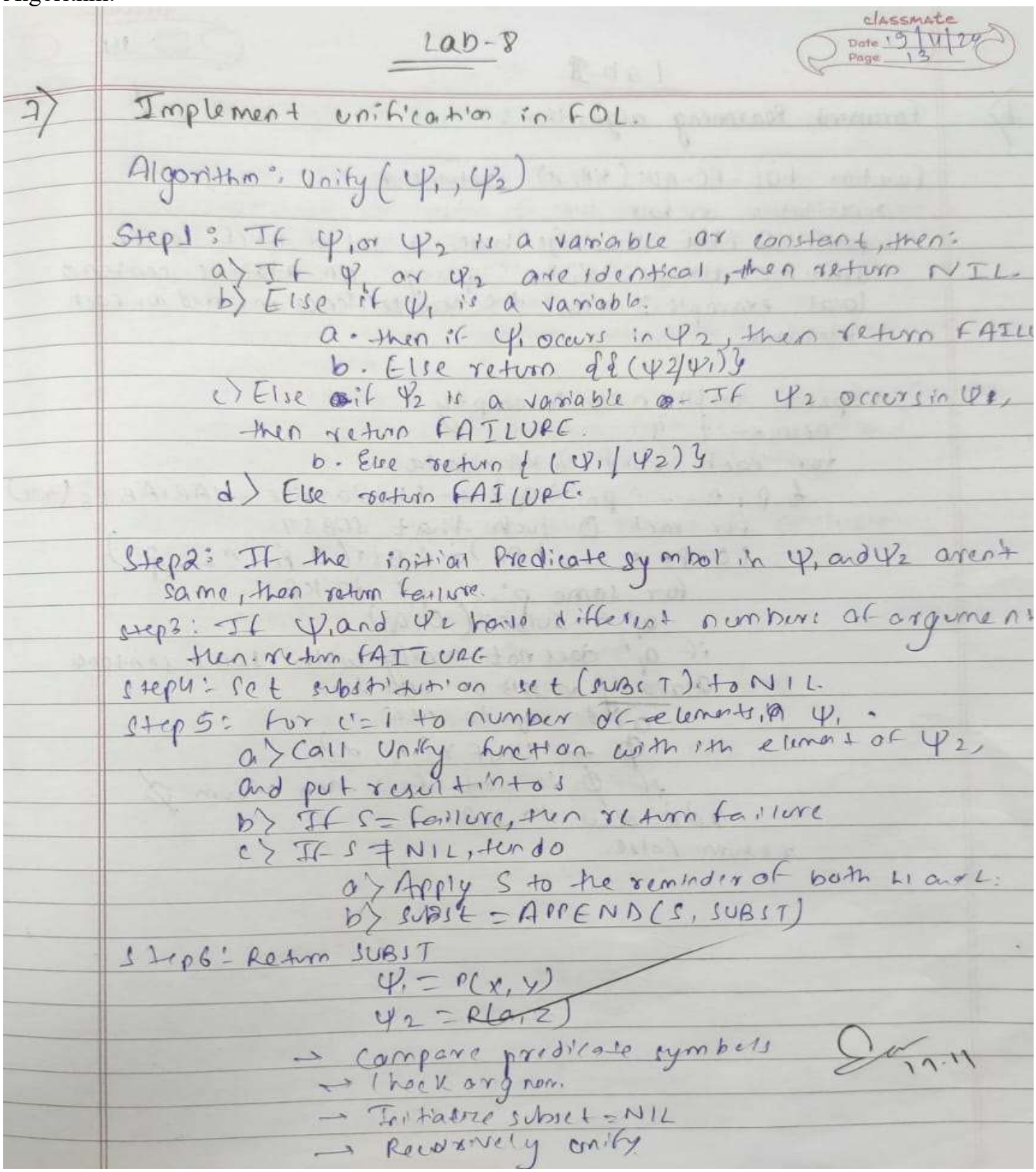
```
def truth_table_entailment():
    print(f"{'A':<7}{'B':<7}{'C':<7}{'A or C':<12}{'B or not
C':<15}{'KB':<8}{'alpha':<10}")
    print("-" * 65)
    all_entail = True
    for A in [False, True]:
        for B in [False, True]:
            for C in [False, True]:
                # Calculate individual components
                A_or_C = A or C                    # A or C
                B_or_not_C = B or (not C)          # B or not C
                KB = A_or_C and B_or_not_C         # KB = (A or C) and
(B or not C)
                alpha = A or B                     # alpha = A or B

                # Determine if KB entails alpha for this row
                kb_entails_alpha = (not KB) or alpha  # True if KB
implies alpha

                # If in any row KB does not entail alpha, set flag to
False
                if not kb_entails_alpha:
                    all_entail = False

                # Print the results for this row

print(f"{str(A):<7}{str(B):<7}{str(C):<7}{str(A_or_C):<12}{str(B_or_n
ot_C):<15}{str(KB):<8}{str(alpha):<10}")

    # Final result based on all rows
    if all_entail:
        print("\nKB entails alpha for all cases.")
    else:
        print("\nKB does not entail alpha for all cases.")

# Run the function to display the truth table and final result
truth_table_entailment()
```

```
A      B      C      A or C      B or not C     KB      alpha
-------------------------------------------------------------------
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

KB entails alpha for all cases.
```

Program 7

Implement unification in first order logic

Algorithm:



Lab-8

7) Implement unification in FOL.

Algorithm: Unify(Ψ_1, Ψ_2)

Step 1: If Ψ_1 or Ψ_2 is a variable or constant, then:
a) If Ψ_1 or Ψ_2 are identical, then return NIL.
b) Else if Ψ_1 is a variable.
a. then if Ψ_1 occurs in Ψ_2, then return FAIL
b. Else return {(Ψ_2/Ψ_1)}
c) Else if Ψ_2 is a variable - If Ψ_2 occurs in Ψ_1, then return FAILURE.
b. Else return {(Ψ_1/Ψ_2)}
d) Else return FAILURE.

Step 2: If the initial Predicate symbol in Ψ_1 and Ψ_2 aren't same, then return failure.

Step 3: If Ψ_1 and Ψ_2 have different number of argument then return FAILURE

Step 4: Set substitution set (SUBST) to NIL.

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

Step 6: Return SUBST

Ψ_1 = P(x, y)
Ψ_2 = R(a, z)

→ Compare predicate symbols
→ Check arg nos.
→ Initialize subset = NIL
→ Recursively unify

17.11

```
def unify(expr1, expr2, substitution=None):
```

```
    """
    Perform unification on two expressions in first-order logic.

    Args:
        expr1: The first expression (can be a variable, constant, or list
representing a function).
        expr2: The second expression.
        substitution: The current substitution (dictionary).

    Returns:
        A dictionary representing the most general unifier (MGU), or None if
unification fails.
    """
    if substitution is None:
        substitution = {}

    # Debug: Print inputs and current substitution
    print(f"Unifying {expr1} and {expr2} with substitution {substitution}")

    # Apply existing substitutions to both expressions
    expr1 = apply_substitution(expr1, substitution)
    expr2 = apply_substitution(expr2, substitution)

    # Debug: Print expressions after applying substitution
    print(f"After substitution: {expr1} and {expr2}")

    # Case 1: If expressions are identical, no substitution is needed
    if expr1 == expr2:
        return substitution

    # Case 2: If expr1 is a variable
    if is_variable(expr1):
        return unify_variable(expr1, expr2, substitution)

    # Case 3: If expr2 is a variable
    if is_variable(expr2):
        return unify_variable(expr2, expr1, substitution)

    # Case 4: If both are compound expressions (e.g., functions or
predicates)
    if is_compound(expr1) and is_compound(expr2):
```

```
        if expr1[0] != expr2[0] or len(expr1) != len(expr2):
            print(f"Failure: Predicate names or arity mismatch {expr1[0]} !=
{expr2[0]}")
            return None  # Function names or arity mismatch
        for arg1, arg2 in zip(expr1[1:], expr2[1:]):
            substitution = unify(arg1, arg2, substitution)
            if substitution is None:
                print(f"Failure: Could not unify arguments {arg1} and
{arg2}")
                return None
        return substitution

    # Case 5: Otherwise, unification fails
    print(f"Failure: Could not unify {expr1} and {expr2}")
    return None


def unify_variable(var, expr, substitution):
    """
    Handles the unification of a variable with an expression.

    Args:
        var: The variable.
        expr: The expression to unify with.
        substitution: The current substitution.

    Returns:
        The updated substitution, or None if unification fails.
    """
    if var in substitution:
        # Apply substitution recursively
        return unify(substitution[var], expr, substitution)
    elif occurs_check(var, expr):
        # Occurs check fails if the variable appears in the term it's being
unified with
        print(f"Occurs check failed: {var} in {expr}")
        return None
    else:
        substitution[var] = expr
        print(f"Substitution added: {var} -> {expr}")
        return substitution
```

```
def occurs_check(var, expr):
    """
    Checks if a variable occurs in an expression (to prevent cyclic
substitutions).

    Args:
        var: The variable to check.
        expr: The expression to check against.

    Returns:
        True if the variable occurs in the expression, otherwise False.
    """
    if var == expr:
        return True
    elif is_compound(expr):
        return any(occurs_check(var, arg) for arg in expr[1:])
    return False


def is_variable(expr):
    """Checks if the expression is a variable."""
    return isinstance(expr, str) and expr[0].islower()


def is_compound(expr):
    """Checks if the expression is compound (e.g., function or predicate)."""
    return isinstance(expr, list) and len(expr) > 0


def apply_substitution(expr, substitution):
    """
    Applies a substitution to an expression.

    Args:
        expr: The expression to apply the substitution to.
        substitution: The current substitution.

    Returns:
        The updated expression with substitutions applied.
```

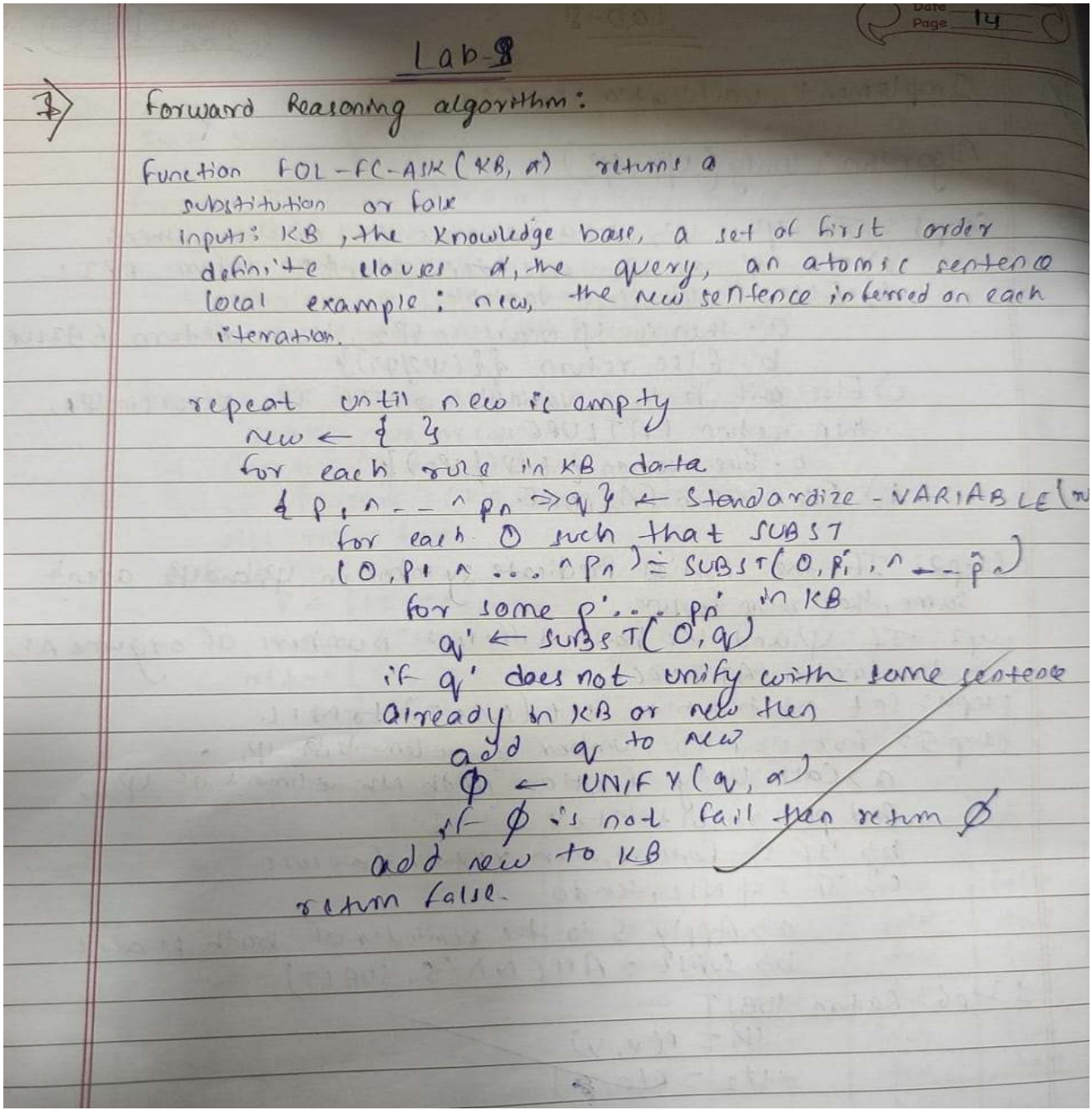
```
    """
    if is_variable(expr) and expr in substitution:
        return apply_substitution(substitution[expr], substitution)
    elif is_compound(expr):
        return [apply_substitution(arg, substitution) for arg in expr]
    return expr


# Example Usage:
expr1 = ['P', 'X', 'Y']
expr2 = ['P', 'a', 'Z']
result = unify(expr1, expr2)
print("Unification Result:", result)
```

```
Unifying ['P', 'X', 'Y'] and ['P', 'a', 'Z'] with substitution {}
After substitution: ['P', 'X', 'Y'] and ['P', 'a', 'Z']
Unifying X and a with substitution {}
After substitution: X and a
Substitution added: a -> X
Unifying Y and Z with substitution {'a': 'X'}
After substitution: Y and Z
Failure: Could not unify Y and Z
Failure: Could not unify arguments Y and Z
Unification Result: None
```

Program 8

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

Algorithm:



Lab-8

Forward Reasoning algorithm:

Function FOL-FC-ASK(KB, α) returns a substitution or false

inputs: KB, the knowledge base, a set of first order definite clauses
α, the query, an atomic sentence
local example: new, the new sentence inferred on each iteration.

repeat until new is empty
new ← { }
for each rule in KB data
{ p1 ∧ ... ∧ pn ⇒ q } ← Standardize-VARIABLE(r
for each θ such that SUBST
(θ, p1 ∧ ... ∧ pn) = SUBST(θ, p'1 ∧ ... ∧ p'n)
for some p'1 ... p'n in KB
q' ← SUBST(θ, q)
if q' does not unify with some sentence
already in KB or new then
add q to new
φ ← UNIFY(q, α)
if φ is not fail then return φ
add new to KB
return false.

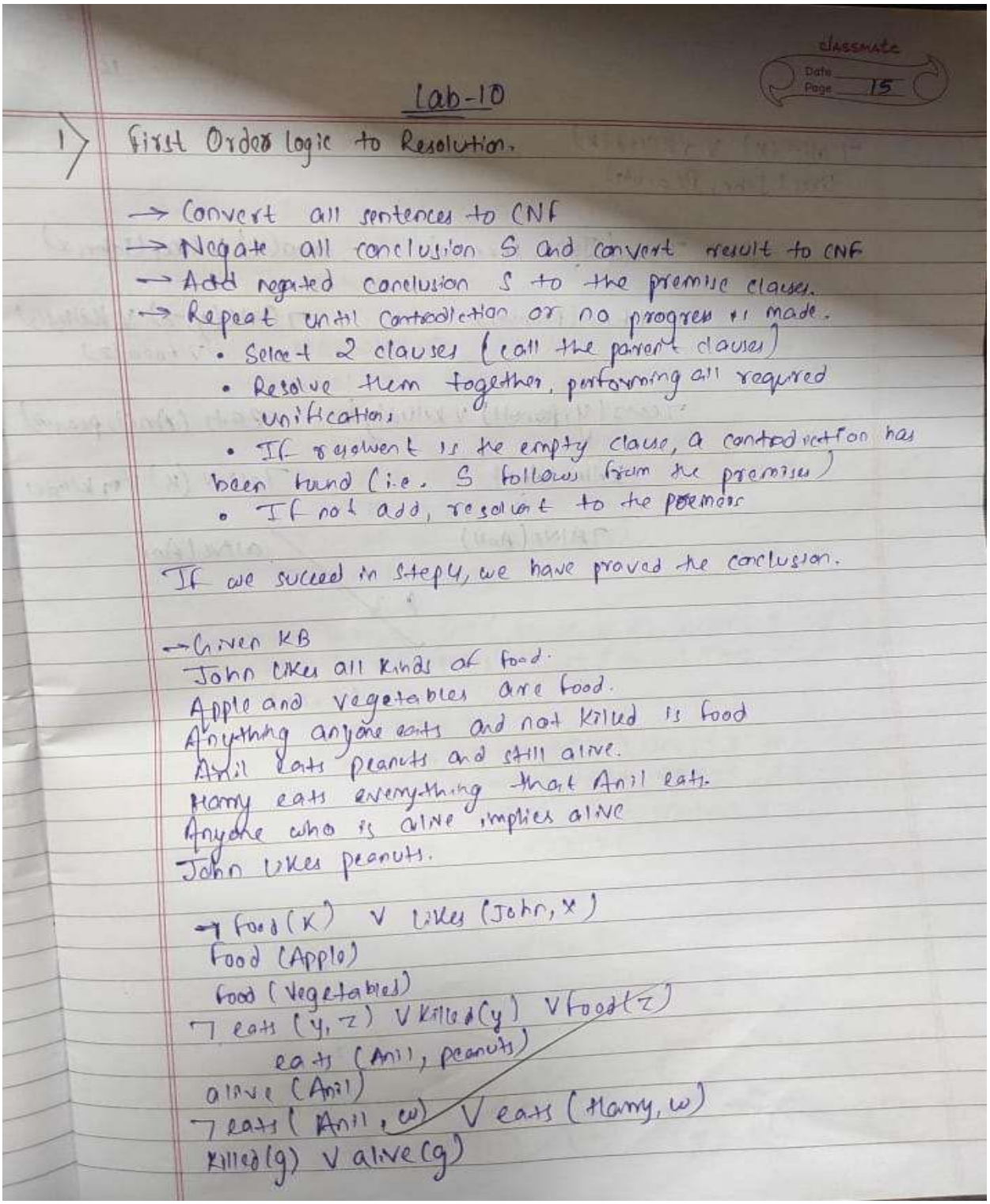
```
class ForwardReasoning:
    def __init__(self, rules, facts):
        self.rules = rules  # List of rules (condition -> result)
        self.facts = set(facts)  # Known facts

    def infer(self):
        applied_rules = True

        while applied_rules:
            applied_rules = False
            for rule in self.rules:
                condition, result = rule
                if condition.issubset(self.facts) and result not in self.facts:
                    self.facts.add(result)
                    applied_rules = True
                    print(f"Applied rule: {condition} -> {result}")
        return self.facts

# Define rules as (condition, result) where condition is a set
rules = [
    ({"A"}, "B"),
    ({"B"}, "C"),
    ({"C", "D"}, "E"),
    ({"E"}, "F")
]

# Define initial facts
facts = {"A", "D"}

# Initialize and run forward reasoning
reasoner = ForwardReasoning(rules, facts)
final_facts = reasoner.infer()

print("\nFinal facts:")
print(final_facts)
```

```
Applied rule: {'A'} -> B
Applied rule: {'B'} -> C
Applied rule: {'C', 'D'} -> E
Applied rule: {'E'} -> F

Final facts:
{'C', 'E', 'B', 'F', 'A', 'D'}
```

Program 9

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

Algorithm:



Lab-10

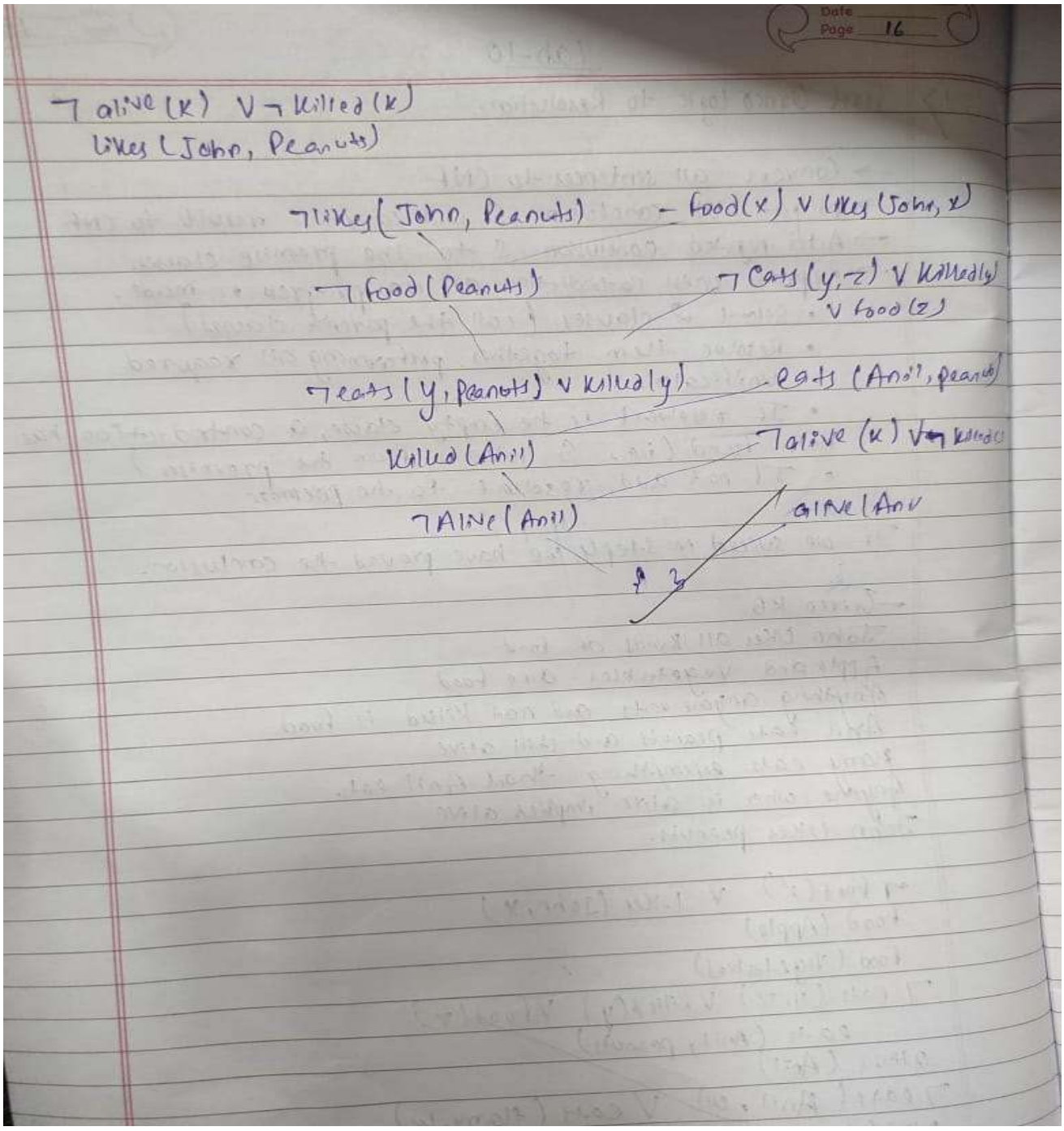
1) First Order logic to Resolution.

→ Convert all sentences to CNF
→ Negate all conclusion S and convert result to CNF
→ Add negated conclusion S to the premise clauses.
→ Repeat until contradiction or no progress is made.
- Select 2 clauses (call the parent clauses)
- Resolve them together, performing all required unifications
- If resolvent is the empty clause, a contradiction has been found (i.e. S follows from the premises)
- If not add, resolvent to the premises

If we succeed in step 4, we have proved the conclusion.

→ Given KB
John likes all kinds of food.
Apple and vegetables are food.
Anything anyone eats and not killed is food
Anil eats peanuts and still alive.
Harry eats everything that Anil eats.
Anyone who is alive implies alive
John likes peanuts.

→ food(x) V likes(John, x)
food(Apple)
food(vegetables)
¬ eats(y, z) V killed(y) V food(z)
eats(Anil, peanuts)
alive(Anil)
¬ eats(Anil, w) V eats(Harry, w)
killed(g) V alive(g)




```
# Define the knowledge base (KB) as a set of facts
KB = set()
# Premises based on the provided FOL problem
KB.add('American(Robert)')
KB.add('Enemy(America, A)')
KB.add('Missile(T1)')
KB.add('Owns(A, T1)')
# Define inference rules
```

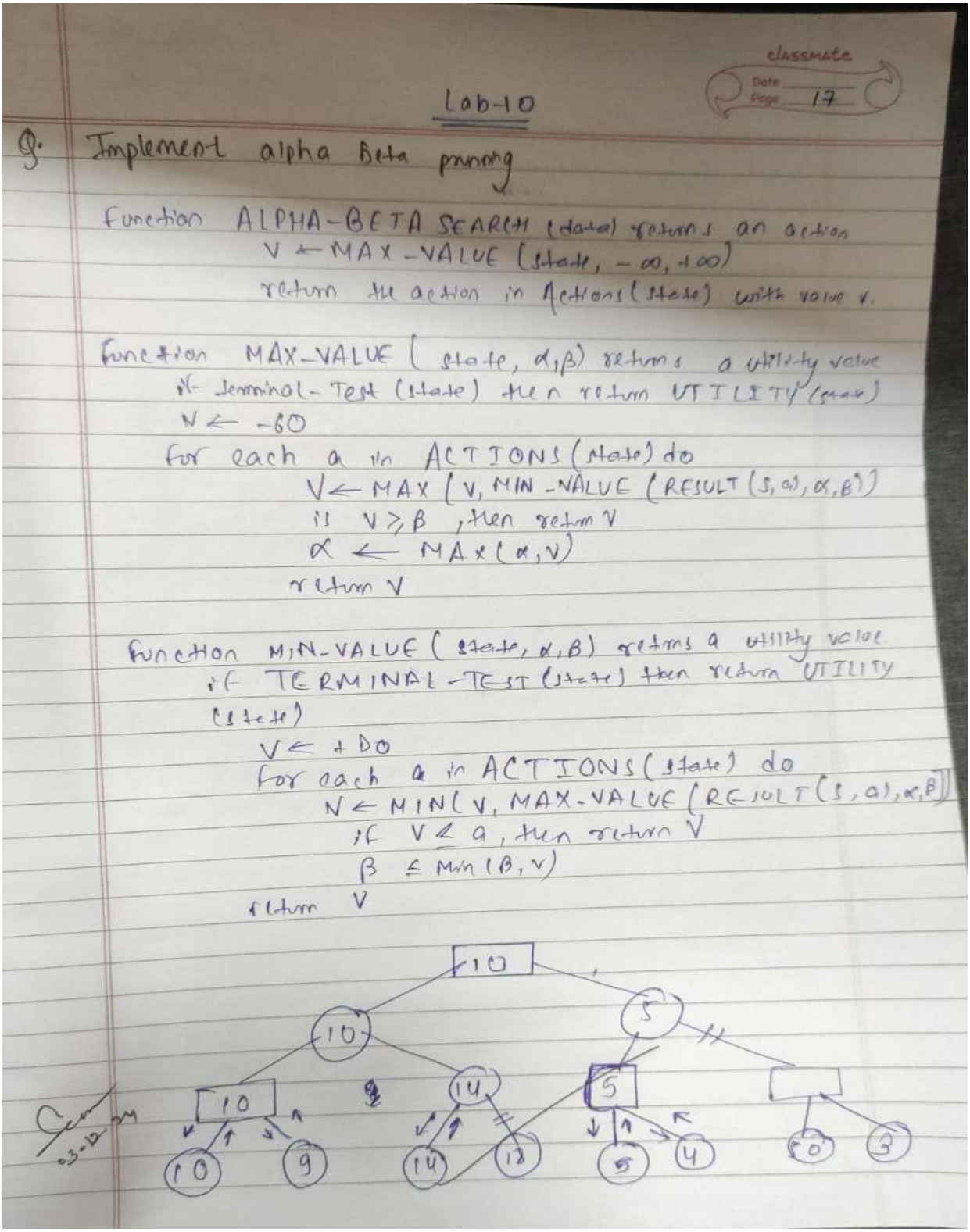
```
def modus_ponens(fact1, fact2, conclusion):
 """ Apply modus ponens inference rule: if fact1 and fact2 are true, then conclude conclusion
"""
 if fact1 in KB and fact2 in KB:
 KB.add(conclusion)
 print(f"Inferred: {conclusion}")
def forward_chaining():
 """ Perform forward chaining to infer new facts until no more inferences can be made """
 # 1. Apply: Missile(x) → Weapon(x)
 if 'Missile(T1)' in KB:
 KB.add('Weapon(T1)')
 print(f"Inferred: Weapon(T1)")
1
 # 2. Apply: Sells(Robert, T1, A) from Owns(A, T1) and Weapon(T1)
 if 'Owns(A, T1)' in KB and 'Weapon(T1)' in KB:
 KB.add('Sells(Robert, T1, A)')
 print(f"Inferred: Sells(Robert, T1, A)")
 # 3. Apply: Hostile(A) from Enemy(A, America)
 if 'Enemy(America, A)' in KB:
 KB.add('Hostile(A)')
 print(f"Inferred: Hostile(A)")
 # 4. Now, check if the goal is reached (i.e., if 'Criminal(Robert)' can be inferred)
 if 'American(Robert)' in KB and 'Weapon(T1)' in KB and 'Sells(Robert, T1, A)' in KB and
'Hostile(A)' in KB:
 KB.add('Criminal(Robert)')
 print("Inferred: Criminal(Robert)")
 # Check if we've reached our goal
 if 'Criminal(Robert)' in KB:
 print("Robert is a criminal!")
 else:
 print("No more inferences can be made.")
# Run forward chaining to attempt to derive the conclusion
forward_chaining()
```

```
Inferred: Weapon(T1)
Inferred: Sells(Robert, T1, A)
Inferred: Hostile(A)
Inferred: Criminal(Robert)
Robert is a criminal!
```

Program 10

Implement Alpha-Beta Pruning.

Algorithm:



```
# Alpha-Beta Pruning Implementation
def alpha_beta_pruning(node, alpha, beta, maximizing_player):
 # Base case: If it's a leaf node, return its value (simulating evaluation of the node)
 if type(node) is int:
 return node
if maximizing_player:
 max_eval = -float('inf')
 for child in node: # Iterate over children of the maximizer node
 eval = alpha_beta_pruning(child, alpha, beta, False)
 max_eval = max(max_eval, eval)
 alpha = max(alpha, eval) # Maximize alpha
 if beta <= alpha: # Prune the branch
 break
 return max_eval
 else:
 min_eval = float('inf')
 for child in node: # Iterate over children of the minimizer node
 eval = alpha_beta_pruning(child, alpha, beta, True)
 min_eval = min(min_eval, eval)
 beta = min(beta, eval) # Minimize beta
 if beta <= alpha: # Prune the branch
1
 break
 return min_eval
# Function to build the tree from a list of numbers
def build_tree(numbers):
 # We need to build a tree with alternating levels of maximizers and minimizers
 # Start from the leaf nodes and work up
 current_level = [[n] for n in numbers]

 while len(current_level) > 1:
 next_level = []
 for i in range(0, len(current_level), 2):
 if i + 1 < len(current_level):
 next_level.append(current_level[i] + current_level[i + 1]) # Combine two nodes
 else:
 next_level.append(current_level[i]) # Odd number of elements, just carry forward
 current_level = next_level

 return current_level[0] # Return the root node, which is a maximizer
# Main function to run alpha-beta pruning
def main():
 # Input: User provides a list of numbers
 numbers = list(map(int, input("Enter numbers for the game tree (space-separated): ").split()))
2
```

```
# Build the tree with the given numbers
tree = build_tree(numbers)

# Parameters: Tree, initial alpha, beta, and the root node is a maximizing player
alpha = -float('inf')
beta = float('inf')
maximizing_player = True # The root node is a maximizing player
# Perform alpha-beta pruning and get the final result
result = alpha_beta_pruning(tree, alpha, beta, maximizing_player)
print("Final Result of Alpha-Beta Pruning:", result)
if _name_ == "_main_":
main()
```

```
Enter numbers for the game tree (space-separated): 10 9 14 18 5 4 50 3
Final Result of Alpha-Beta Pruning: 50
```