VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

ABHISHEK PATIL (1BM23CS013)

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

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
BENGALURU-560019
Aug 2025 to Dec 2025

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

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Abhishek patil(1BM23CS013),** 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.

Swathi Sridharan Assistant Professor Department of CSE, BMSCE	Dr. Kavitha Sooda Professor & HOD Department of CSE, BMSCE

Index

Sl. No.	Date	Experiment Title	Page No.
1	20-8-2025	Implement Tic –Tac –Toe Game Implement vacuum cleaner agent	
2	3-9-2025	Implement 8 puzzle problems using Depth First Search (DFS) Implement Iterative deepening search algorithm	
3	10-9-2025	Implement A* search algorithm	
4	8-10-2025	Implement Hill Climbing search algorithm to solve N-Queens problem	
5	8-10-2025	Simulated Annealing to Solve 8-Queens problem	
6	15-10-2025	Create a knowledge base using propositional logic and show that the given query entails the knowledge base or not.	
7	29-10-2025	Implement unification in first order logic	
8	29-10-2025	Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.	
9	12-11-2025	Create a knowledge base consisting of first order logic statements and prove the given query using Resolution	
10	12-11-2025	Implement Alpha-Beta Pruning.	

Infosys®
Navigate your next

CERTIFICATE OF ACHIEVEMENT

The certificate is awarded to

Abhishek patil

for successfully completing

Principles of Generative AI Certification

on November 25, 2025

Infosys | Springboard

Congratulations! You make us proud!

Satheesha B.N.
Satheesha B. Nanjappa
Senior Vice President and Head
Education, Training and Assessment
Infosys Limited

Issued on: Tuesday, November 25, 2025
To verify, scan the QR code at https://verify.onwingspan.com

INDEX

Name : Abhishek patil Class : V

Section : 5 Roll No. : CS013 Subject : AI LAB

Sl. No.	Date	Title	Page No.	Teacher's Sign. / Remarks
1	20/8/25	fic-fac-foe & vaccum cleaner	10	
2	3/9/25	IDDFS & Memoryfic	10	
3	10/9/25	A* s for 8-puzzle	10	
4	8/10/25	Hill climbing . N Queen	10	
5	8/10/25	Simulatid Annealing N Queen	10	
6	15/10/25	knowledge Base & prepositional logic	10	
7	29/10/25	Unification & minimax alpha-beta	10	
8	12/11/25	First order logic		
9	12/11/25	Resolutions		

CIE - 10/10

or

9/5

Github Link: https://github.com/abhishekpatil-bms/AI_lab

Program 1

Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

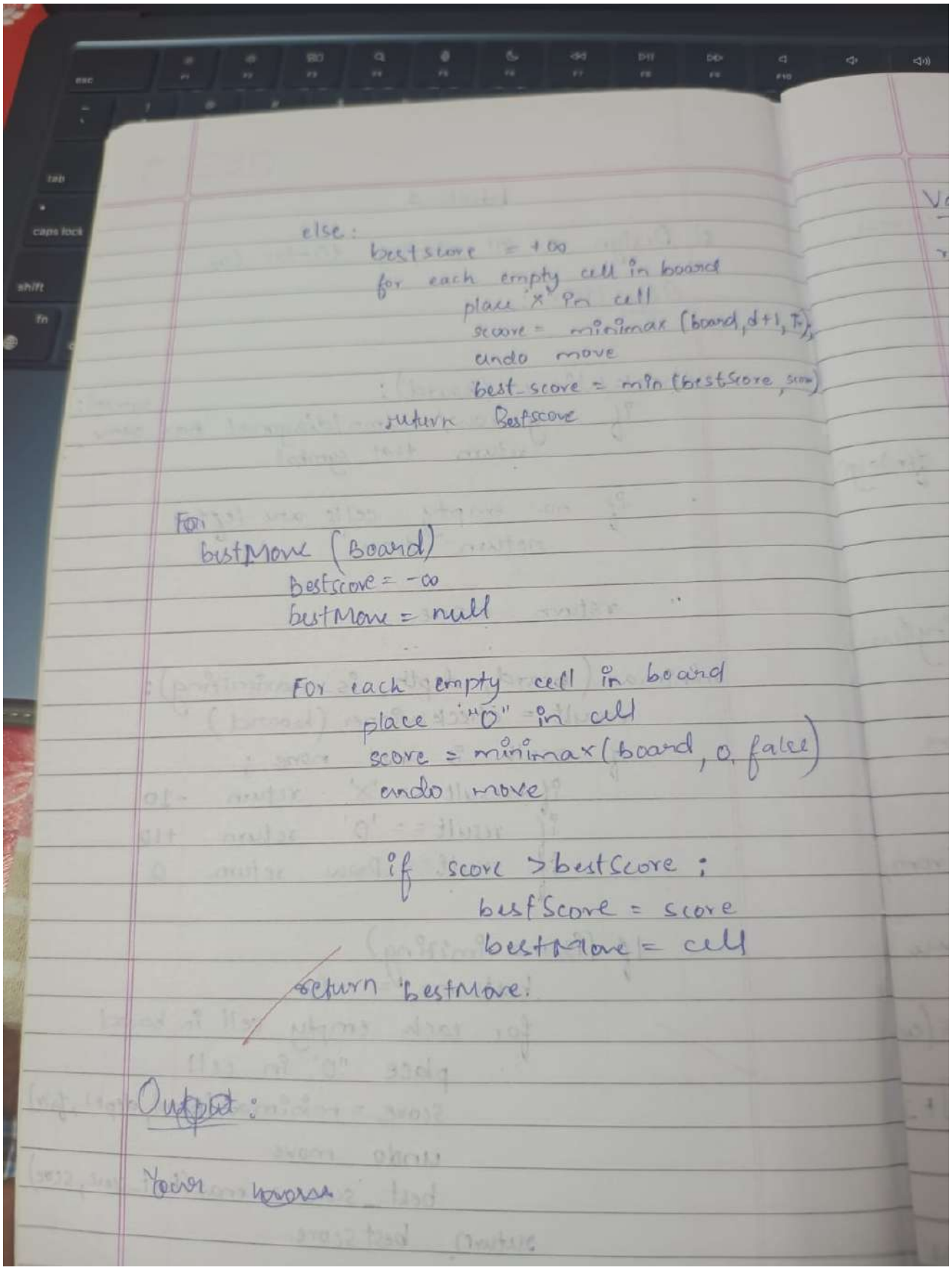
Algorithm:

Week-1

Q) Design a AI playing tic-tac-toe

Algorithm:

```
checkWinner(board):
    if any row/column/diagonal has same symbol:
        return that symbol

    if no empty cells are left:
        return "draw"

    return none

minimax(board, depth, is_maximizing):
    result = checkWinner(board)
    if result is not none;
        if result == 'X'  return -10
        if result == 'O'  return +10
        if result == Draw return 0

    If (is_maximizing)
        bestscore = -∞
        for each empty cell in board
            place "O" in cell
            score = minimax(board, depth+1, false)
            undo move
            best_score = max(best_score, score)
        return best score
```



```
else:
    bestscore = +∞
    for each empty cell in board
        place 'X' in cell
        score = minimax(board, d+1, T)
        undo move
        best_score = min(bestScore, score)
    return BestScore
```

For:

```
bestMove(Board)
    Bestscore = -∞
    bestMove = null

    For each empty cell in board
        place "O" in cell
        score = minimax(board, 0, false)
        undo move

        if score > bestScore:
            bestScore = score
            bestMove = cell
    return bestMove.
```

Output:

Your hoorah

Vaccum cleaner

```
room = {
    'A' : 'Dirty'
    'B' : 'Dirty'
}
vac_loc = 'A'
def suck():
    print(f"Sucking dirt! {vac_loc}");
    rooms[vac_loc] = 'clean'

def move():
    global vac_loc
    if (vac_loc == A):
        print( move to B)
        vac_loc = B
    else if (vac_loc == B):
        print (move to C)
        vac_loc = C
    else if (vac_loc = C)
        print (move to D):
        vac_loc = D
    else {
        print (move to A)
        vac_loc = A
    }
while 'Dirty' in room.values():
    if rooms[vac_loc] == 'Dirty':
        suck()
    else
        move()
```

Code:
Tic tac toe:

```
def print_board(board):
    for row in board:
        print(" ".join(row))
    print()

def check_winner(board, player):
    for i in range(3):
        if all(board[i][j] == player for j in range(3)):
            return True
        if all(board[j][i] == player for j in range(3)):
            return True
    if all(board[i][i] == player for i in range(3)):
        return True
    if all(board[i][2 - i] == player for i in range(3)):
        return True
    return False

def is_draw(board):
    return all(board[i][j] != '-' for i in range(3) for j in range(3))

def minimax(board, is_ai_turn):
    if check_winner(board, 'O'):
        return 1
    if check_winner(board, 'X'):
        return -1
    if is_draw(board):
        return 0

    if is_ai_turn:
        best_score = -float('inf')
        for i in range(3):
            for j in range(3):
                if board[i][j] == '-':
                    board[i][j] = 'O'
                    score = minimax(board, False)
                    board[i][j] = '-'
                    best_score = max(score, best_score)
        return best_score
    else:
        best_score = float('inf')
        for i in range(3):
            for j in range(3):
                if board[i][j] == '-':
                    board[i][j] = 'X'
                    score = minimax(board, True)
```

```
                board[i][j] = '-'
                best_score = min(score, best_score)
        return best_score

def manual_game():
    board = [['-' for _ in range(3)] for _ in range(3)]
    print("Initial Board:")
    print_board(board)

    while True:
        while True:
            try:
                x_row = int(input("Enter X row (1-3): ")) - 1
                x_col = int(input("Enter X col (1-3): ")) - 1
                if board[x_row][x_col] == '-':
                    board[x_row][x_col] = 'X'
                    break
                else:
                    print("Cell occupied!")
            except:
                print("Invalid input!")

        print("Board after X move:")
        print_board(board)

        if check_winner(board, 'X'):
            print("X wins!")
            break
        if is_draw(board):
            print("Draw!")
            break

        while True:
            try:
                o_row = int(input("Enter O row (1-3): ")) - 1
                o_col = int(input("Enter O col (1-3): ")) - 1
                if board[o_row][o_col] == '-':
                    board[o_row][o_col] = 'O'
                    break
                else:
                    print("Cell occupied!")
            except:
                print("Invalid input!")

        print("Board after O move:")
        print_board(board)
```

```
                if check_winner(board, 'O'):
                    print("O wins!")
                    break
                if is_draw(board):
                    print("Draw!")
                    break

                cost = minimax(board, True)
                print(f"AI evaluation cost from this position: {cost}")

        manual_game()
        print("Name: Sanchit Mehta and USN : 1BM23CS299")
```

vaccum cleaner:

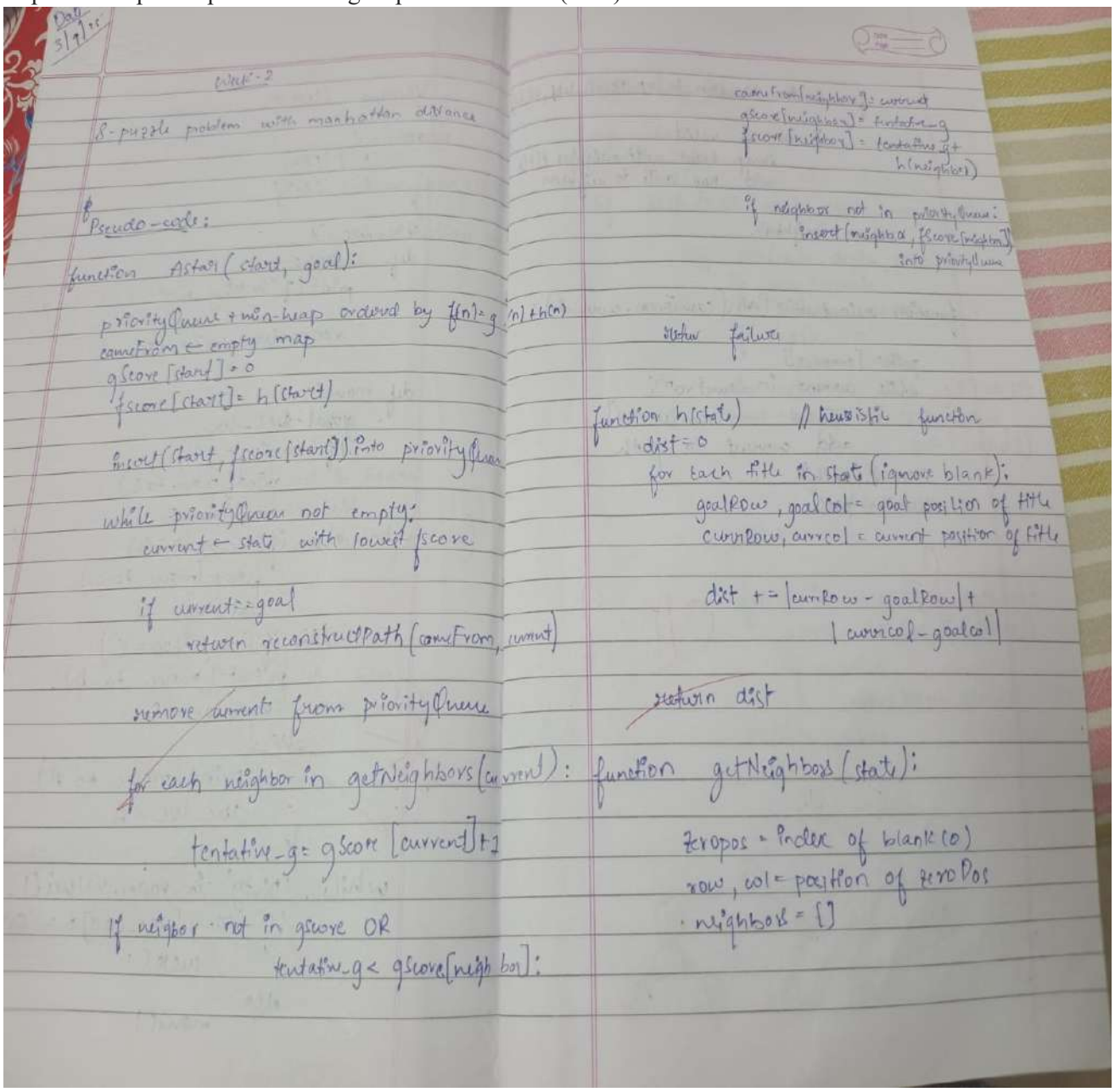
```
rooms = int(input("Enter Number of rooms: "))
Rooms = "ABCDEFGHIJKLMNOPQRSTUVWXYZ"
cost = 0
Roomval = {}


for i in range(rooms):
    print(f"Enter Room {Rooms[i]} state (0 for clean, 1 for dirty): ")
    n = int(input())
    Roomval[Rooms[i]] = n

loc = input(f"Enter Location of vacuum ({Rooms[:rooms]}): ").upper()

while 1 in Roomval.values():
    if Roomval[loc] == 1:
        print(f"Room {loc} is dirty. Cleaning...")
        Roomval[loc] = 0
        cost += 1
    else:
        print(f"Room {loc} is already clean.")

    move = input("Enter L or R to move left or right (or Q to quit): ").upper()

    if move == "L":
        if loc != Rooms[0]:
            loc = Rooms[Rooms.index(loc) - 1]
        else:
            print("No room to move left.")
    elif move == "R":
        if loc != Rooms[rooms - 1]:
            loc = Rooms[Rooms.index(loc) + 1]
        else:
            print("No room to move right.")
```

```
    elif move == "Q":
        break
    else:
        print("Invalid input. Please enter L, R, or Q.")

print("\nAll Rooms Cleaned." if 1 not in Roomval.values() else "Exited before cleaning all rooms.")
print(f"Total cost: {cost}")
print("1BM23CS299")
print("Sanchit Mehta")
```

```
Enter Number of rooms: 4
Enter Room A state (0 for clean, 1 for dirty):
0
Enter Room B state (0 for clean, 1 for dirty):
1
Enter Room C state (0 for clean, 1 for dirty):
0
Enter Room D state (0 for clean, 1 for dirty):
1
Enter Location of vacuum (ABCD): A
Room A is already clean.
Enter L or R to move left or right (or Q to quit): L
No room to move left.
Room A is already clean.
Enter L or R to move left or right (or Q to quit): R
Room B is dirty. Cleaning...
Enter L or R to move left or right (or Q to quit): R
Room C is already clean.
Enter L or R to move left or right (or Q to quit): R
Room D is dirty. Cleaning...
Enter L or R to move left or right (or Q to quit): R
No room to move right.

All Rooms Cleaned.
Total cost: 2
1BM23CS299
Sanchit Mehta

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

Program 2

Implement 8 puzzle problems using Depth First Search (DFS):



for each direction in [up, down, left, right]

if move is valid

swap blank with neighbor tile

add new state to neighbors

return neighbors.

function reConstructionPath(cameFrom, current):

path = [current]

while current in cameFrom:

current = cameFrom[current]

add current to path

reverse(path)

return path

O/P - ?

IDDF

def

Pseu

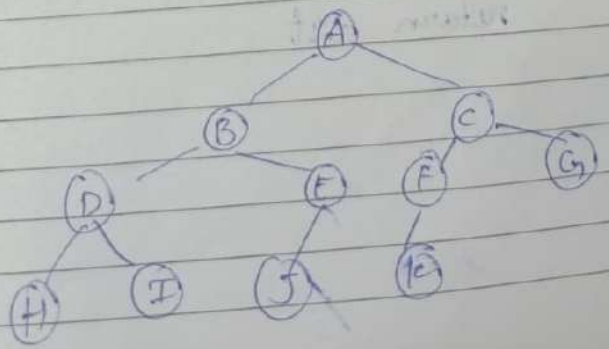
def

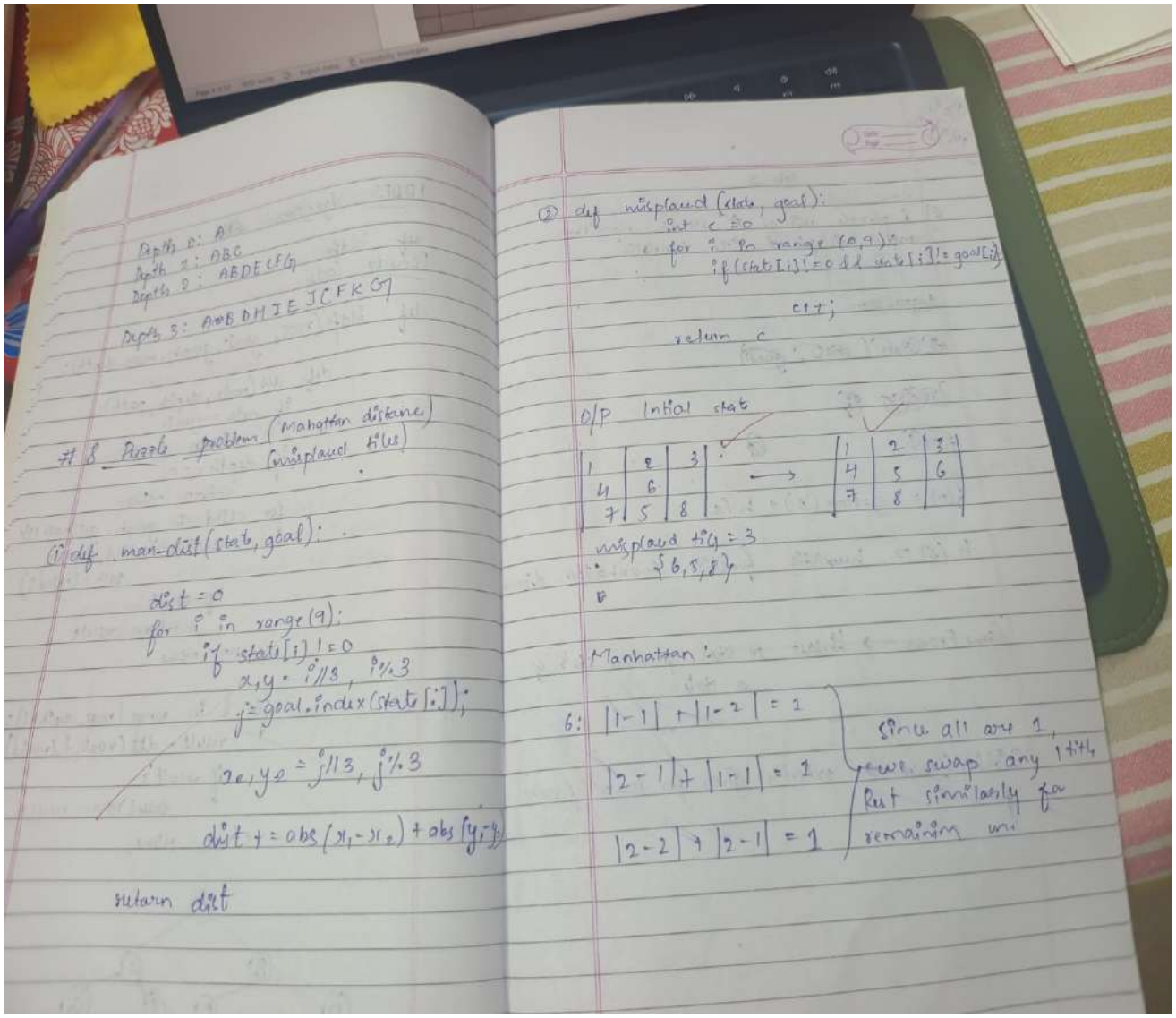
IDDFS algorithm with

def iddfs

Pseudo code

```
def iddfs(root, goal, graph, max_depth):
    def dls(node, depth, path):
        if node == goal:
            return path
        if depth == 0:
            return None
        for child in graph.get(node, []):
            result = dls(child, depth-1,
                         path + [child])
            if result:
                return result
        return None
    for l in range(max_depth+1):
        result = dls(root, l, [root])
        if result:
            return result
    return None
```






```
goal_state = '123804765'

moves = {
   'U': -3,
   'D': 3,
   'L': -1,
   'R': 1
}
count = 0
invalid_moves = {
   0: ['U', 'L'], 1: ['U'], 2: ['U', 'R'],
   3: ['L'],       5: ['R'],
   6: ['D', 'L'], 7: ['D'], 8: ['D', 'R']
}

def move_tile(state, direction):
   index = state.index('0')
   if direction in invalid_moves.get(index, []):
```

```
        return None

    new_index = index + moves[direction]
    if new_index < 0 or new_index >= 9:
        return None

    state_list = list(state)
    state_list[index], state_list[new_index] = state_list[new_index], state_list[index]
    return ''.join(state_list)

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

def dfs(start_state, max_depth=50):
    visited = set()
    stack = [(start_state, [])]  # Each element: (state, path)

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

        if current_state in visited:
            continue

        # Print every visited state
        print("Visited state:")
        print_state(current_state)

        if current_state == goal_state:
            return path

        visited.add(current_state)
        global count
        count +=1
        if len(path) >= max_depth:
            continue

        for direction in moves:
            new_state = move_tile(current_state, direction)
            if new_state and new_state not in visited:
                stack.append((new_state, path + [direction]))

    return None

start = input("Enter start state (e.g., 724506831): ")

if len(start) == 9 and set(start) == set('012345678'):
    print("Start state:")
    print_state(start)

    result = dfs(start)
```

```
    if result is not None:
        print("Solution found!")
        print("Moves:", ' '.join(result))
        print("Number of moves:", len(result))
        print("Number of visited states",count)
        print("1BM23CS299 Sanchit Mehta\n")

        current_state = start
        for i, move in enumerate(result, 1):
            current_state = move_tile(current_state, move)
            print(f"Move {i}: {move}")
            print_state(current_state)
    else:
        print("No solution exists for the given start state or max depth reached.")
else:
    print("Invalid input! Please enter a 9-digit string using digits 0-8 without repetition.")
```

Implement Iterative deepening search algorithm:

```
goal_state = '123456780'

moves = {
    'U': -3,
    'D': 3,
    'L': -1,
    'R': 1
}

invalid_moves = {
    0: ['U', 'L'], 1: ['U'], 2: ['U', 'R'],
    3: ['L'],       5: ['R'],
    6: ['D', 'L'], 7: ['D'], 8: ['D', 'R']
}

def move_tile(state, direction):
    index = state.index('0')
    if direction in invalid_moves.get(index, []):
        return None

    new_index = index + moves[direction]
    if new_index < 0 or new_index >= 9:
        return None

    state_list = list(state)
    state_list[index], state_list[new_index] = state_list[new_index], state_list[index]
    return ''.join(state_list)

def print_state(state):
```

```
    for i in range(0, 9, 3):
        print(' '.join(state[i:i+3]).replace('0', ' '))
    print()

def dls(state, depth, path, visited, visited_count):
    visited_count[0] += 1  # Increment visited states count
    if state == goal_state:
        return path

    if depth == 0:
        return None

    visited.add(state)

    for direction in moves:
        new_state = move_tile(state, direction)
        if new_state and new_state not in visited:
            result = dls(new_state, depth - 1, path + [direction], visited, visited_count)
            if result is not None:
                return result

    visited.remove(state)
    return None

def iddfs(start_state, max_depth=50):
    visited_count = [0]  # Using list to pass by reference
    for depth in range(max_depth + 1):
        visited = set()
        result = dls(start_state, depth, [], visited, visited_count)
        if result is not None:
            return result, visited_count[0]
    return None, visited_count[0]

# Main
start = input("Enter start state (e.g., 724506831): ")

if len(start) == 9 and set(start) == set('012345678'):
    print("Start state:")
    print_state(start)

    result, visited_states = iddfs(start,15)

    print(f"Total states visited: {visited_states}")

    if result is not None:
        print("Solution found!")
        print("Moves:", ' '.join(result))
```

```
        print("Number of moves:", len(result))
        print("1BM23CS307 Uzair\n")

        current_state = start
        for i, move in enumerate(result, 1):
            current_state = move_tile(current_state, move)
            print(f"Move {i}: {move}")
            print_state(current_state)
    else:
        print("No solution exists for the given start state or max depth reached.")
else:
    print("Invalid input! Please enter a 9-digit string using digits 0-8 without repetition.")
```

```
Enter start state (e.g., 724506831): 724506831
Start state:
7 2 4
5   6
8 3 1

Visited state:
7 2 4
5   6
8 3 1

Visited state:
7 2 4
5 6
8 3 1

Visited state:
7 2 4
5 6 1
8 3

Visited state:
7 2 4
5 6 1
8   3
```

Program 3

Implement A* search algorithm

Date 10/9/25

lab - 3

Q) 8 puzzle using A* search algorithm and misplaced title heuristic

~~Algorithm~~

~~State (state, goal)~~

~~Tracing~~

~~f(n)~~

$f(n) = g\text{-score}(s) + h(s)$

$h(s)$ → heuristic function manhattan distance

Came From → linked to store previous state of a state

Priority Queue → priority given for lowest fscore

f

Initial state

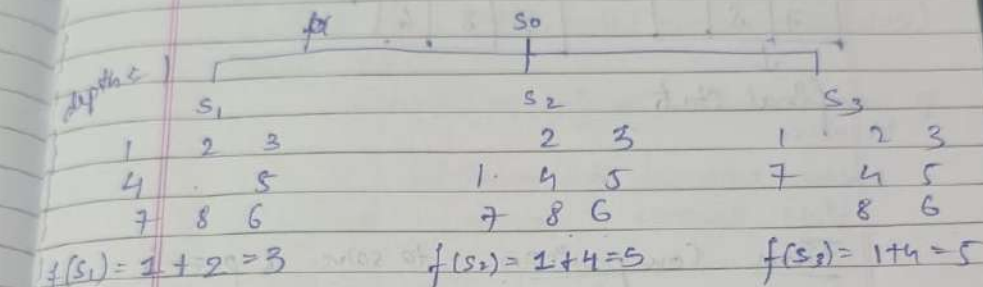
S_0

1	2	3
	4	5
7	8	6

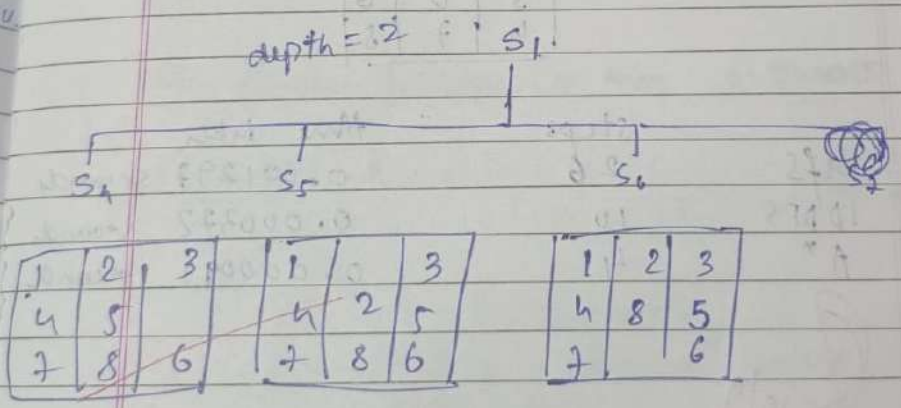
Goal state

S_f

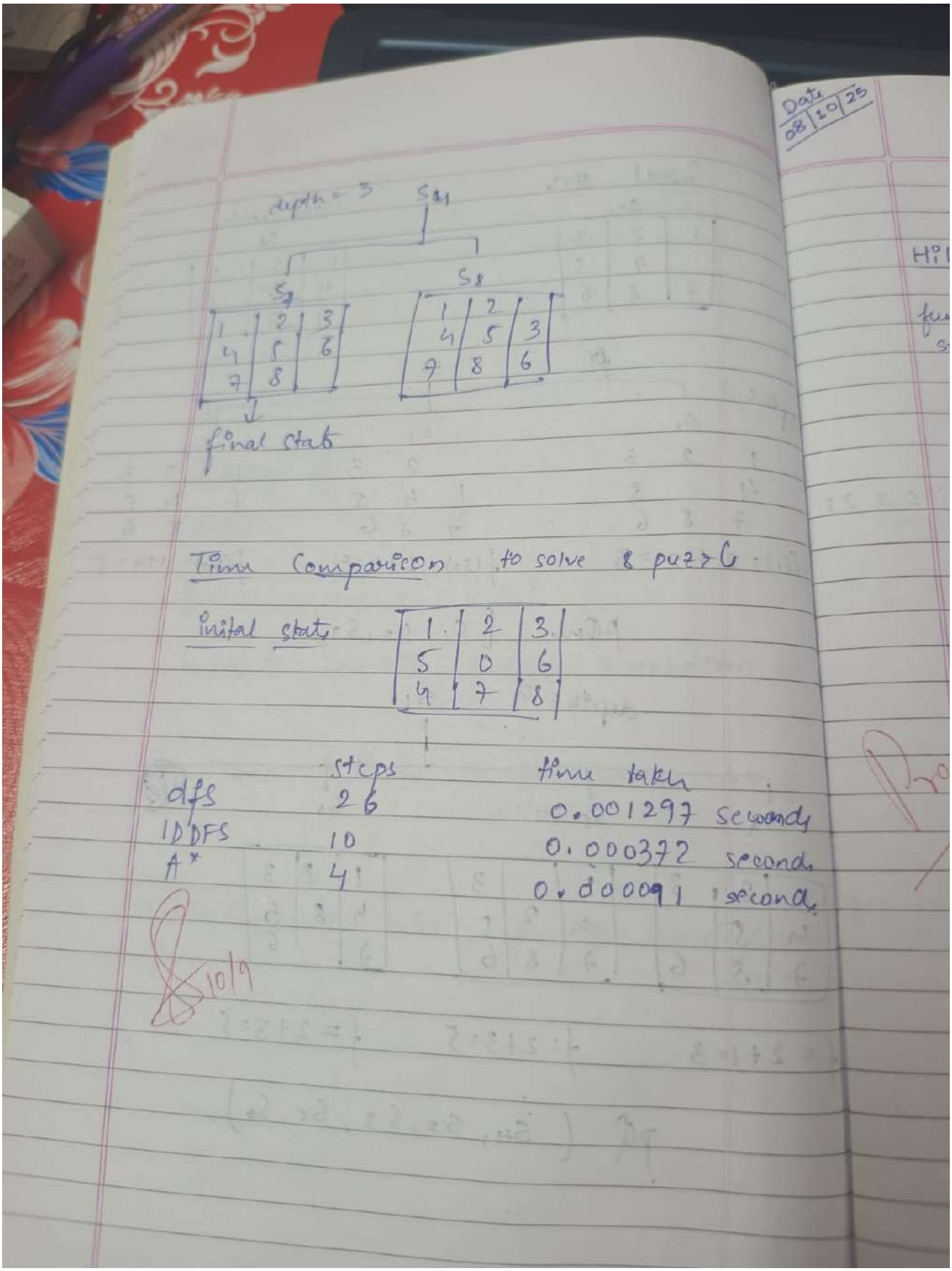
1	2	3
4	5	6
7	8	



pQue: $[S_1, S_2, S_3]$



pQ $(S_4, S_2, S_3, S_5, S_6)$



Time Comparison to solve 8 puzzle

Initial state

1	2	3
5	0	6
4	7	8

	steps	time taken
dfs	26	0.001297 seconds
IDDFS	10	0.000372 seconds
A*	4	0.000091 seconds

10/9

```
import heapq

goal_state = '123456780'

moves = {
    'U': -3,
    'D': 3,
    'L': -1,
    'R': 1
}

invalid_moves = {
    0: ['U', 'L'], 1: ['U'], 2: ['U', 'R'],
    3: ['L'],        5: ['R'],
    6: ['D', 'L'], 7: ['D'], 8: ['D', 'R']
}

def move_tile(state, direction):
    index = state.index('0')
    if direction in invalid_moves.get(index, []):
        return None

    new_index = index + moves[direction]
    if new_index < 0 or new_index >= 9:
        return None

    state_list = list(state)
    state_list[index], state_list[new_index] = state_list[new_index], state_list[index]
    return ''.join(state_list)

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

def manhattan_distance(state):
    distance = 0
    for i, val in enumerate(state):
        if val == '0':
            continue
        goal_pos = int(val) - 1
        current_row, current_col = divmod(i, 3)
        goal_row, goal_col = divmod(goal_pos, 3)
        distance += abs(current_row - goal_row) + abs(current_col - goal_col)
    return distance

def a_star(start_state):
```

```
    visited_count = 0
    open_set = []
    heapq.heappush(open_set, (manhattan_distance(start_state), 0, start_state, []))
    visited = set()

    while open_set:
        f, g, current_state, path = heapq.heappop(open_set)
        visited_count += 1

        if current_state == goal_state:
            return path, visited_count

        if current_state in visited:
            continue
        visited.add(current_state)

        for direction in moves:
            new_state = move_tile(current_state, direction)
            if new_state and new_state not in visited:
                new_g = g + 1
                new_f = new_g + manhattan_distance(new_state)
                heapq.heappush(open_set, (new_f, new_g, new_state, path + [direction]))

    return None, visited_count

# Main
start = input("Enter start state (e.g., 724506831): ")

if len(start) == 9 and set(start) == set('012345678'):
    print("Start state:")
    print_state(start)

    result, visited_states = a_star(start)

    print(f"Total states visited: {visited_states}")

    if result is not None:
        print("Solution found!")
        print("Moves:", ' '.join(result))
        print("Number of moves:", len(result))
        print("1BM23CS299 sanchit mehta\n")

        current_state = start
        for i, move in enumerate(result, 1):
            current_state = move_tile(current_state, move)
            print(f"Move {i}: {move}")
            print_state(current_state)
```

```
    else:
        print("No solution exists for the given start state.")
else:
    print("Invalid input! Please enter a 9-digit string using digits 0-8 without repetition.")
```

```
Enter start state (e.g., 724506831): 283164705
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
1BM23CS299 sanchit mehta

Move 1: U
2 8 3
1   4
7 6 5

Move 2: U
2   3
1 8 4
7 6 5

Move 3: L
  2 3
1 8 4
7 6 5

Move 4: D
1 2 3
  8 4
7 6 5

Move 5: R
1 2 3
8   4
7 6 5
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Date 08/10/20

lab-4 & 5

Hill climbing Algorithm

function hillclimbing(problem) returns a state that is a local maximum
current ← MakeNode(problem.initial_state)
loop do
neighbour ← highest value successor of current
if neighbour <= current value
then return current state
current ← neighbour

Prob: Hill climbing technique to solve 4-Queens.

Simulated Annealing:

$$P(E) = e^{\frac{-\Delta E}{\Delta T}}$$

current ← initial state
T ← a large positive value
while T>0 do
next ← a random neighbour of current
ΔE ← current cost - next cost
if ΔE >0
current ← next
else
current ← next with probability P(E)
end if

decrease T
end while
return current

→ 4 Queens using hill climbing search

Enter the initial state (e.g., 2 0 3 1): 0 1 2 3
initial state : [0, 1, 2, 3] with cost : 6
Q _ _ _
_ Q _ _
_ _ Q _
_ _ _ Q

step 1 :
Best neighbor [1, 0, 2, 3], cost : 6
_ Q _ _
Q _ _ _
_ _ Q _
_ _ _ Q

Step 2 :
Best neighbour [2, 0, 1, 3], cost : 1
_ Q _ _
_ _ Q _
Q _ _ _
_ _ _ Q

Step 3
Best neighbour [2, 0, 3, 1] cost = 0
- Q - -
- - - Q
Q - - -
- - Q -

Goal state reached

1 23

→ Simulated annealing for N queens

initial state: [2, 0, 1, 3] cost : 1
- Q - -
- - Q -
Q - - -
- - - Q

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

Checking simulated Annealing Threshold
N = 4 → success rate : 100%
N = 14 → " : 100%
N = 24 → " : 90%
N = 34 → " : 60%
N = 44 → " : 40%

```
import random
import time

def print_board(state):
    """Prints the chessboard for a given state."""
    n = len(state)
    for row in range(n):
        line = ""
        for col in range(n):
            if state[col] == row:
                line += "Q "
            else:
                line += ". "
        print(line)
    print()

def compute_heuristic(state):
    """Computes the number of attacking pairs of queens."""
    h = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                h += 1
    return h

def get_neighbors(state):
    """Generates all possible neighbors by moving one queen in its column."""
    neighbors = []
    n = len(state)
    for col in range(n):
        for row in range(n):
            if row != state[col]:
                neighbor = list(state)
                neighbor[col] = row
                neighbors.append(neighbor)
    return neighbors

def hill_climb_verbose(initial_state, step_delay=0.5):
    """Hill climbing algorithm with verbose output at each step."""
    current = initial_state
    current_h = compute_heuristic(current)
    step = 0

    print(f"Initial state (heuristic: {current_h}):")
    print_board(current)
    time.sleep(step_delay)
```

```
    while True:
        neighbors = get_neighbors(current)
        next_state = None
        next_h = current_h

        for neighbor in neighbors:
            h = compute_heuristic(neighbor)
            if h < next_h:
                next_state = neighbor
                next_h = h

        if next_h >= current_h:
            print(f"Reached local minimum at step {step}, heuristic: {current_h}")
            return current, current_h

        current = next_state
        current_h = next_h
        step += 1
        print(f"Step {step}: (heuristic: {current_h})")
        print_board(current)
        time.sleep(step_delay)

def solve_n_queens_verbose(n, max_restarts=1000):
    """Solves N-Queens problem using hill climbing with restarts and verbose output."""
    for attempt in range(max_restarts):
        print(f"\n=== Restart {attempt + 1} ===\n")
        initial_state = [random.randint(0, n - 1) for _ in range(n)]
        solution, h = hill_climb_verbose(initial_state)
        if h == 0:
            print(f" Solution found after {attempt + 1} restart(s):")
            print_board(solution)
            return solution
        else:
            print(f"No solution in this attempt (local minimum).\n")
    print("Failed to find a solution after max restarts.")
    return None

# --- Run the algorithm ---
if __name__ == "__main__":
    N = int(input("Enter the number of queens (N): "))
    solve_n_queens_verbose(N)
    print("1BM23CS299 Sanchit Mehta")
```

Output:

```
Enter the number of queens (N): 4

=== Restart 1 ===
```

Initial state (heuristic: 3):
Q . Q .
. Q . .
. . . Q
. . . .

Step 1: (heuristic: 1)
. . Q .
. Q . .
. . . Q
Q . . .

Reached local minimum at step 1, heuristic: 1
❌ No solution in this attempt (local minimum).

=== Restart 2 ===

Initial state (heuristic: 3):
. Q . .
. . Q .
. . . .
Q . . Q

Step 1: (heuristic: 1)
. Q . .
. . Q .
Q . . .
. . . Q

Reached local minimum at step 1, heuristic: 1
❌ No solution in this attempt (local minimum).

=== Restart 3 ===

Initial state (heuristic: 2):
. . . .
. Q . Q
. . . .
Q . Q .

Step 1: (heuristic: 1)
. Q . .
. . . Q
. . . .

Q . Q .

Step 2: (heuristic: 0)
. Q . .
. . . Q
Q . . .
. . Q .

Reached local minimum at step 2, heuristic: 0
✅ Solution found after 3 restart(s):
. Q . .
. . . Q
Q . . .
. . Q .

1BM23CS299 sanchit
Program 5

Simulated Annealing to Solve 8-Queens problem

Q Write a program to implement simulated Annealing Algorithm

Step-1 : State = [1, 3, 2, 0], cost = 1

. . . Q
Q . . .
. . Q .
. Q . .

Step 2 : State = [1, 3, 0, 2], cost = 0

. . Q .
Q . . .
. . . Q
. Q . .

Solution found at step 2

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

final cost (no of attacking pairs) : 0

. . Q .
Q . . .
. . . Q
. Q . .

Algo :→

```
Current ← initial state
T ← a large positive value
while T > 0 do
    next ← a random neighbour of current
    ΔE ← current cost − next cost
    if ΔE > 0 then
        current ← next
    else
        current ← next with probability P = e^(ΔE/T)
    end if
    decrease T
end while
return current
```

Output :→ Initial state : [1, 0, 2, 3]

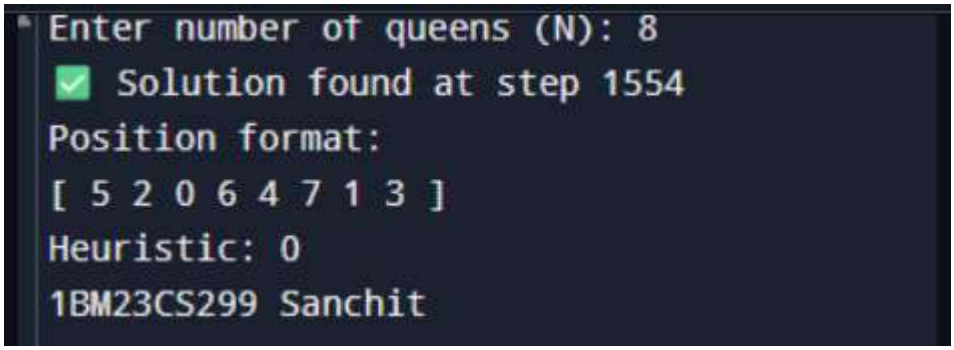
- Q - -
- Q - -
- - Q -
- - - Q

Step 0 : State : [1, 0, 2, 3] Cost =

- Q - -
- Q - -
- - Q -
- - - Q

```
import random
import math

def compute_heuristic(state):
    """Number of attacking pairs."""
    h = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                h += 1
    return h

def random_neighbor(state):
    """Returns a neighbor by randomly changing one queen's row."""
    n = len(state)
    neighbor = state[:]
    col = random.randint(0, n - 1)
    old_row = neighbor[col]
    new_row = random.choice([r for r in range(n) if r != old_row])
    neighbor[col] = new_row
    return neighbor

def dual_simulated_annealing(n, max_iter=10000, initial_temp=100.0, cooling_rate=0.99):
    """Simulated Annealing with dual acceptance strategy."""
    current = [random.randint(0, n - 1) for _ in range(n)]
    current_h = compute_heuristic(current)
    temperature = initial_temp

    for step in range(max_iter):
        if current_h == 0:
            print(f"✅ Solution found at step {step}")
            return current

        neighbor = random_neighbor(current)
        neighbor_h = compute_heuristic(neighbor)
        delta = neighbor_h - current_h

        if delta < 0:
            current = neighbor
            current_h = neighbor_h
        else:
            # Dual acceptance: standard + small chance of higher uphill move
            probability = math.exp(-delta / temperature)
            if random.random() < probability:
                current = neighbor
                current_h = neighbor_h
```

```
        temperature *= cooling_rate
        if temperature < 1e-5:  # Restart if stuck
            temperature = initial_temp
            current = [random.randint(0, n - 1) for _ in range(n)]
            current_h = compute_heuristic(current)

    print("❌ Failed to find solution within max iterations.")
    return None

# --- Run the algorithm ---
if __name__ == "__main__":
    N = int(input("Enter number of queens (N): "))
    solution = dual_simulated_annealing(N)

    if solution:
        print("Position format:")
        print("[", " ".join(str(x) for x in solution), "]")
        print("Heuristic:", compute_heuristic(solution))
        print("1BM23CS299 Sanchit")
```



Program 6

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

Lab-6

a) KB using propositional logic & query entails the knowledge base

→ Algorithm TT_ENTAILS_USER_INPUTS()

Input:
KB_sentences ← list of propositional sentences from user
query ← query sentence from user

Process:
symbols ← all unique propositional symbols appearing in KB_sentences and query
return TT_CHECK_ALL(KB_sentences, query, symbols, empty_model)

→ Function TT_CHECK_ALL(KB, α, symbols, model):

if symbols is empty then
    if PL_True?(KB, model) then
        return PL_True?(α, model)
    else
        return True
else
    P ← first(symbols)
    rest ← symbols - {P}

model_true = model ∪ {P: True}
model_false = model ∪ {P: False}

return (TT_CHECK_ALL(KB, α, rest, model_true)
    AND
    TT_CHECK_ALL(KB, α, rest, model_false))

→ Function PL_TRUE?(sentence_set, model):

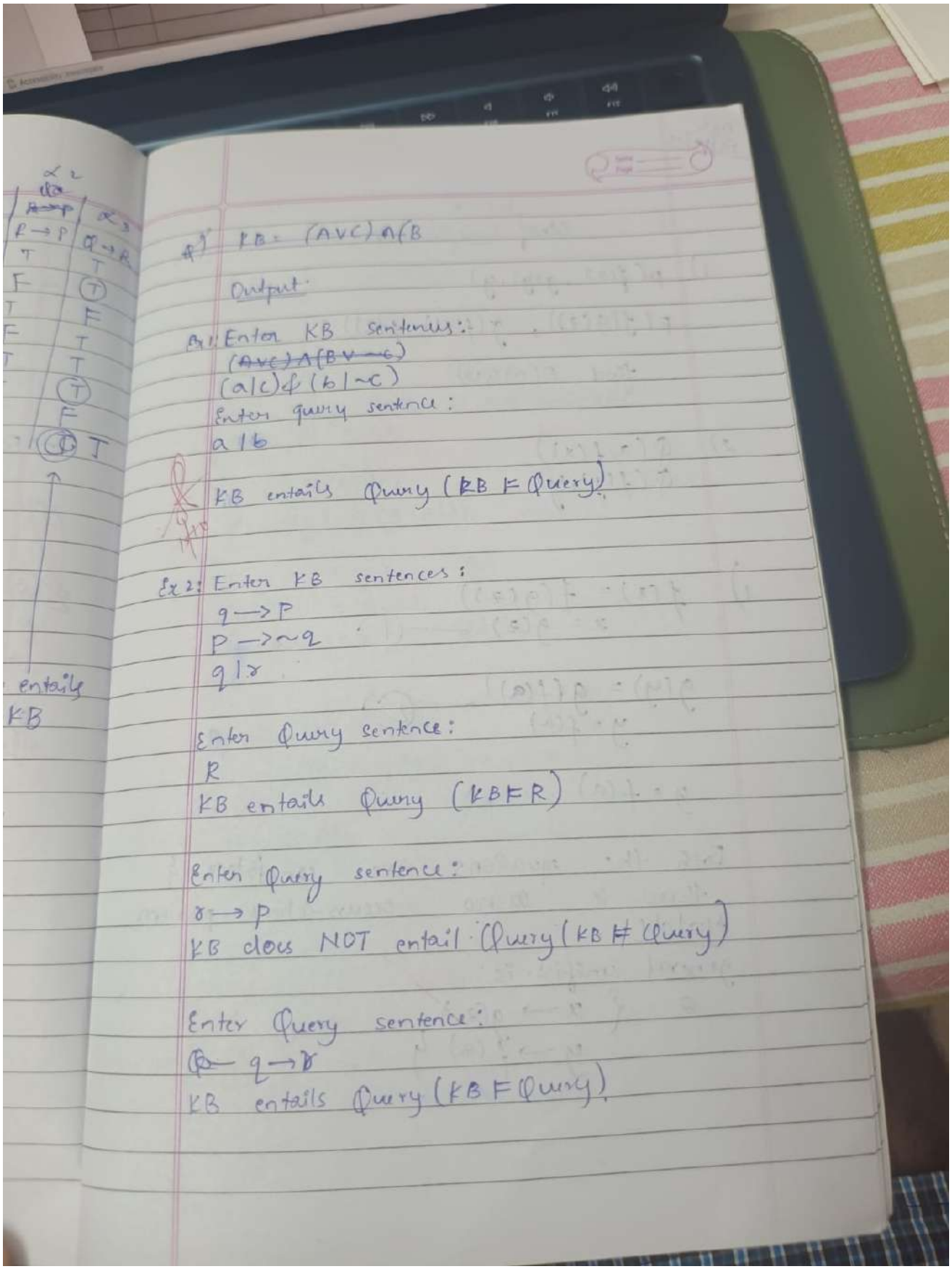
for each sentence S in sentence_set:
    if S evaluates to False under model:
        return False
return True.

2) KB:
1) Q → P
2) P → ¬Q
3) Q ∨ R

4) ~~Truth table~~

Query

1) R
2) ~~¬¬P~~ → P
3) Q → R



KB: (A∨C)∧(B

Output:

Enter KB sentences:
(A∨C)∧(B∨~C)
(a|c)&(b|~c)
Enter query sentence:
a|b

KB entails Query (KB ⊨ Query)

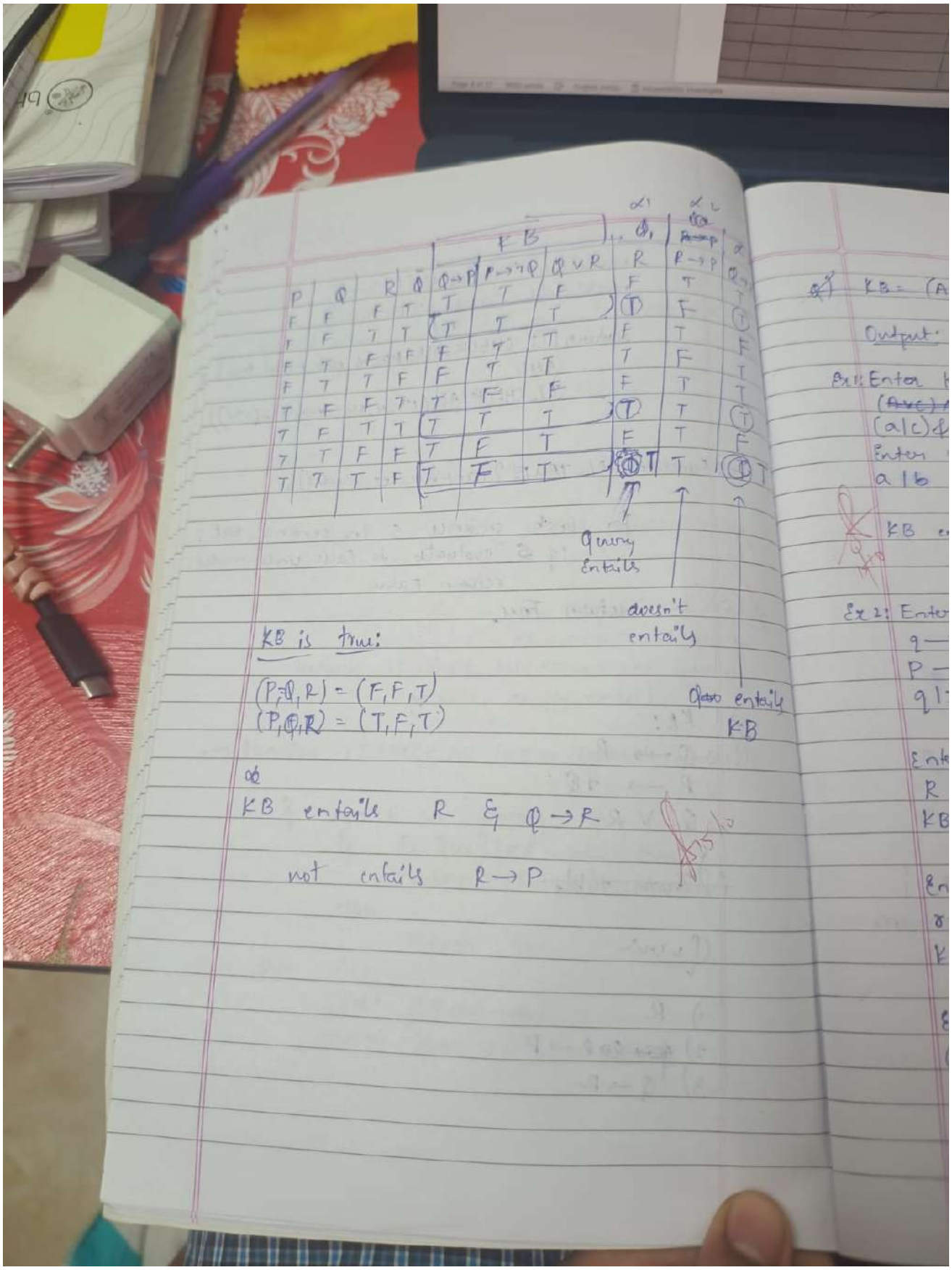
Ex 2: Enter KB sentences:
q → p
p → ~q
q|r

Enter Query sentence:
R
KB entails Query (KB⊨R)

Enter Query sentence:
r → p
KB does NOT entail Query (KB ⊭ Query)

Enter Query sentence:
q → r
KB entails Query (KB ⊨ Query)

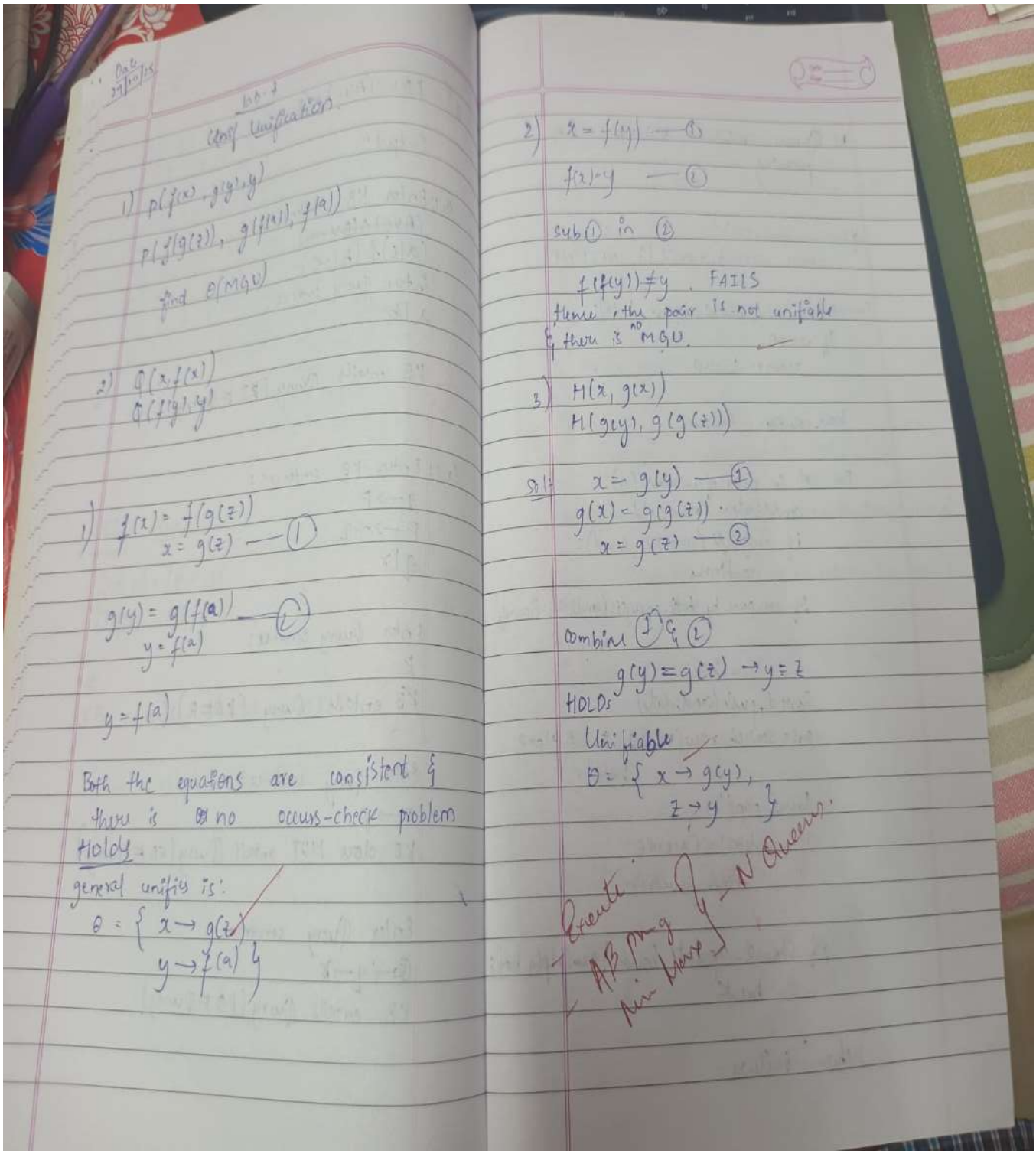
entails
KB


KB
query entails
doesn't entails
KB is true:
(P, Q, R) = (F, F, T)
(P, Q, R) = (T, F, T)
KB entails R & Q → R
not entails R → P

```
Enter knowledge base (e.g. (and A (or B C))): A
Enter query (e.g. A): A
Symbols: ['A']
A   KB  α
True    True    True
False   False   False

Does KB entail α? : True

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

Program 7

Implement unification in first order logic:




```
import json

# --- Helper Functions for Term Manipulation ---

def is_variable(term):
    """Checks if a term is a variable (a single capital letter string)."""
    return isinstance(term, str) and len(term) == 1 and 'A' <= term[0] <= 'Z'
```

```
def occurs_check(variable, term, sigma):
    """
    Checks if 'variable' occurs anywhere in 'term' under the current substitution 'sigma'.
    This prevents infinite recursion (e.g., unifying X with f(X)).
    """
    term = apply_substitution(term, sigma) # Check the substituted term

    if term == variable:
        return True

    # If the term is a list (function/predicate), check its arguments recursively
    if isinstance(term, list):
        for arg in term[1:]:
            if occurs_check(variable, arg, sigma):
                return True

    return False

def apply_substitution(term, sigma):
    """
    Applies the current substitution 'sigma' to a 'term' recursively.
    """
    if is_variable(term):
        # If the variable is bound in sigma, apply the binding
        if term in sigma:
            # Recursively apply the rest of the substitutions to the binding's value
            # This is critical for chains like X/f(Y), Y/a -> X/f(a)
            return apply_substitution(sigma[term], sigma)
        return term

    if isinstance(term, list):
        # Apply substitution to the arguments of the function/predicate
        new_term = [term[0]] # Keep the function/predicate symbol
        for arg in term[1:]:
            new_term.append(apply_substitution(arg, sigma))
        return new_term

    # Term is a constant or an unhandled type, return as is
    return term

def term_to_string(term):
    """
    Converts the internal list representation of a term into standard logic notation string.
    e.g., ['f', 'Y'] -> "f(Y)"
    """
    if isinstance(term, str):
```

```
        return term

    if isinstance(term, list):
        # Term is a function or predicate
        symbol = term[0]
        args = [term_to_string(arg) for arg in term[1:]]
        return f"{symbol}({', '.join(args)})"

    return str(term)


# --- Main Unification Function ---

def unify(term1, term2):
    """
    Implements the Unification Algorithm to find the MGU for term1 and term2.
    Returns the MGU as a dictionary or None if unification fails.
    """
    # Initialize the substitution set (MGU)
    sigma = {}

    # Initialize the list of pairs to resolve (the difference set)
    diff_set = [[term1, term2]]

    print(f"--- Unification Process Started ---")
    print(f"Initial Terms:")
    print(f"L1: {term_to_string(term1)}")
    print(f"L2: {term_to_string(term2)}")
    print("-" * 35)

    while diff_set:
        # Pop the current pair of terms to unify
        t1, t2 = diff_set.pop(0)

        # 1. Apply the current MGU to the terms before comparison
        t1_prime = apply_substitution(t1, sigma)
        t2_prime = apply_substitution(t2, sigma)

        print(f"Attempting to unify: {term_to_string(t1_prime)} vs {term_to_string(t2_prime)}")


        # 2. Check if terms are identical
        if t1_prime == t2_prime:
            print(f"  -> Identical. Current MGU: {term_to_string(sigma)}")
            continue

        # 3. Handle Variable-Term unification
```

```
        if is_variable(t1_prime):
            var, term = t1_prime, t2_prime
        elif is_variable(t2_prime):
            var, term = t2_prime, t1_prime
        else:
            var, term = None, None

        if var:
            # Check if term is a variable, and if so, don't bind V/V
            if is_variable(term):
                print(f"  -> Both are variables. Skipping {var} / {term}")
                # Ensure they are added back if not identical (which is caught by step 2).
                # If V1 != V2, we add V1/V2 or V2/V1 to sigma. Since step 2 handles V/V, this means V1
!= V2 here.
                if var != term:
                    sigma[var] = term
                    print(f"  -> Variable binding added: {var} / {term_to_string(term)}. New MGU:
{term_to_string(sigma)}")
            # Occurs Check: Fail if the variable occurs in the term it's being bound to
            elif occurs_check(var, term, sigma):
                print(f"  -> OCCURS CHECK FAILURE: Variable {var} occurs in
{term_to_string(term)}")
                return None

            # Create a new substitution {var / term}
            else:
                sigma[var] = term
                print(f"  -> Variable binding added: {var} / {term_to_string(term)}. New MGU:
{term_to_string(sigma)}")

        # 4. Handle Complex Term (Function/Predicate) unification
        elif isinstance(t1_prime, list) and isinstance(t2_prime, list):
            # Check functor/predicate symbol and arity (number of arguments)
            if t1_prime[0] != t2_prime[0] or len(t1_prime) != len(t2_prime):
                print(f"  -> FUNCTOR/ARITY MISMATCH: {t1_prime[0]} != {t2_prime[0]} or arity
mismatch.")
                return None

            # Add corresponding arguments to the difference set
            # Start from index 1 (after the symbol)
            for arg1, arg2 in zip(t1_prime[1:], t2_prime[1:]):
                diff_set.append([arg1, arg2])
            print(f"  -> Complex terms matched. Adding arguments to difference set.")

        # 5. Handle Constant-Constant or other mismatches (Fail)
        else:
            print(f"  -> TYPE/CONSTANT MISMATCH: {term_to_string(t1_prime)} and
```

```
{term_to_string(t2_prime)} cannot be unified.")
            return None

    print("-" * 35)
    print("--- Unification Successful ---")

    # Final cleanup to ensure all bindings are fully resolved
    final_mgu = {k: apply_substitution(v, sigma) for k, v in sigma.items()}
    return final_mgu

# --- Define the Input Terms ---

# L1 = Q(a, g(X, a), f(Y))
literal1 = ['Q', 'a', ['g', 'X', 'a'], ['f', 'Y']]

# L2 = Q(a, g(f(b), a), X)
literal2 = ['Q', 'a', ['g', ['f', 'b'], 'a'], 'X']

# --- Run the Unification ---

mgu_result = unify(literal1, literal2)

if mgu_result is not None:
    print("\n[ Final MGU Result ]")

    # Format the final MGU for display using the new helper function
    clean_mgu = {k: term_to_string(v) for k, v in mgu_result.items()}
    final_output = ', '.join([f"{k} / {v}" for k, v in clean_mgu.items()])
    print(f"Final MGU: {{ {final_output} }}")

    # --- Verification ---
    print("\n[ Verification ]")
    unified_l1 = apply_substitution(literal1, mgu_result)
    unified_l2 = apply_substitution(literal2, mgu_result)

    print(f"L1 after MGU: {term_to_string(unified_l1)}")
    print(f"L2 after MGU: {term_to_string(unified_l2)}")

    if unified_l1 == unified_l2:
        print("-> SUCCESS: L1 and L2 are identical after applying the MGU.")
    else:
        print("-> ERROR: Unification failed verification.")
else:
    print("\nUnification FAILED.")

print("Sanchit Mehta 1BM23CS299")
```

Output

```
--- Unification Process Started ---
Initial Terms:
L1: Q(a, g(X, a), f(Y))
L2: Q(a, g(f(b), a), X)
----------------------------------
Attempting to unify: Q(a, g(X, a), f(Y)) vs Q(a, g(f(b), a), X)
  -> Complex terms matched. Adding arguments to difference set.
Attempting to unify: a vs a
  -> Identical. Current MGU: {}
Attempting to unify: g(X, a) vs g(f(b), a)
  -> Complex terms matched. Adding arguments to difference set.
Attempting to unify: f(Y) vs X
  -> Variable binding added: X / f(Y). New MGU: {'X': ['f', 'Y']}
Attempting to unify: f(Y) vs f(b)
  -> Complex terms matched. Adding arguments to difference set.
Attempting to unify: a vs a
  -> Identical. Current MGU: {'X': ['f', 'Y']}
Attempting to unify: Y vs b
  -> Variable binding added: Y / b. New MGU: {'X': ['f', 'Y'], 'Y': 'b'}
----------------------------------
--- Unification Successful ---

[ Final MGU Result ]
Final MGU: { X / f(b), Y / b }

[ Verification ]
L1 after MGU: Q(a, g(f(b), a), f(b))
L2 after MGU: Q(a, g(f(b), a), f(b))
-> SUCCESS: L1 and L2 are identical after applying the MGU.
Sanchit Mehta 1BM23CS299

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

Program 8

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

Date
17/11/22

Lab-8

First Order logic

function FOL-FC-ASK(KB, α) returns a substitution or fail

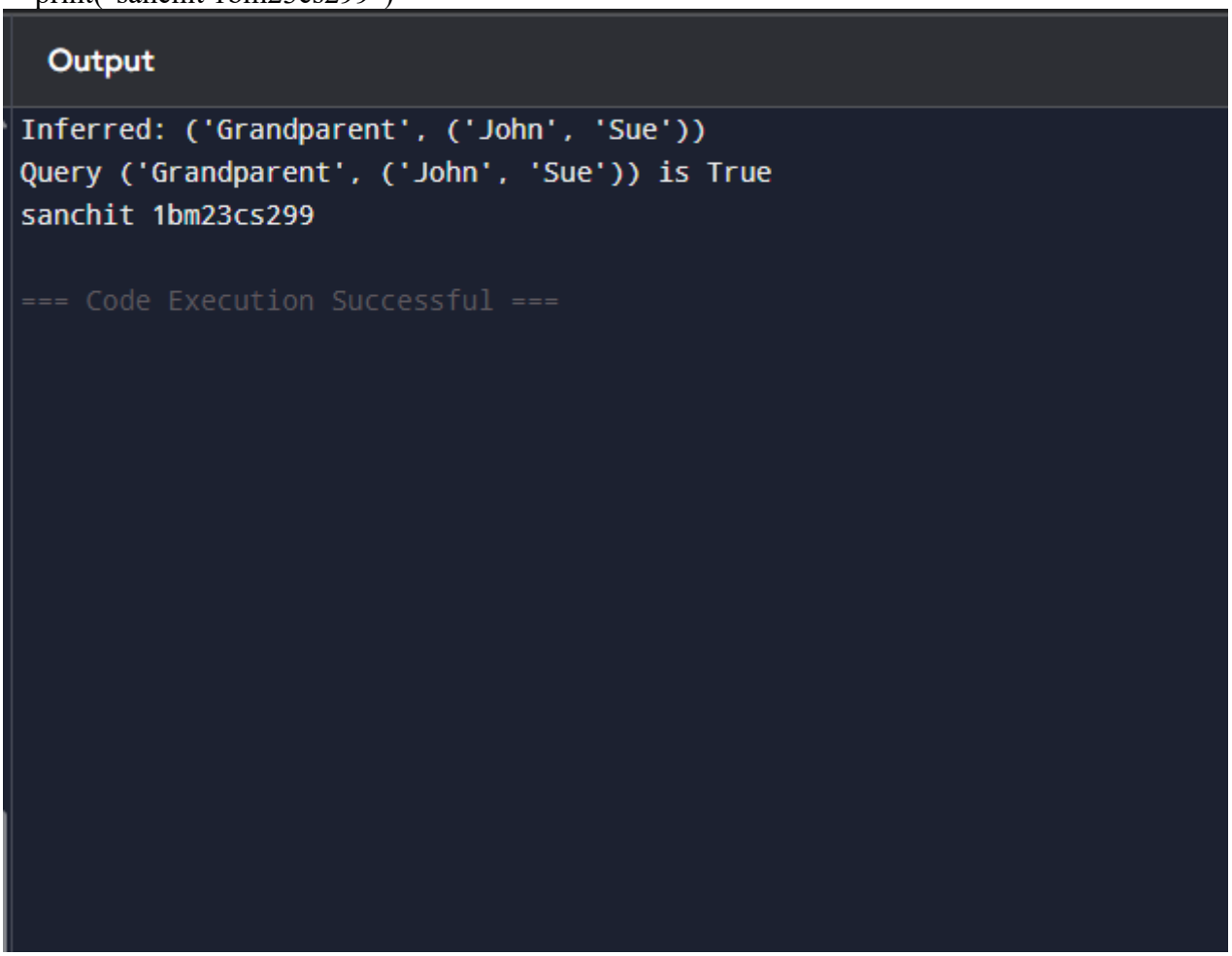
inputs: KB, the knowledge base, a set of first order definite clauses
α, the query, an atomic sentence

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

repeat until new is empty
  new ← { }
  for each rule in KB do
    (p1 ∧ ... ∧ pr ⇒ q) ← standardize variables(rule)
    for each θ such that subst(θ, p1 ∧ ... ∧ pr) = subst(θ, p'1 ∧ ... ∧ p'r)
      for some p'1, ..., p'r 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

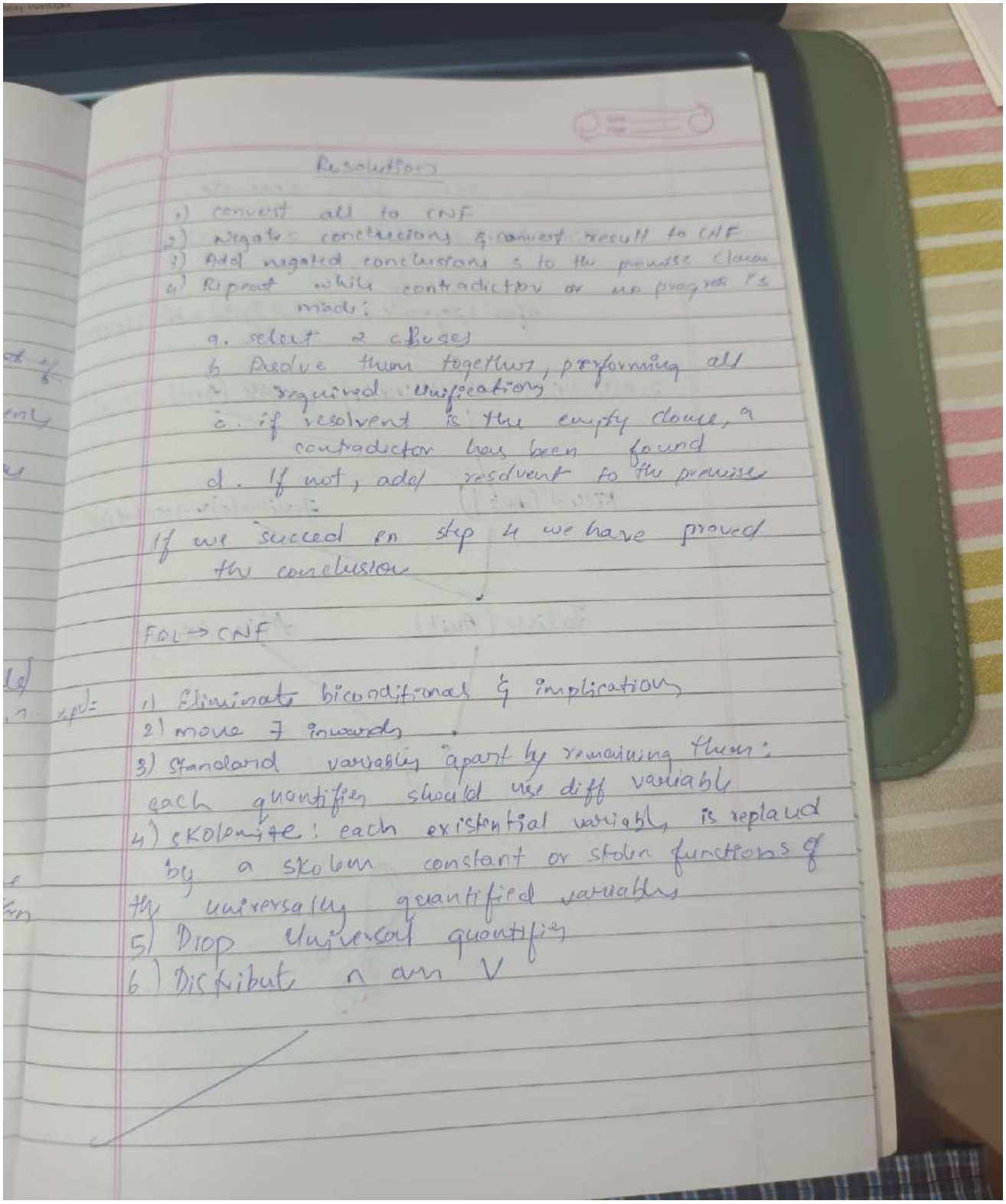
```
from typing import List, Tuple, Dict, Set, Union

Predicate = Tuple[str, Tuple[str, ...]]

class Rule:
    def __init__(self, head: Predicate, body: List[Predicate]):
        self.head = head
        self.body = body

    def __repr__(self):
        body_str = ', '.join(f"{p[0]}{p[1]}" for p in self.body)
        return f"{body_str} => {self.head[0]}{self.head[1]}"

# Knowledge base
class KnowledgeBase:
    def __init__(self):
        self.facts: Set[Predicate] = set()
        self.rules: List[Rule] = []

    def add_fact(self, fact: Predicate):
        self.facts.add(fact)

    def add_rule(self, rule: Rule):
        self.rules.append(rule)

    def forward_chain(self, query: Predicate) -> bool:
        inferred = set(self.facts)
        added = True

        while added:
            added = False
            for rule in self.rules:
                if all(self._match_fact(body_pred, inferred) for body_pred in rule.body):
                    if not self._match_fact(rule.head, inferred):
                        inferred.add(rule.head)
                        added = True
                        print(f"Inferred: {rule.head}")

                        if self._match_fact(query, inferred):
                            return True
        return self._match_fact(query, inferred)

    def _match_fact(self, pred: Predicate, fact_set: Set[Predicate]) -> bool:
        return pred in fact_set

# --- Example usage ---
if __name__ == "__main__":
```

```
kb = KnowledgeBase()

kb.add_fact(("Parent", ("John", "Mary")))
kb.add_fact(("Parent", ("Mary", "Sue")))

facts_list = list(kb.facts)
for f1 in facts_list:
    for f2 in facts_list:
        if f1[0] == "Parent" and f2[0] == "Parent":
            if f1[1][1] == f2[1][0]:
                head = ("Grandparent", (f1[1][0], f2[1][1]))
                body = [f1, f2]
                kb.add_rule(Rule(head, body))

query = ("Grandparent", ("John", "Sue"))
result = kb.forward_chain(query)

print(f"Query {query} is", "True" if result else "False")
print("sanchit 1bm23cs299")
```



Program 9

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



```
Output

Knowledge Base CNF Clauses:
   Parent(John,Mary)
   ~Parent(x,y)|Ancestor(x,y)
   Parent(Mary,Sam)
   ~Parent(x,y)|~Ancestor(y,z)|Ancestor(x,z)

Query: Ancestor(John, Sam) => TRUE
```

Program 10

Implement Alpha-Beta Pruning

```
def conflict((r1,c1),(r2,c2)):
    return (r1==r2) or (c1==c2) or
           (abs(r1-r2)==abs(c1-c2))

conflicts(r,c), Board):
    for q in Board:
        if all_conflict((r,c),q):
            return True
    return false

Order_of_columns(n):
    return heuristic_colocum_order_list

can_prune_by_static_analysers(candidate, Board, row, n):
    return 'counf_analy_prune(n-row)
```

Output:

Board = []
row = 1
column order tried = [1, 2, 3, 4]

[(1,1), (2,3), (3,4), (4,2)]

. Q . .
. . . Q
Q . . .
. . Q .

N Queens minimax w/ alpha - beta pruning

```
def solve_n_queens(n):
    return search_row(1, [], -INF, +INF)

search_row(row, board, alpha, beta):
    if row > n
        return board

    best_solution = FAILURE

    For col in order_of_columns(n):
        candidate = (row, col)
        if conflicts(candidate, board):
            continue
        if can_prune_by_static_analysis(candidate, board,
                                        row, n):
            continue
        board.push(candidate)
        sol = search_row(row+1, board, alpha,
                         beta)
        board.pop()
        if solution != FAILURE:
            return solution

        if should_update_bounds_&_prune(alpha, beta):
            break

    return Failure
```

Code:

```
import math

def alpha_beta_search(state):
    return max_value(state, -math.inf, math.inf)

def max_value(state, alpha, beta):
    if terminal_test(state):
        return utility(state)
    v = -math.inf
    for a in actions(state):
        v = max(v, min_value(result(state, a), alpha, beta))
        if v >= beta:
            return v
        alpha = max(alpha, v)
    return v

def min_value(state, alpha, beta):
    if terminal_test(state):
        return utility(state)
    v = math.inf
    for a in actions(state):
        v = min(v, max_value(result(state, a), alpha, beta))
        if v <= alpha:
            return v
        beta = min(beta, v)
    return v

values = [3, 5, 6, 9, 1, 2, 0, -1]
max_depth = 3

def terminal_test(state):
    return state >= len(values) // 2**(max_depth - depth[state])

def utility(state):
    return values[state]

def actions(state):
    if depth[state] == max_depth:
        return []
    return [0, 1]

def result(state, action):
    child = state * 2 + 1 + action
    depth[child] = depth[state] + 1
    return child
```

```
depth = {0: 0}
print("Optimal value:", alpha_beta_search(0))
print("Sanchit Mehta")
```

```
Best value for maximizer: 3
Sanchit Mehta 1bm23cs299
```