VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

Makadia Rishit Dilipbhai (1BM23CS177)

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 **Makadia Rishit Dilipbhai (1BM23CS177),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence (23CS5PCAIN) work prescribed for the said degree.

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

Index

Github Link:

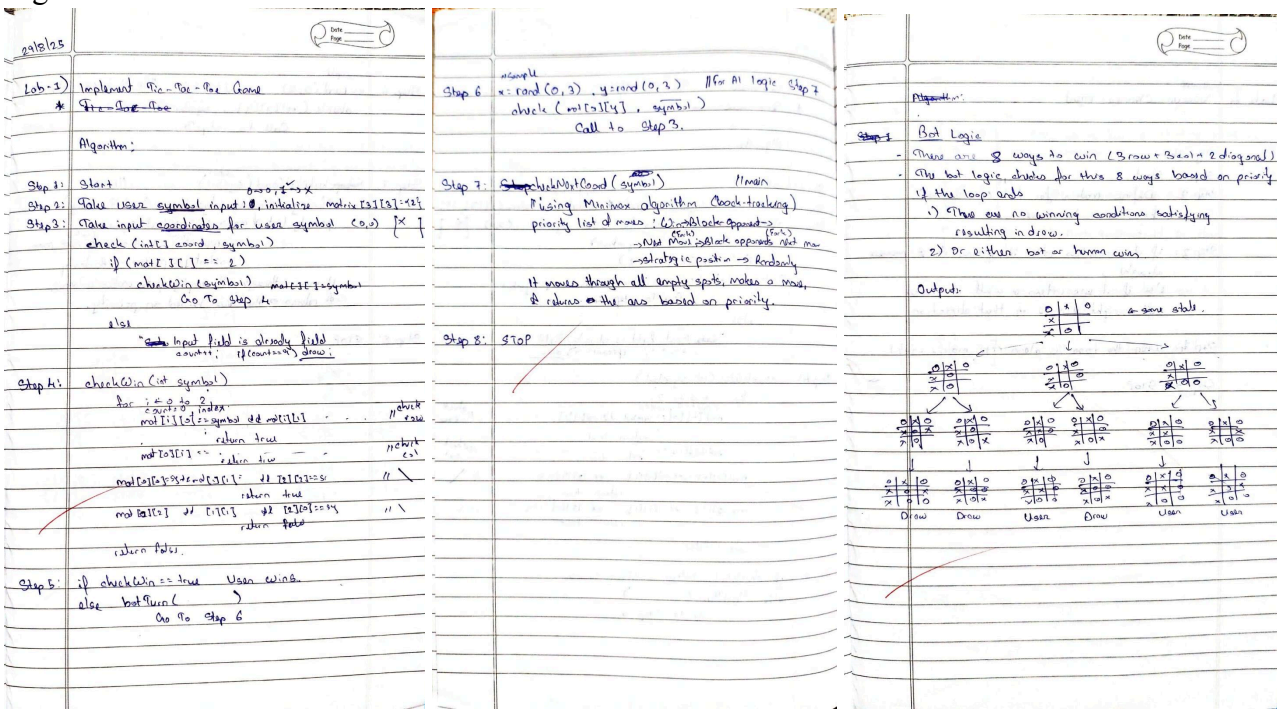
https://github.com/rishitmakadia/1BM23CS177_AIN_5

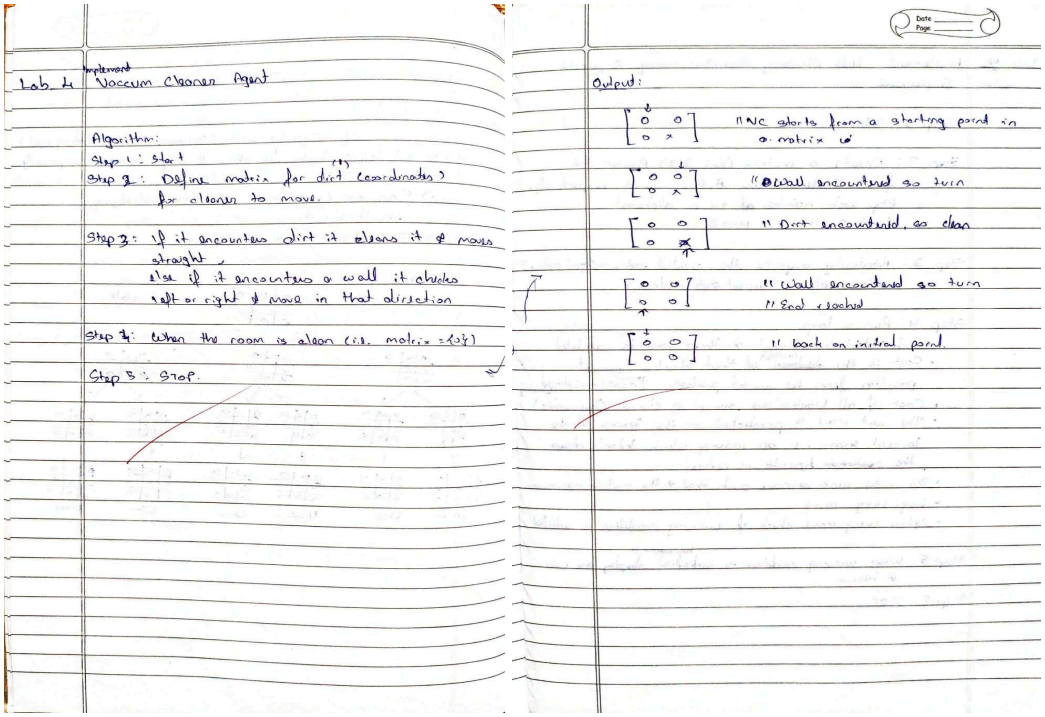
Program 1

Implement Tic –Tac –Toe Game

Implement vacuum cleaner agent

Algorithm:





Code:

```
Tic - Tac - Toe
print('tic_tac_toe')
board={1:' ',2:' ',3:' ',
      4:' ',5:' ',6:' ',
      7:' ',8:' ',9:' '
}

def printBoard(board):
   print(board[1]+'|'+board[2]+'|'+board[3])
   print('-+-+-')
   print(board[4] + '|' + board[5] + '|' + board[6])
   print('-+-+-')
   print(board[7] + '|' + board[8] + '|' + board[9])
   print('\n')


def spaceFree(pos):
   if(board[pos]==' '):
      return True
   else:
      return False

def checkWin():
   if(board[1]==board[2] and board[1]==board[3] and board[1]!=' '):
      return True
   elif(board[4]==board[5] and board[4]==board[6] and board[4]!=' '):
      return True
   elif(board[7]==board[8] and board[7]==board[9] and board[7]!=' '):
      return True
   elif (board[1] == board[5] and board[1] == board[9] and board[1] != ' '):
      return True
   elif (board[3] == board[5] and board[3] == board[7] and board[3] != ' '):
      return True
   elif (board[1] == board[4] and board[1] == board[7] and board[1] != ' '):
      return True
   elif (board[2] == board[5] and board[2] == board[8] and board[2] != ' '):
      return True
   elif (board[3] == board[6] and board[3] == board[9] and board[3] != ' '):
      return True
   else:
      return False

def checkMoveForWin(move):
   if (board[1]==board[2] and board[1]==board[3] and board[1] ==move):
      return True
```

```
    elif (board[4]==board[5] and board[4]==board[6] and board[4] ==move):
        return True
    elif (board[7]==board[8] and board[7]==board[9] and board[7] ==move):
        return True
    elif (board[1]==board[5] and board[1]==board[9] and board[1] ==move):
        return True
    elif (board[3]==board[5] and board[3]==board[7] and board[3] ==move):
        return True
    elif (board[1]==board[4] and board[1]==board[7] and board[1] ==move):
        return True
    elif (board[2]==board[5] and board[2]==board[8] and board[2] ==move):
        return True
    elif (board[3]==board[6] and board[3]==board[9] and board[3] ==move):
        return True
    else:
        return False

def checkDraw():
    for key in board.keys():
        if (board[key]==' '):
            return False
    return True

def insertLetter(letter, position):
    if (spaceFree(position)):
        board[position] = letter
        printBoard(board)
        if (checkDraw()):
            print('Draw!')
        elif (checkWin()):
            if (letter == 'X'):
                print('Bot wins!')
            else:
                print('You win!')
        return
    else:
        print('Position taken, please pick a different position.')
        position = int(input('Enter new position: '))
        insertLetter(letter, position)
        return

player = 'O'
bot ='X'

def playerMove():
    position=int(input('Enter position for O:'))
    insertLetter(player, position)
```

```
    return

def compMove():
    bestScore=-1000
    bestMove=0
    for key in board.keys():
        if (board[key]==' '):
            board[key]=bot
            score = minimax(board, False)
            board[key] = ' '
            if (score > bestScore):
                bestScore = score
                bestMove = key
    insertLetter(bot, bestMove)
    return

def minimax(board, isMaximizing):
    if (checkMoveForWin(bot)):
        return 1
    elif (checkMoveForWin(player)):
        return -1
    elif (checkDraw()):
        return 0

    if isMaximizing:
        bestScore = -1000
        for key in board.keys():
            if board[key] == ' ':
                board[key] = bot
                score = minimax(board, False)
                board[key] = ' '
                if (score > bestScore):
                    bestScore = score
        return bestScore
    else:
        bestScore = 1000
        for key in board.keys():
            if board[key] == ' ':
                board[key] = player
                score = minimax(board, True)
                board[key] = ' '
                if (score < bestScore):
                    bestScore = score
        return bestScore

while not checkWin():
    compMove()
```

```
  playerMove()
```

Vacuum-Cleaner

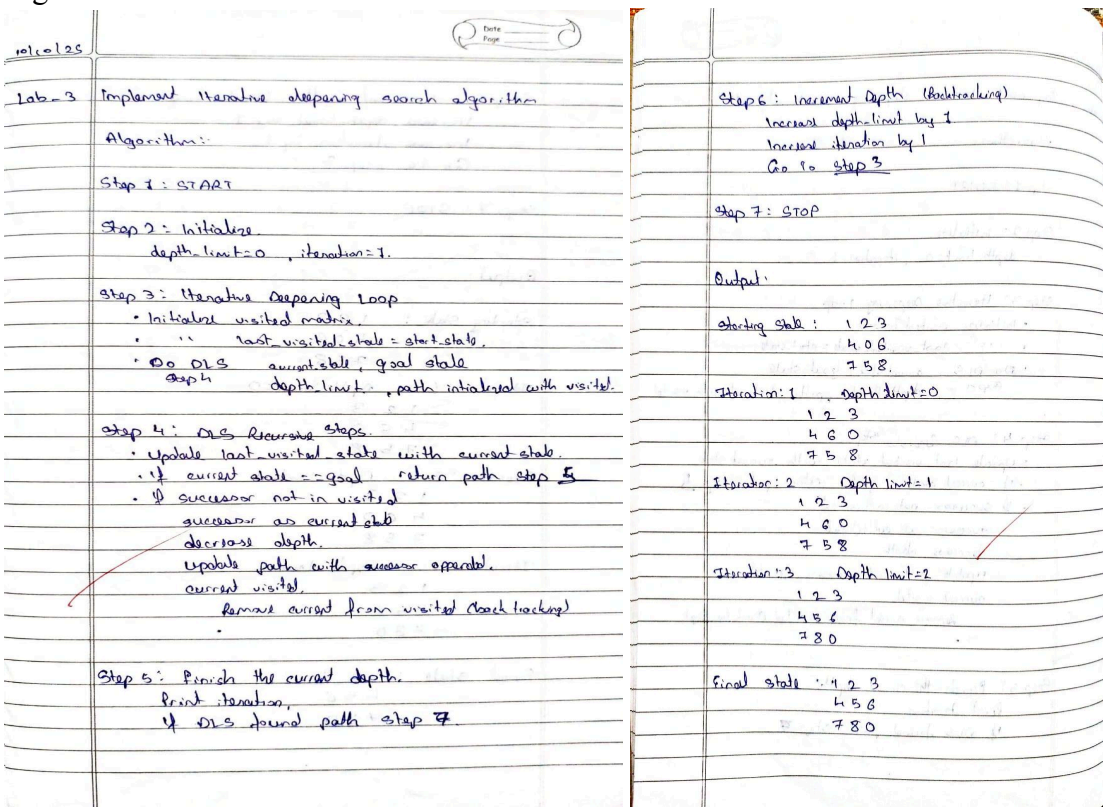
```
import random

# Define environment
rooms = {
    'A': random.choice(['Clean', 'Dirty']),
    'B': random.choice(['Clean', 'Dirty']),
    'C': random.choice(['Clean', 'Dirty']),
    'D': random.choice(['Clean', 'Dirty'])
}

# Initial position of the agent
agent_position = random.choice(['A', 'B', 'C', 'D'])

# Display current state
def display_state():
    print(f"Agent is in Room {agent_position}")
    for room, status in rooms.items():
        print(f"Room {room}: {status}")
    print()

# Rule-based agent logic with smart movement
def vacuum_agent():
    global agent_position
    steps = 0

    # Keep track of cleaned rooms
    cleaned_rooms = set()

    while len(cleaned_rooms) < 4:
        display_state()

        # Clean current room if dirty
        if rooms[agent_position] == 'Dirty':
            print(f" Cleaning Room {agent_position}")
            rooms[agent_position] = 'Clean'
            cleaned_rooms.add(agent_position)
        else:
            print(f" Room {agent_position} is already clean.")
            cleaned_rooms.add(agent_position)

        # Decide next move only if not all rooms are clean
        if len(cleaned_rooms) < 4:
            # Move to the next room that is still dirty
```

```
            for next_room in ['A', 'B', 'C', 'D']:
                if next_room not in cleaned_rooms:
                    agent_position = next_room
                    break

        steps += 1
        print(f"Step {steps} complete.\n")

    print(" All rooms are clean!")
    display_state()

vacuum_agent()
```

Program 2

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

Algorithm:



Lab-3 Implement Iterative deepening search algorithm

Algorithm:

Step 1: START

Step 2: Initialize
depth_limit=0, iteration=1.

Step 3: Iterative Deepening Loop
- Initialize visited matrix.
- " last_visited_state = start_state.
- Do DLS current_state, goal state, depth_limit, path initialized with visited.

Step 4: DLS Recursive steps.
- Update last_visited_state with current state.
- If current state == goal return path step 5
- If successor not in visited
  successor as current state
  decrease depth.
  Update path with successor appended.
  current visited.
  Remove current from visited (Backtracking)

Step 5: Finish the current depth.
Print iteration,
If DLS found path step 7.

Step 6: Increment Depth (Backtracking)
Increase depth_limit by 1
Increase iteration by 1
Go to step 3

Step 7: STOP

Output:

Starting state: 1 2 3
4 0 6
7 5 8.

Iteration: 1, Depth limit=0
1 2 3
4 6 0
7 5 8

Iteration: 2 Depth limit=1
1 2 3
4 6 0
7 5 8

Iteration: 3 Depth limit=2
1 2 3
4 5 6
7 8 0

Final state: 1 2 3
4 5 6
7 8 0

Code:

```
// IDFS

from collections import deque

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

MOVES = {
    'up': -3,
    'down': 3,
    'left': -1,
    'right': 1
}

def is_valid_move(blank_idx, move):
    if move == 'left' and blank_idx % 3 == 0:
        return False
```

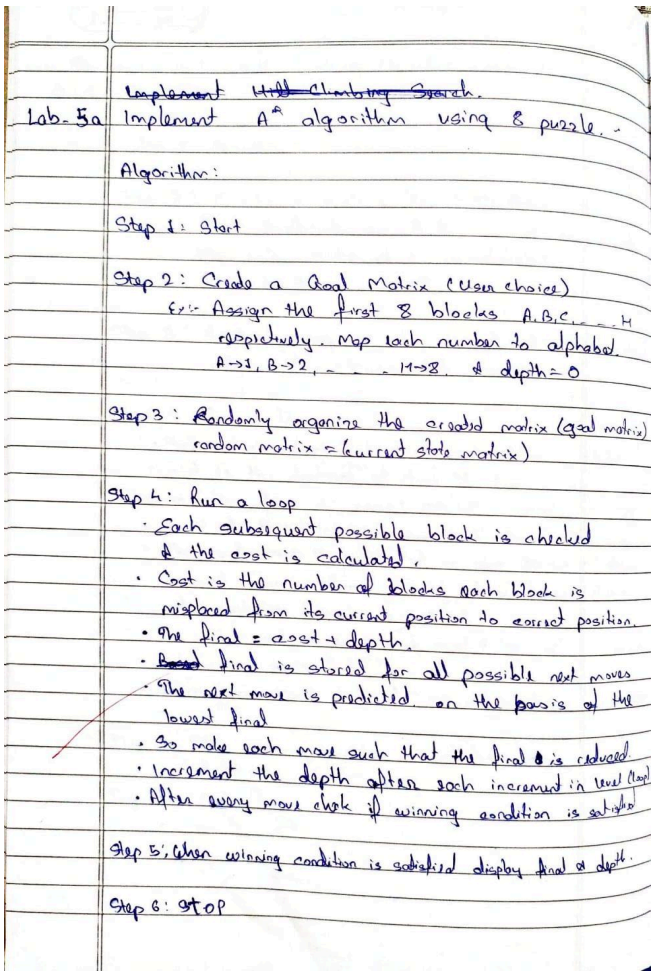
```
    if move == 'right' and blank_idx % 3 == 2:
        return False
    if move == 'up' and blank_idx < 3:
        return False
    if move == 'down' and blank_idx > 5:
        return False
    return True

def get_successors(state):
    successors = []
    blank_idx = state.index(0)

    for move in MOVES:
        if is_valid_move(blank_idx, move):
            swap_idx = blank_idx + MOVES[move]
            new_state = list(state)
            new_state[blank_idx], new_state[swap_idx] = new_state[swap_idx], new_state[blank_idx]
            successors.append(tuple(new_state))
    return successors

def DLS(state, goal, limit, path, visited, last_state_holder):
    last_state_holder[0] = state

    if state == goal:
        return path
    if limit == 0:
        return None

    visited.add(state)

    for successor in get_successors(state):
        if successor not in visited:
            result = DLS(successor, goal, limit - 1, path + [successor], visited, last_state_holder)
            if result is not None:
                return result

    visited.remove(state)
    return None

def IDDFS(start, goal):
    depth = 0
    iteration = 1
    while True:
        visited = set()
        last_state_holder = [start]
        path = DLS(start, goal, depth, [start], visited, last_state_holder)
```

```
        print(f"Iteration {iteration} completed at Depth limit = {depth}")
        print("Last visited puzzle state in this iteration:")
        print_puzzle(last_state_holder[0])

        if path is not None:
            return path
        depth += 1
        iteration += 1

def print_puzzle(state):
    for i in range(0, 9, 3):
        print(state[i:i+3])
    print()

if __name__ == "__main__":
    start_state = (1, 2, 4,
                   0, 8, 6,
                   7, 5, 3)

    print("Starting state:")
    print_puzzle(start_state)

    solution_path = IDDFS(start_state, GOAL_STATE)

    print(f"Solution found in {len(solution_path) - 1} moves:")
    for step in solution_path:
        print_puzzle(step)
```

Program 3

Implement A* search algorithm

Algorithm:



Lab-5a Implement A* algorithm using 8 puzzle.

Algorithm:

Step 1: Start

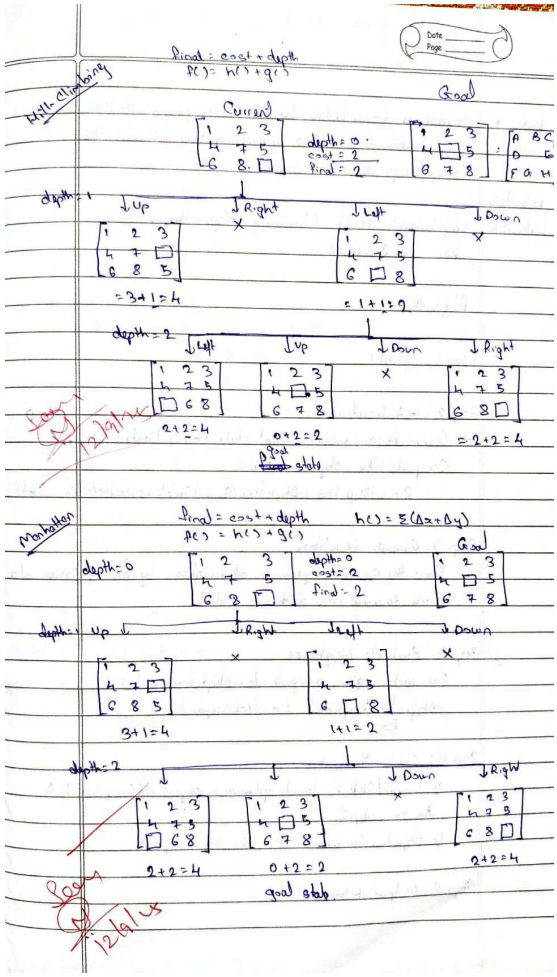
Step 2: Create a Goal Matrix (User choice)
Ex:- Assign the first 8 blocks A,B,C,...,H respectively. Map each number to alphabet. A->1, B->2, ..., H->8. & depth = 0

Step 3: Randomly organize the created matrix (goal matrix) random matrix = (current state matrix)

Step 4: Run a loop
- Each subsequent possible block is checked & the cost is calculated.
- Cost is the number of blocks each block is misplaced from its current position to correct position.
- The final = cost + depth.
- final is stored for all possible next moves
- The next move is predicted on the basis of the lowest final
- Do make each move such that the final is reduced
- Increment the depth after each increment in level (loop)
- After every move check if winning condition is satisfied

Step 5: When winning condition is satisfied display final & depth.

Step 6: Stop



Code:

```
import heapq

class PuzzleState:
    def __init__(self, board, parent=None, move="", depth=0, cost=0):
        self.board = board
        self.parent = parent
        self.move = move
        self.depth = depth
        self.cost = cost  # g(n) + h(n)

    def __lt__(self, other):
        return self.cost < other.cost
```

```
    def find_blank(self):
        return self.board.index(0)

    def get_moves(self):
        """Generate possible moves"""
        blank = self.find_blank()
        moves = []
        row, col = divmod(blank, 3)
        directions = {
            "Up": (row - 1, col),
            "Down": (row + 1, col),
            "Left": (row, col - 1),
            "Right": (row, col + 1)
        }
        for move, (r, c) in directions.items():
            if 0 <= r < 3 and 0 <= c < 3:
                new_blank = r * 3 + c
                new_board = self.board[:]
                new_board[blank], new_board[new_blank] = new_board[new_blank], new_board[blank]
                moves.append(PuzzleState(new_board, self, move, self.depth + 1))
        return moves

    def path(self):
        """Reconstruct solution path"""
        node, p = self, []
        while node:
            p.append((node.move, node.board))
            node = node.parent
        return list(reversed(p))

    def print_board(self):
        """Print the board in 3x3 matrix form"""
        for i in range(0, 9, 3):
            print(self.board[i:i+3])  # Print rows of the board


# ---------- Heuristics ----------
def misplaced_tiles(state, goal):
    return sum(1 for i in range(9) if state.board[i] != 0 and state.board[i] != goal[i])

def manhattan_distance(state, goal):
    dist = 0
    for i in range(9):
        if state.board[i] != 0:
            r1, c1 = divmod(i, 3)
            r2, c2 = divmod(goal.index(state.board[i]), 3)
            dist += abs(r1 - r2) + abs(c1 - c2)
```

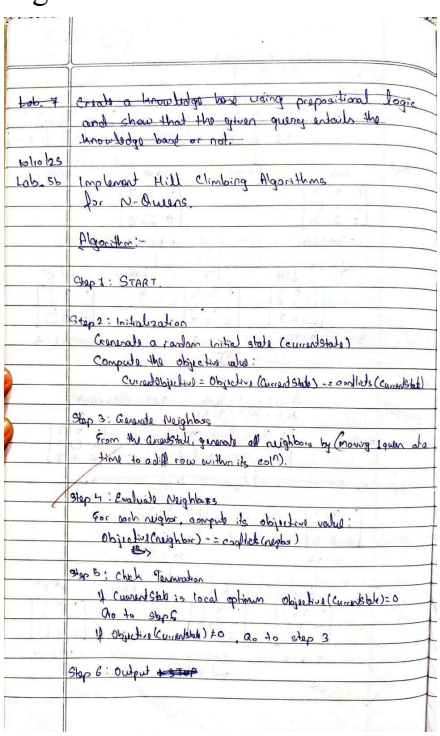
```
    return dist


# ----------------- A* Search -----------------
def a_star(start, goal, heuristic):
    open_list = []
    closed_set = set()
    start_state = PuzzleState(start)
    start_state.cost = heuristic(start_state, goal)
    heapq.heappush(open_list, start_state)

    while open_list:
        current = heapq.heappop(open_list)

        if current.board == goal:
            return current.path()

        closed_set.add(tuple(current.board))

        for neighbor in current.get_moves():
            if tuple(neighbor.board) in closed_set:
                continue
            neighbor.cost = neighbor.depth + heuristic(neighbor, goal)
            heapq.heappush(open_list, neighbor)

    return None


# ----------------- Example Run -----------------
# if __name__ == "__main__":
    initial_state = [1, 2, 3,
                     4, 7, 5,
                     6, 8, 0]

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

    print("A* with Misplaced Tiles:")
    solution1 = a_star(initial_state, goal_state, misplaced_tiles)
    for move, state in solution1:
        print(f"Move: {move}")
        PuzzleState(state).print_board()  # Print the board as a matrix

    print("\nA* with Manhattan Distance:")
    solution2 = a_star(initial_state, goal_state, manhattan_distance)
    for move, state in solution2:
```

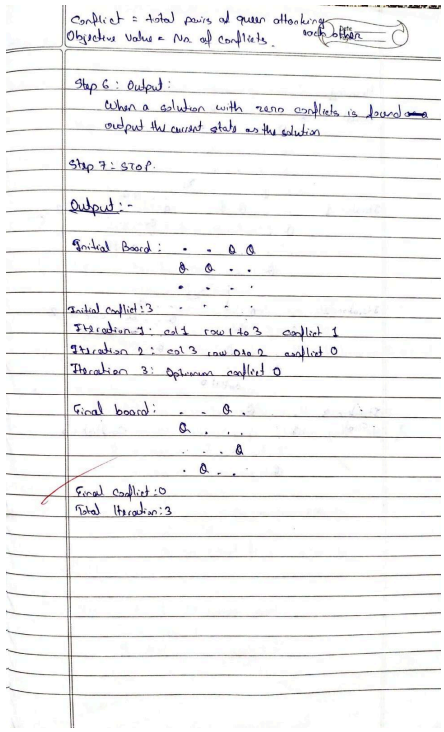
```
        print(f"Move: {move}")
        PuzzleState(state).print_board()  # Print the board as a matrix
if __name__ == "__main__":
    initial_state = [1, 2, 3,
                     4, 7, 5,
                     6, 8, 0]

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

    print("A* with Misplaced Tiles:")
    solution1 = a_star(initial_state, goal_state, misplaced_tiles)
    for idx, (move, state) in enumerate(solution1):
        ps = PuzzleState(state)
        h = misplaced_tiles(ps, goal_state)
        g = idx  # depth = move number in path
        cost = g + h
        print(f"Move: {move}, Depth: {g}, Heuristic: {h}, Total cost: {cost}")
        ps.print_board()

    print("\nA* with Manhattan Distance:")
    solution2 = a_star(initial_state, goal_state, manhattan_distance)
    for idx, (move, state) in enumerate(solution2):
        ps = PuzzleState(state)
        h = manhattan_distance(ps, goal_state)
        g = idx  # depth
        cost = g + h
        print(f"Move: {move}, Depth: {g}, Heuristic: {h}, Total cost: {cost}")
        ps.print_board()
```

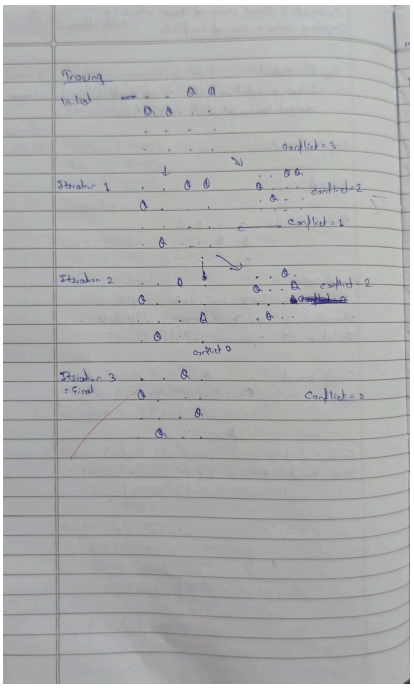
Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:







Code:

```
import random

def conflicts(state):
    """Count number of pairs of queens attacking each other."""
    n = len(state)
    count = 0
    for i in range(n):
        for j in range(i + 1, n):
            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):
                count += 1
    return count

def generate_neighbors(state):
    """Generate all neighbors by moving one queen to another row in its column."""
    neighbors = []
    n = len(state)
    for col in range(n):
        for row in range(n):
            if row != state[col]:
                neighbor = state.copy()
```

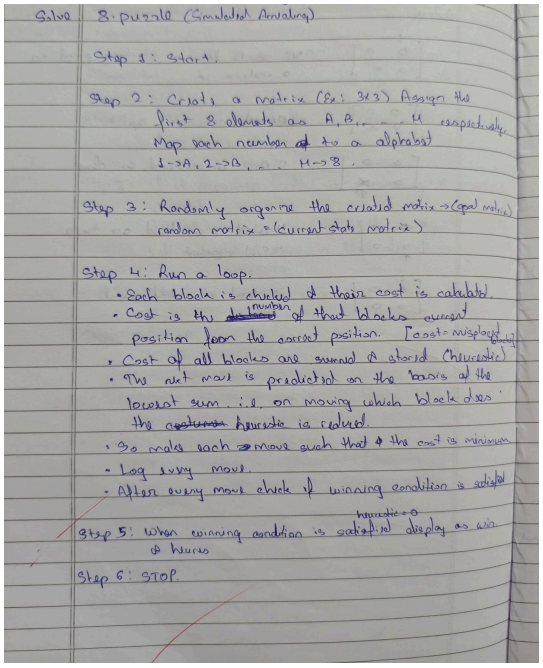
```
            neighbor[col] = row
            neighbors.append(neighbor)
    return neighbors

def print_board(state):
    """Print the board configuration."""
    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("\n")

def hill_climbing_n_queens(n, max_iterations=1000, max_restarts=50):
    def random_state():
        return [random.randint(0, n - 1) for _ in range(n)]

    current_state = random_state()
    current_conflicts = conflicts(current_state)

    print("Initial board:")
    print_board(current_state)
    print(f"Initial conflicts: {current_conflicts}\n")

    restarts = 0
    iteration = 0

    while restarts < max_restarts:
        improved = True
        while improved and iteration < max_iterations:
            iteration += 1
            neighbors = generate_neighbors(current_state)
            neighbor_conflicts = [conflicts(neigh) for neigh in neighbors]

            min_conflicts = min(neighbor_conflicts)
            min_indices = [i for i, val in enumerate(neighbor_conflicts) if val == min_conflicts]

            if min_conflicts < current_conflicts:
                chosen_index = random.choice(min_indices)
                next_state = neighbors[chosen_index]
                # Find which column changed and rows before/after
                for col in range(n):
                    if current_state[col] != next_state[col]:
```

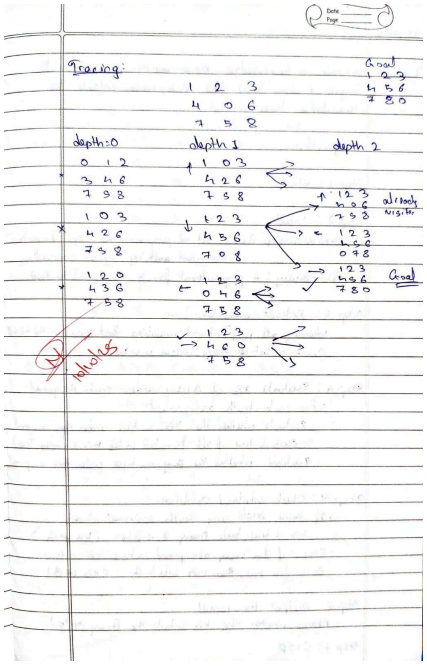
```
                    moved_col = col
                    old_row = current_state[col]
                    new_row = next_state[col]
                    break
            direction = "up" if new_row < old_row else "down"
            print(f"Iteration {iteration}: Moved queen in column {moved_col} from row {old_row}
{direction} to row {new_row}, conflicts {min_conflicts}")
            current_state = next_state
            current_conflicts = min_conflicts

        elif min_conflicts == current_conflicts:
            chosen_index = random.choice(min_indices)
            next_state = neighbors[chosen_index]
            # Find which column changed and rows before/after
            for col in range(n):
                if current_state[col] != next_state[col]:
                    moved_col = col
                    old_row = current_state[col]
                    new_row = next_state[col]
                    break
            direction = "up" if new_row < old_row else "down"
            print(f"Iteration {iteration}: Moved queen in column {moved_col} from row {old_row}
{direction} to row {new_row} (equal objective), conflicts {min_conflicts}")
            current_state = next_state
            current_conflicts = min_conflicts

        else:
            print(f"Iteration {iteration}: Local optimum reached with conflicts {current_conflicts}")
            improved = False

    if current_conflicts == 0:
        print("\nGlobal optimum found!")
        break
    restarts += 1
    current_state = random_state()
    current_conflicts = conflicts(current_state)
    print(f"\nRestart {restarts}: New random state with conflicts {current_conflicts}")
print("\nFinal board:")
print_board(current_state)
print(f"Final conflicts: {current_conflicts}")
print(f"Total iterations: {iteration}")
print(f"Total restarts: {restarts}")
return current_state
# Example: Solve 8-Queens
n = 5
hill_climbing_n_queens(n)
```

Program 5

Simulated Annealing to Solve 8-Queens problem

Algorithm:





Code:

```
// (8-Puzzle)
from collections import deque

class PuzzleState:
    def __init__(self, board, parent=None, move="", depth=0):
        self.board = board
        self.parent = parent
        self.move = move
        self.depth = depth  # number of moves from start

    def find_blank(self):
        return self.board.index(0)

    def get_moves(self):
        """Generate possible moves from current state"""
        blank = self.find_blank()
        moves = []
        row, col = divmod(blank, 3)
        directions = {
            "Up": (row - 1, col),
            "Down": (row + 1, col),
            "Left": (row, col - 1),
```

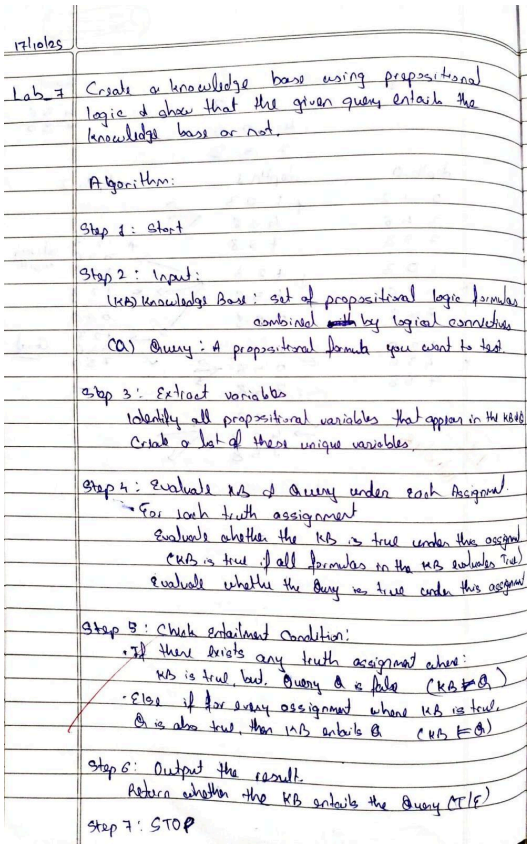
```
            "Right": (row, col + 1)
        }
        for move, (r, c) in directions.items():
            if 0 <= r < 3 and 0 <= c < 3:
                new_blank = r * 3 + c
                new_board = self.board[:]
                new_board[blank], new_board[new_blank] = new_board[new_blank], new_board[blank]
                moves.append(PuzzleState(new_board, self, move, self.depth + 1))
        return moves

    def path(self):
        """Reconstruct the path from start to current state"""
        node, p = self, []
        while node:
            p.append((node.move, node.board))
            node = node.parent
        return list(reversed(p))

    def print_board(self):
        """Print the board in 3x3 format"""
        for i in range(0, 9, 3):
            print(self.board[i:i+3])
        print()


def bfs(start, goal):
    start_state = PuzzleState(start)
    if start == goal:
        return start_state.path()

    queue = deque([start_state])
    visited = set()
    visited.add(tuple(start))

    while queue:
        current = queue.popleft()

        if current.board == goal:
            return current.path()

        for neighbor in current.get_moves():
            t_board = tuple(neighbor.board)
            if t_board not in visited:
                visited.add(t_board)
                queue.append(neighbor)
    return None
```

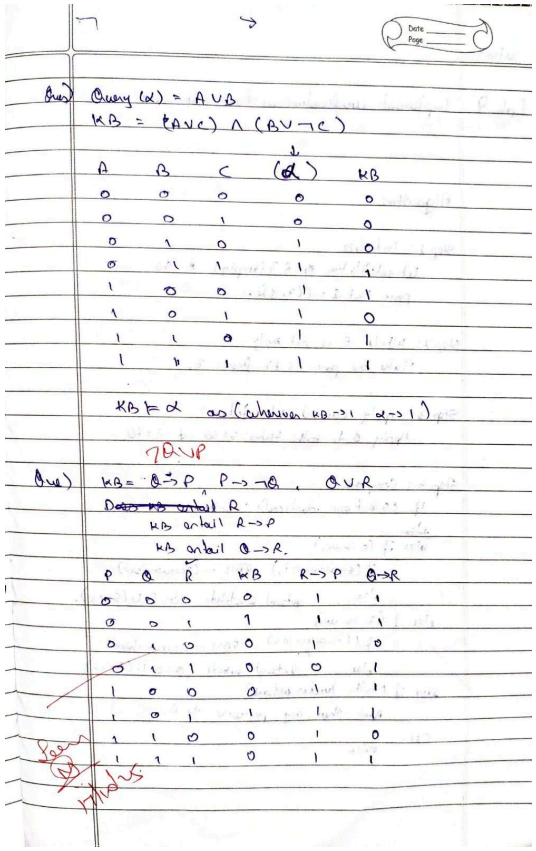
```
if __name__ == "__main__":
    initial_state = [
        1, 2, 3,
        4, 7, 5,
        6, 8, 0
    ]

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

    solution = bfs(initial_state, goal_state)

    if solution:
        print(f"Solution found in {len(solution)-1} moves:\n")
        for idx, (move, board) in enumerate(solution):
            print(f"Step {idx}: Move: {move}")
            for i in range(0, 9, 3):
                print(board[i:i+3])
            print()
    else:
        print("No solution found.")
```

Program 6

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

Algorithm:





Code:

```
import itertools
import re


def extract_variables(expressions):
    vars = set()
    pattern = r'\b[A-Z]\b'
    for expr in expressions:
        vars.update(re.findall(pattern, expr))
    return sorted(vars)


def eval_expr(expr, assignment):
    for var, val in assignment.items():
        expr = re.sub(r'\b' + var + r'\b', str(val), expr)

    expr = expr.replace('¬', ' not ')
```

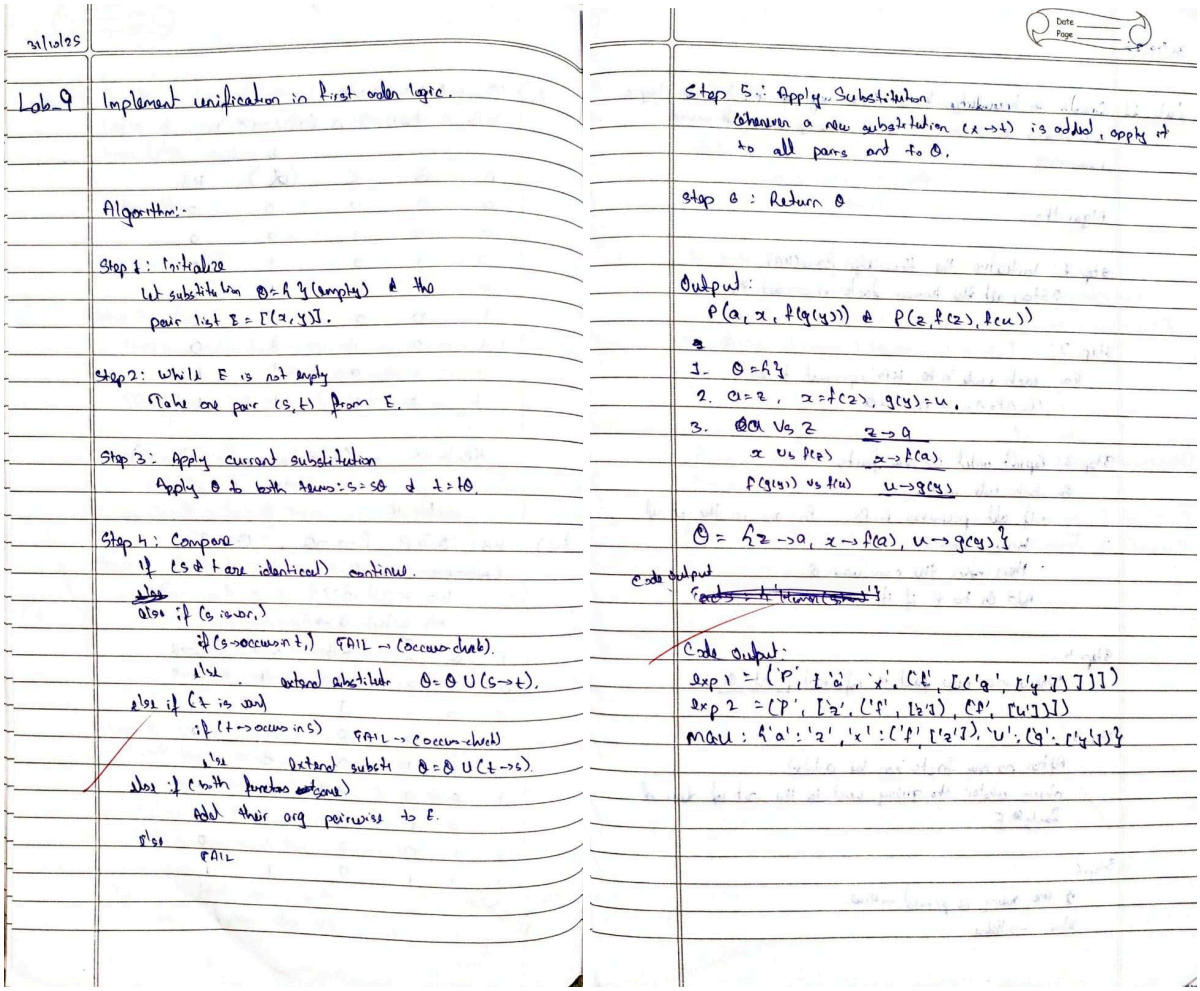
```
    expr = expr.replace('∧', ' and ')
    expr = expr.replace('∨', ' or ')

    while '→' in expr:
        match = re.search(r'([^() ]+) *→ *([^() ]+)', expr)
        if not match:
            expr = expr.replace('→', ' <= ')
            break
        left = match.group(1)
        right = match.group(2)
        replacement = f'((not ({left})) or ({right}))'
        expr = expr[:match.start()] + replacement + expr[match.end():]

    try:
        return eval(expr)
    except Exception as e:
        raise ValueError(f"Error evaluating expression '{expr}': {e}")


def entails(KB, query):
    all_exprs = KB + [query]
    variables = extract_variables(all_exprs)

    truth_table = []

    # Generate all possible truth assignments
    for values in itertools.product([False, True], repeat=len(variables)):
        assignment = dict(zip(variables, values))

        KB_true = all(eval_expr(kb, assignment) for kb in KB)
        query_true = eval_expr(query, assignment)

        truth_table.append((assignment, KB_true, query_true))

        if KB_true and not query_true:
            return False, truth_table

    return True, truth_table


# Hardcoded KB and query as per your example
if __name__ == "__main__":
    # Define KB and Query for the problem
    KB = ['(A ∨ C)', '(B ∨ ¬C)']  # Knowledge Base (KB)
    query = '(A ∨ B)'  # Query (α)

    # Check entailment and get truth table
```

```
entails_result, truth_table = entails(KB, query)

# Output entailment result
print(f"Does KB entail '{query}'? {entails_result}")

# Print the truth table
print("\nTruth Table:")
header = ["Assignment", "KB Evaluation", "Query Evaluation"]
print(f"{header[0]:<25} {header[1]:<20} {header[2]:<20}")

for assignment, KB_true, query_true in truth_table:
    print(f"{str(assignment):<25} {str(KB_true):<20} {str(query_true):<20}")
```

Program 7

Implement unification in first order logic

Algorithm:



Lab 9 Implement unification in first order logic.

Algorithm:-

Step 1: Initialize
Let substitution $\theta = \{\}$ (empty) & the pair list $E = [(x, y)]$.

Step 2: While E is not empty
Take one pair (s, t) from E.

Step 3: Apply current substitution
Apply θ to both terms: $s = s\theta$ & $t = t\theta$.

Step 4: Compare
if (s & t are identical) continue.
else if (s is var)
if (s occurs in t) FAIL → (occurs check).
else extend substitute $\theta = \theta \cup (s \to t)$.
else if (t is var)
if (t occurs in s) FAIL → (occurs check)
else extend subst $\theta = \theta \cup (t \to s)$.
else if (both functions same)
Add their arg pairwise to E.
else
FAIL

Step 5: Apply Substitution
Whenever a new substitution $(x \to t)$ is added, apply it to all pairs and to θ.

Step 6: Return θ

Output:
$P(a, x, f(g(y)))$ & $P(z, f(z), f(u))$

1. $\theta = \{\}$
2. $a = z$, $x = f(z)$, $g(y) = u$.
3. a vs z $z \to a$
x vs f(z) $x \to f(a)$
f(g(y)) vs f(u) $u \to g(y)$

$\theta = \{z \to a, x \to f(a), u \to g(y)\}$

Code output
~~Terms = [('P', 'a', 'x', 'f(g(y))'), ('P', 'z', 'f(z)', 'f(u)')]~~

Code Output:
exp 1 = ('P', 'a', 'x', ('f', ('g', 'y'))])
exp 2 = ('P', 'z', ('f', 'z'), ('f', ('g', 'y'))])
mgu : {'a': 'z', 'x': ('f', 'z'), 'u': ('g', 'y')}

Code:

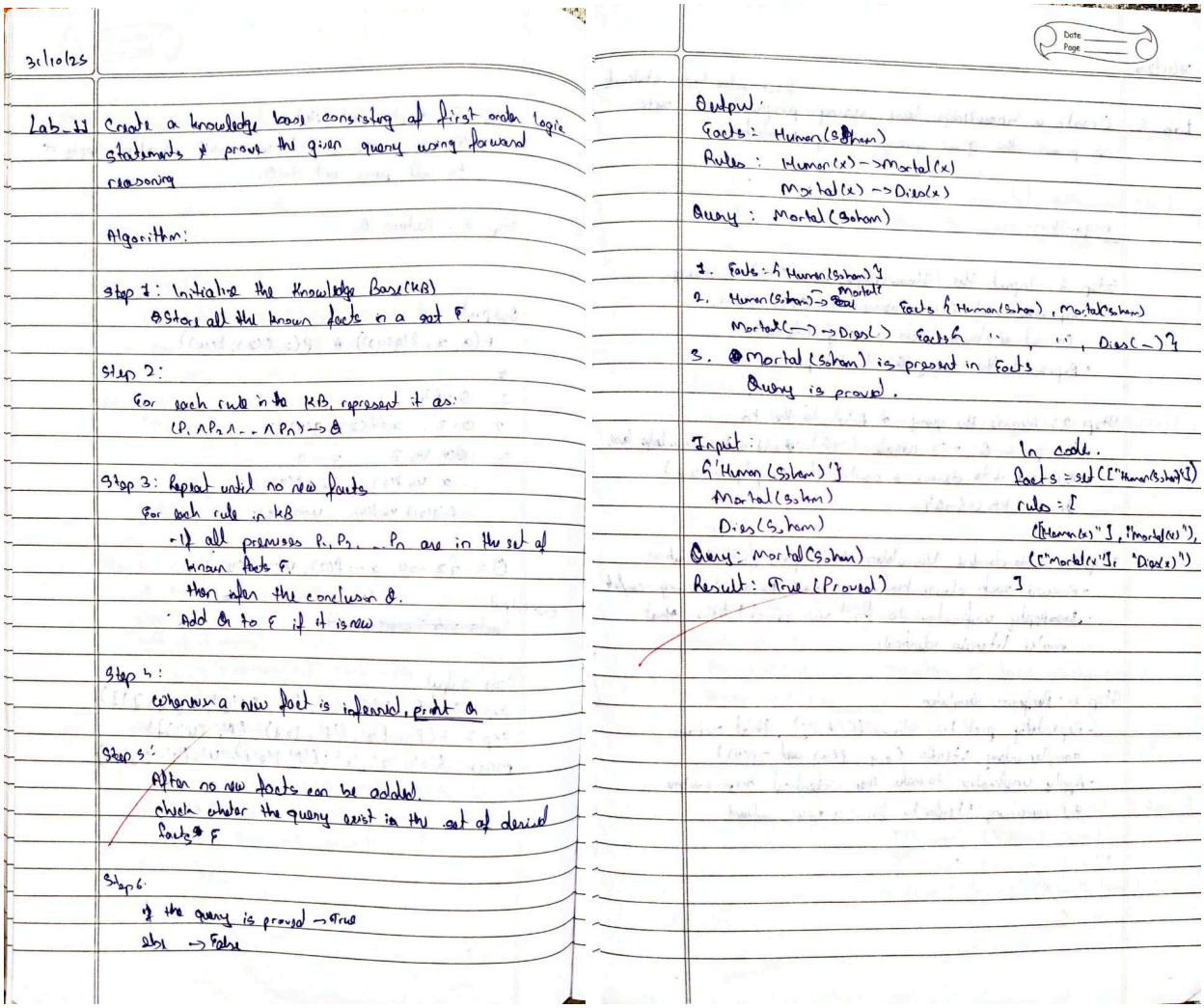
```
def is_variable(x):
    return isinstance(x, str) and x[0].islower()

def occurs_check(var, expr):
    if var == expr:
        return True
    elif isinstance(expr, tuple):
        return any(occurs_check(var, sub) for sub in expr[1])
    return False

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

```
    if x == y:
        return theta
    elif is_variable(x):
        if occurs_check(x, y):
            return None
        theta[x] = y
        return {k: substitute(v, theta) for k, v in theta.items()}
    elif is_variable(y):
        return unify(y, x, theta)
    elif isinstance(x, tuple) and isinstance(y, tuple) and x[0] == y[0]:
        for a, b in zip(x[1], y[1]):
            theta = unify(substitute(a, theta), substitute(b, theta), theta)
            if theta is None:
                return None
        return theta
    else:
        return None

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


# ---------- Example ----------
# Represent P(a, x, f(g(y))) as ('P', ['a','x',('f',[('g',['y'])])])
# Represent P(z, f(z), f(u)) as ('P', ['z',('f',['z']),('f',['u'])])

expr1 = ('P', ['a', 'x', ('f', [('g', ['y'])])])
expr2 = ('P', ['z', ('f', ['z']), ('f', ['u'])])

result = unify(expr1, expr2)
print("Most General Unifier (MGU):", result)
```

Program 8

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

Algorithm:



Code:

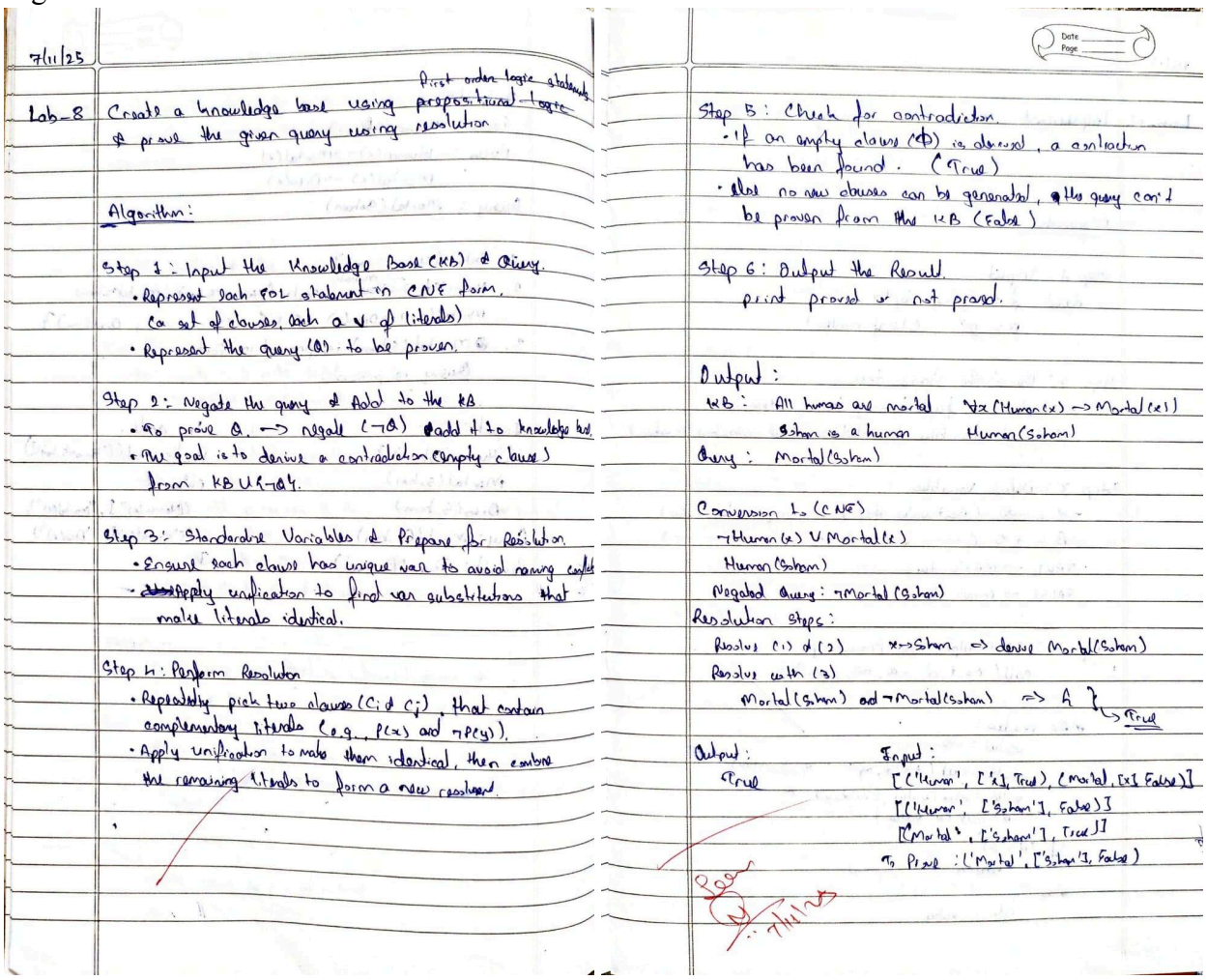
```
from collections import defaultdict

# ---------- Step 1: Define Knowledge Base ----------
facts = set(["Human(Socrates)"])

# Rules are stored as (premises, conclusion)
rules = [
    (["Human(x)"], "Mortal(x)"),
    (["Mortal(x)"], "Dies(x)")
]
```

```
query = "Mortal(Socrates)"  # What we want to prove


# ---------- Step 2: Substitute variables ----------
def substitute(expr, var, val):
    return expr.replace(var, val)


# ---------- Step 3: Forward Chaining Function ----------
def forward_chain(facts, rules, query):
    new_facts = set(facts)
    added = True

    while added:
        added = False
        for premises, conclusion in rules:
            for fact in list(new_facts):
                # Check if any variable substitution is possible
                if '(' in fact:
                    const = fact[fact.find('(')+1:fact.find(')')]
                    temp = conclusion
                    for p in premises:
                        temp = substitute(temp, 'x', const)

                    if all(substitute(p, 'x', const) in new_facts for p in premises):
                        if temp not in new_facts:
                            print(f"Inferred: {temp}")
                            new_facts.add(temp)
                            added = True

    return query in new_facts


# ---------- Step 4: Run the reasoning ----------
print("Initial Facts:", facts)
result = forward_chain(facts, rules, query)
print("\nQuery:", query)
print("Result:", "PROVED" if result else "NOT PROVED")
```

Program 9

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

Algorithm:



Code:

```
import copy

# Each clause is a disjunction of literals
# Each literal is represented as a tuple: ('predicate', [args], is_negated)
# Example: ('Human', ['x'], False) means Human(x)
# Example: ('Mortal', ['x'], True) means ¬Mortal(x)

# Example KB:
# 1. ¬Human(x) ∨ Mortal(x)  (All humans are mortal)
# 2. Human(Socrates)
# Query: Mortal(Socrates)
```

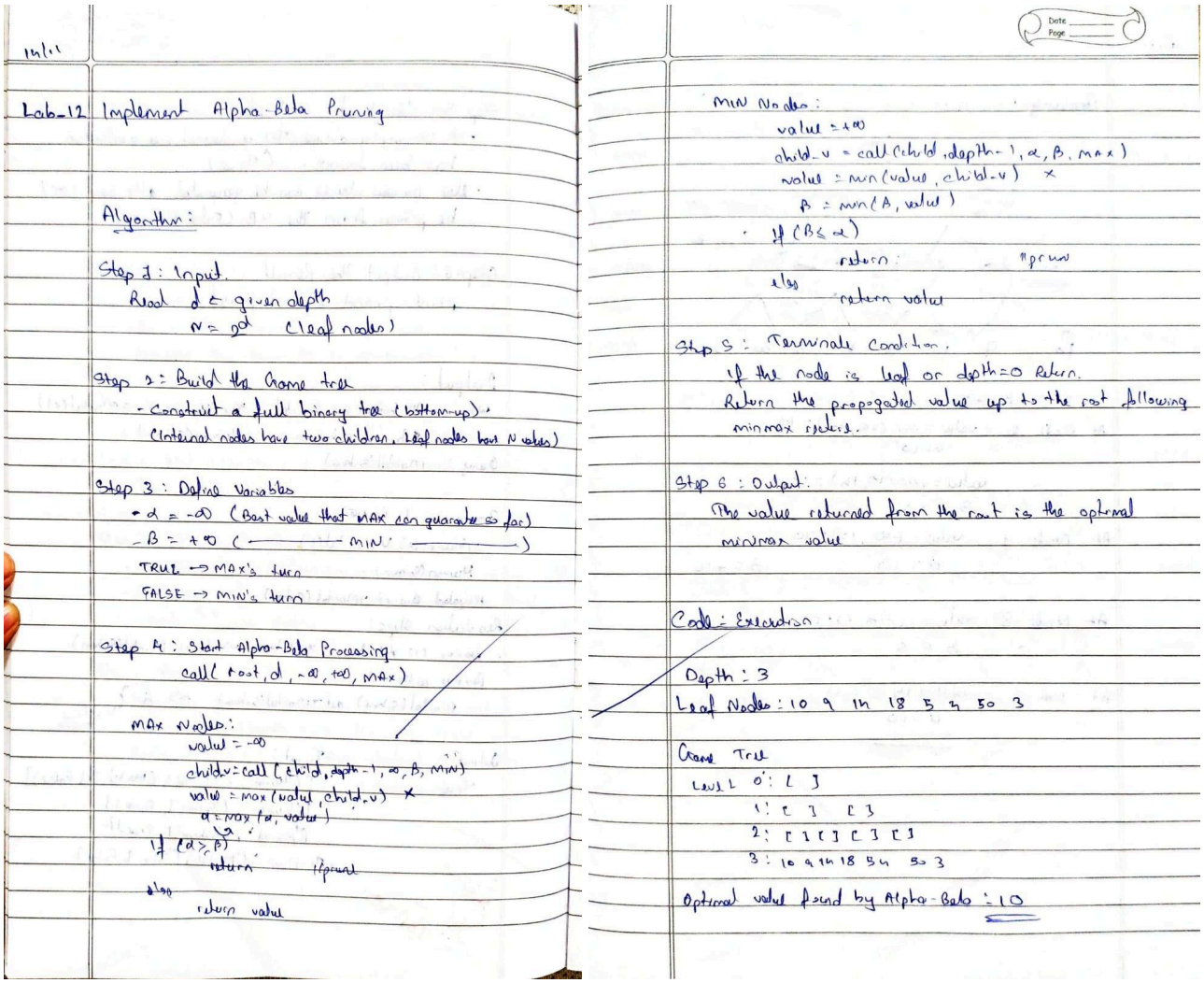
```
KB = [
    [('Human', ['x'], True), ('Mortal', ['x'], False)],
    [('Human', ['Socrates'], False)]
]
query = ('Mortal', ['Socrates'], False)

# ---------- Unification Function ----------
def unify(x, y, theta=None):
    if theta is None:
        theta = {}
    if x == y:
        return theta
    elif isinstance(x, str) and x.islower():  # variable
        return unify_var(x, y, theta)
    elif isinstance(y, str) and y.islower():  # variable
        return unify_var(y, x, theta)
    elif isinstance(x, list) and isinstance(y, list) and len(x) == len(y):
        for xi, yi in zip(x, y):
            theta = unify(xi, yi, theta)
            if theta is None:
                return None
        return theta
    elif isinstance(x, tuple) and isinstance(y, tuple):
        return unify(list(x), list(y), 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

# ---------- Apply Substitution ----------
def substitute(clause, theta):
    new_clause = []
    for (pred, args, neg) in clause:
        new_args = [theta.get(a, a) for a in args]
        new_clause.append((pred, new_args, neg))
    return new_clause

# ---------- Resolution ----------
def resolve(ci, cj):
    resolvents = []
```

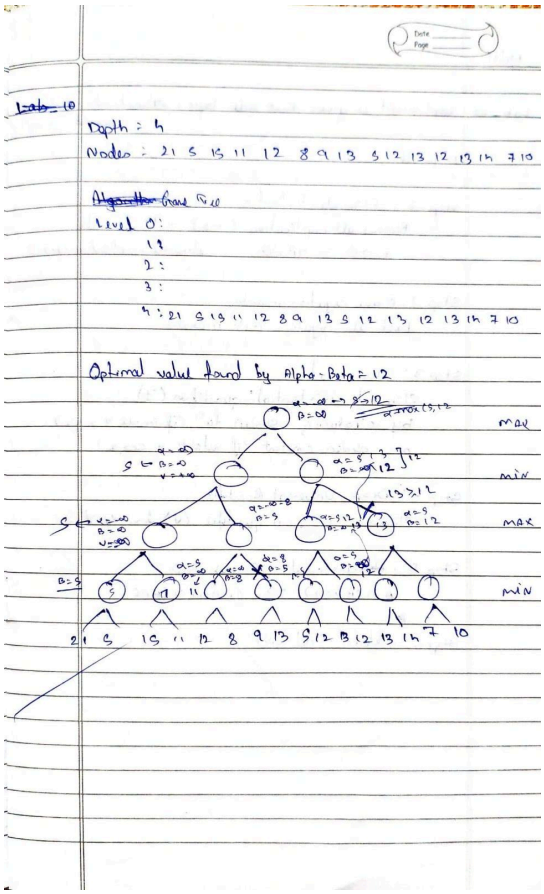
```
    for (pi, args_i, neg_i) in ci:
        for (pj, args_j, neg_j) in cj:
            if pi == pj and neg_i != neg_j:
                theta = unify(args_i, args_j)
                if theta is not None:
                    new_ci = [lit for lit in ci if lit != (pi, args_i, neg_i)]
                    new_cj = [lit for lit in cj if lit != (pj, args_j, neg_j)]
                    merged = new_ci + new_cj
                    resolvent = substitute(merged, theta)
                    # remove duplicates
                    resolvent = [lit for lit in resolvent if lit not in []]
                    resolvents.append(resolvent)
    return resolvents

def resolution(KB, query):
    negated_query = [(query[0], query[1], not query[2])]
    clauses = KB + [negated_query]
    new = []
    print("\nInitial clauses:")
    for c in clauses:
        print(" ", c)

    while True:
        n = len(clauses)
        pairs = [(clauses[i], clauses[j]) for i in range(n) for j in range(i + 1, n)]
        for (ci, cj) in pairs:
            resolvents = resolve(ci, cj)
            for r in resolvents:
                if r == []:
                    print("\nDerived empty clause → Query proven")
                    return True
                new.append(r)
        if all(x in clauses for x in new):
            print("\nNo new clauses → Query cannot be proven")
            return False
        for c in new:
            if c not in clauses:
                clauses.append(c)
if __name__ == "__main__":
    print("Proving:", query)
    result = resolution(KB, query)
    print("\nResult:", "Proved" if result else "Not Proved")
```

Program 10

Implement Alpha-Beta Pruning.

Algorithm:





Code:

```
import math

# ------------------------------
# Pretty Print Tree (Level Order)
# ------------------------------
def print_tree(root):
    print("\n--- Game Tree (Level Order) ---")
    queue = [root]
    level = 0
    while queue:
        next_level = []
        print(f"Level {level}: ", end="")
        for node in queue:
            if isinstance(node, int):
                print(node, end="  ")
            else:
                print("[*]", end="  ")
                next_level.extend(node)
        print()
        queue = next_level
```

```
        level += 1
    print("--------------------------------\n")


# ----------------------------
# Alpha-Beta Pruning with Logging
# ----------------------------
node_id_counter = 1

def alphabeta(node, depth, alpha, beta, maximizing):
    global node_id_counter
    my_id = node_id_counter
    node_id_counter += 1

    # Terminal leaf
    if depth == 0 or isinstance(node, int):
        print(f"Leaf Node {my_id}: value={node}")
        return node

    if maximizing:
        value = -math.inf
        print(f"MAX Node {my_id}: depth={depth}, alpha={alpha}, beta={beta}")

        for child in node:
            child_value = alphabeta(child, depth - 1, alpha, beta, False)
            value = max(value, child_value)
            alpha = max(alpha, value)
            print(f"  MAX Node {my_id} updated: value={value}, alpha={alpha}, beta={beta}")

            if alpha >= beta:
                print(f"  >>> PRUNING at MAX Node {my_id}: alpha >= beta ({alpha} >= {beta})")
                break

        print(f"MAX Node {my_id} returns {value}")
        return value

    else:
        value = math.inf
        print(f"MIN Node {my_id}: depth={depth}, alpha={alpha}, beta={beta}")

        for child in node:
            child_value = alphabeta(child, depth - 1, alpha, beta, True)
            value = min(value, child_value)
            beta = min(beta, value)
            print(f"  MIN Node {my_id} updated: value={value}, alpha={alpha}, beta={beta}")

            if beta <= alpha:
```

```
            print(f"  >>> PRUNING at MIN Node {my_id}: beta <= alpha ({beta} <= {alpha})")
            break

        print(f"MIN Node {my_id} returns {value}")
        return value


# ----------------------------
# Build FULL BINARY TREE
# ----------------------------
def build_tree(values):
    """Build binary tree bottom-up from leaf list."""
    level = values
    while len(level) > 1:
        next_level = []
        for i in range(0, len(level), 2):
            next_level.append([level[i], level[i + 1]])
        level = next_level
    return level[0]


# ----------------------------
# MAIN PROGRAM
# ----------------------------
if __name__ == "__main__":
    depth = int(input("Enter depth of tree: "))

    leaf_count = 2 ** depth
    print(f"Enter {leaf_count} leaf node values:")

    leaves = list(map(int, input().split()))
    if len(leaves) != leaf_count:
        print("Error: incorrect number of leaf values.")
        exit()

    # Build tree
    tree = build_tree(leaves)

    # Print tree
    print_tree(tree)

    # Run Alpha-Beta
    print("\n--- Alpha-Beta Evaluation ---")
    best_value = alphabeta(tree, depth, -math.inf, math.inf, True)

    print("\nOptimal value found by Alpha–Beta:", best_value)
```