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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Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Satish Girish Kudare (1BM23CS306),** 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.

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Completed

Github Link: https://github.com/Satish1895/1BM23CS306_AI.git

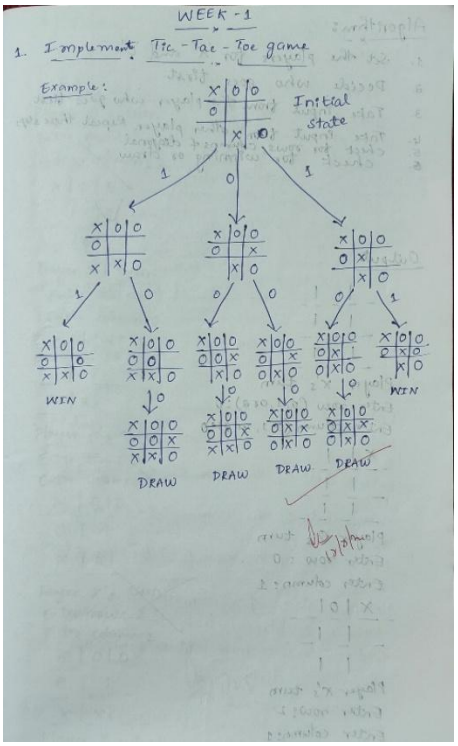
Program 1

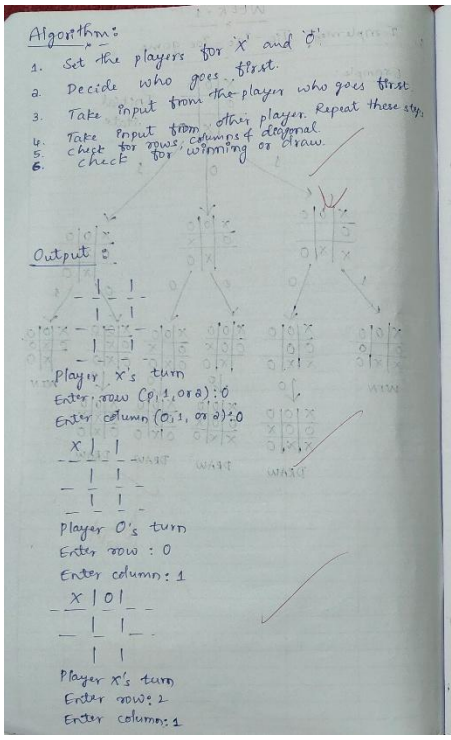
Implement Tic –Tac –Toe Game

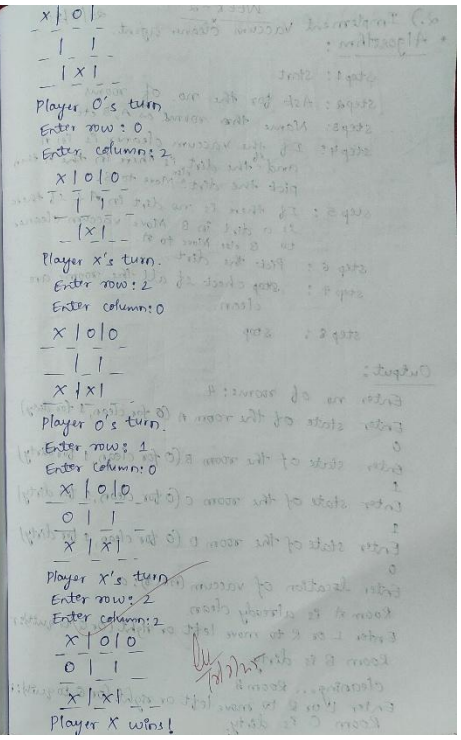
Implement vacuum cleaner agent

Algorithm:

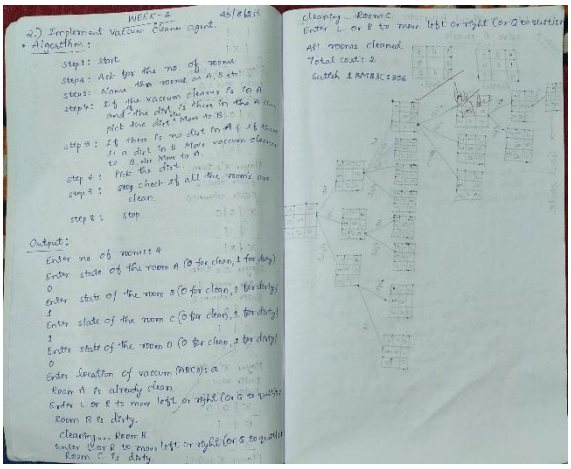
a) Tic Tac Toe







b) Vacuum Cleaner



Code:
a)Tic Tac Toe

```
def print_board(board):
    """Prints the Tic Tac Toe board."""
    for row in board:
        print(" | ".join(row))
        print("-" * 9)

def check_win(board, player):
    """Checks if the current player has won."""
    n = len(board)
    # Check rows
    for row in board:
        if all(cell == player for cell in row):
            return True
    # Check columns
    for col in range(n):
        if all(board[row][col] == player for row in range(n)):
            return True
    # Check diagonals
    if all(board[i][i] == player for i in range(n)) or \
       all(board[i][n - 1 - i] == player for i in range(n)):
        return True
    return False

def check_draw(board):
    """Checks if the game is a draw."""
    for row in board:
        if " " in row:
            return False
    return True

def tic_tac_toe():
    """Runs the Tic Tac Toe game."""
    board = [[" " for _ in range(3)] for _ in range(3)]
    players = ["X", "O"]
    current_player = 0

    while True:
        print_board(board)
        player = players[current_player]
```

```
        print(f"Player {player}'s turn.")

        while True:
            try:
                row = int(input("Enter row (0, 1, or 2): "))
                col = int(input("Enter column (0, 1, or 2): "))
                if 0 <= row < 3 and 0 <= col < 3 and board[row][col] == " ":
                    board[row][col] = player
                    break
                else:
                    print("Invalid move. Try again.")
            except ValueError:
                print("Invalid input. Please enter numbers.")

        if check_win(board, player):
            print_board(board)
            print(f"Player {player} wins!")
            break
        elif check_draw(board):
            print_board(board)1

            print("It's a draw!")
            break

        current_player = (current_player + 1) % 2

if __name__ == "__main__":
    tic_tac_toe()

print("Satish 1BM23CS306")
```

Output:

```
  |  |
---------
 |  |
---------
 |  |
---------
Player X's turn.
Enter row (0, 1, or 2): 0
Enter column (0, 1, or 2): 0
```

```
X |   |
---------
  |   |
---------
  |   |
---------
Player O's turn.
Enter row (0, 1, or 2): 0
Enter column (0, 1, or 2): 2
X |   | O
---------
  |   |
---------
  |   |
---------
Player X's turn.
Enter row (0, 1, or 2): 1
Enter column (0, 1, or 2): 1
X |   | O
---------
  | X |
---------
  |   |
---------
Player O's turn.
Enter row (0, 1, or 2): 2
Enter column (0, 1, or 2): 2
X |   | O
---------
  | X |
---------
  |   | O
---------
Player X's turn.
Enter row (0, 1, or 2): 1
Enter column (0, 1, or 2): 2
X |   | O
---------
  | X | X
---------
  |   | O
```

Player O's turn.
Enter row (0, 1, or 2): 1
Enter column (0, 1, or 2): 0
X | | O

O | X | X

  | | O

Player X's turn.
Enter row (0, 1, or 2): 0
Enter column (0, 1, or 2): 1
X | X | O

O | X | X

  | | O

Player O's turn.
Enter row (0, 1, or 2): 2
Enter column (0, 1, or 2): 1
X | X | O

O | X | X

  | O | O

Player X's turn.
Enter row (0, 1, or 2): 2
Enter column (0, 1, or 2): 0
X | X | O

O | X | X

X | O | O

It's a draw!
Satish 1BM23CS306

b) Vacuum Cleaner

```
rooms = int(input("Enter no. of rooms: "))
Rooms = "ABCDEFGHIJKLMNOPQRSTUVWXYZ"
RoomState = {}
cost = 0
for i in range(rooms):
  print(f"Enter state of the room {Rooms[i]} (0 for clean,1 for dirty)")
  state = int(input())
  RoomState[Rooms[i]] = state
loc = input(f"Enter Location of vacuum ({Rooms[:rooms]}): ").upper()
while 1 in RoomState.values():
    if RoomState[loc] == 1:
        print(f"Room {loc} is dirty.")
        print(f"Cleaning...Room {loc}")
        RoomState[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 RoomState.values() else "Exited before cleaning all
rooms.")
print(f"Total cost: {cost}")
print("Satish 1BM23CS306")
```

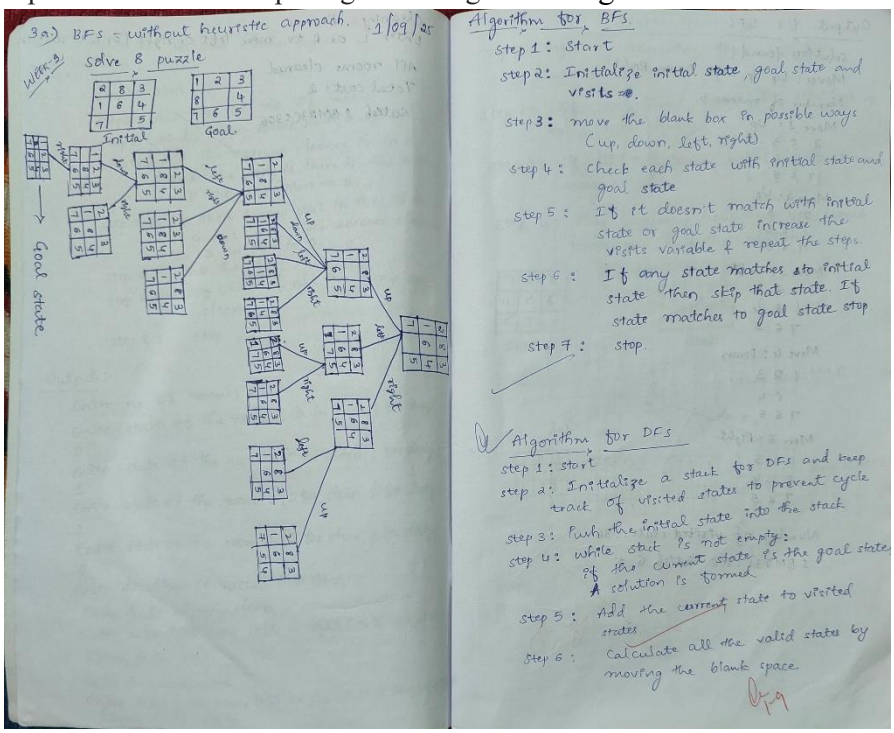
Output:
Enter Number of rooms: 3
Enter Room A state (0 for clean, 1 for dirty): 1
Enter Room B state (0 for clean, 1 for dirty): 0
Enter Room C state (0 for clean, 1 for dirty):
1
Enter Location of vacuum (ABC): B Room
B is already clean.
Enter L or R to move left or right (or Q to quit): L Room
A is dirty. Cleaning...
Enter L or R to move left or right (or Q to quit): R Room
B is already clean.
Enter L or R to move left or right (or Q to quit): R Room
C is dirty. Cleaning...
Enter L or R to move left or right (or Q to quit): R No
room to move right.

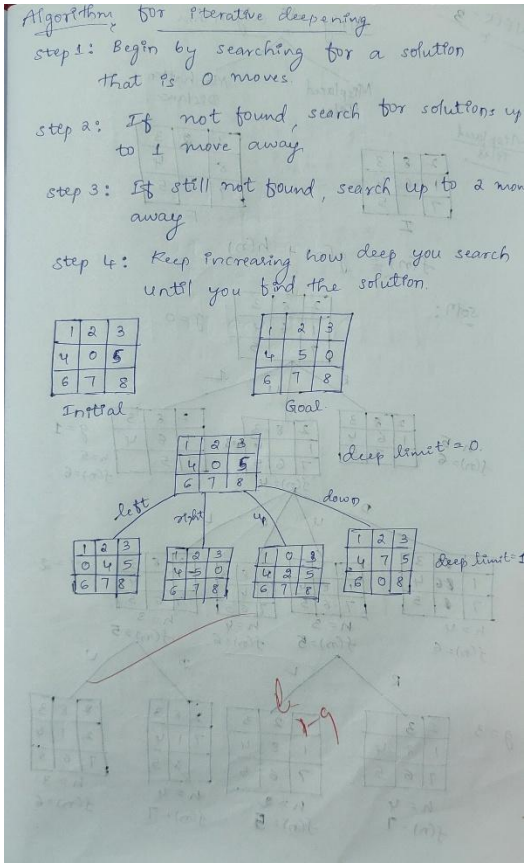
All Rooms Cleaned.
Total cost: 2
Satish 1BM23CS306

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)

Implement Iterative deepening search algorithm Algorithm:





Code:

a) DFS

```
goal_state = '123804765'

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 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)

        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 the INITIAL state (give '0'for empty space): ")

if len(start) == 9 and set(start) == set('012345678'):
    print("INITIAL 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))

        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.")

print("1BM23CS306 Satish")
```

Output:

```
Enter start state (e.g., 724506831): 123456078
Start state:
1 2 3
4 5 6
 7 8

Visited state:
1 2 3
4 5 6
 7 8

Visited state:
1 2 3
4 5 6
7   8

Visited state:
1 2 3
4 5 6
7 8

Solution found!
Moves: R R
Number of moves: 2
Move 1: R
1 2 3
4 5 6
7   8
Move 2: R
1 2 3
4 5 6
7 8
1BM23CS306  Satish
```

b) Iterative Deepening Search

```
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("1BM23CS306 Satish G K\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.")
```

Output:

```
Enter start state (e.g., 724506831): 123450678
Start state:
1 2 3
4 5
6 7 8

Total states visited: 9504
Solution found!
Moves: D L L U R D R U L L D R R
Number of moves: 13
1BM23CS306 Satish G K

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

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

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

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

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

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

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

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

Move 9: L
1 2 3
5 6
4 7 8

Move 10: L
1 2 3
 5 6
4 7 8

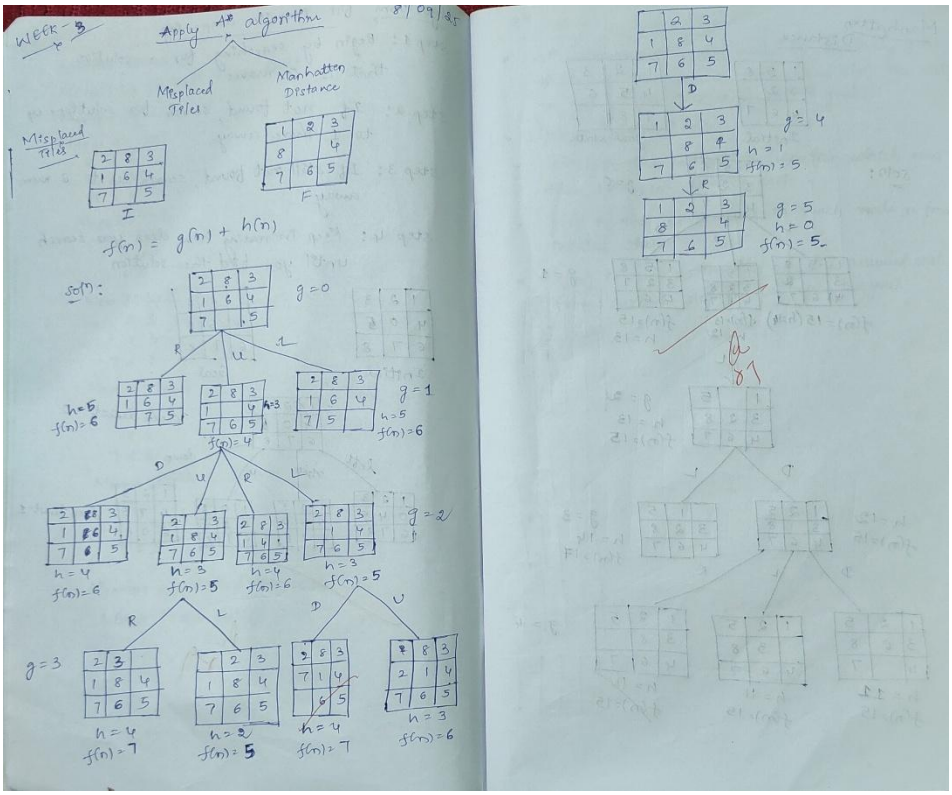
Move 11: D
1 2 3
4 5 6
 7 8

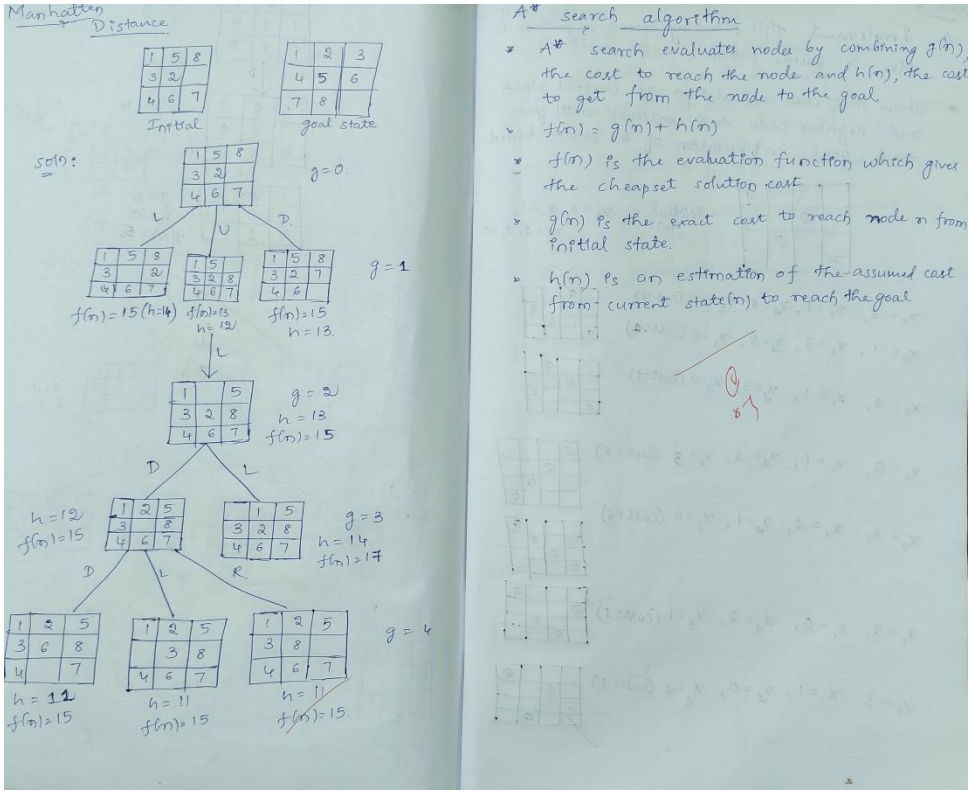
Move 12: R
1 2 3
4 5 6
7 8

Move 13: R
1 2 3
4 5 6
7 8

Program 3

Implement A* search algorithm





Code:

a) Misplaced Tiles

```
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("1BM23CS306 Satish G K\n")

        current_state = start
        g = 0  # initialize cost so far
        for i, move in enumerate(result, 1):
            new_state = move_tile(current_state, move)
            g += 1
            h = manhattan_distance(new_state)
            f = g + h
            print(f"Move {i}: {move}")
            print_state(new_state)
            print(f"g(n) = {g}, h(n) = {h}, f(n) = g(n) + h(n) = {f}\n")
            current_state = new_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.")
```

Output:

Enter start state (e.g., 724506831): 123678405
Start state:
1 2 3
6 7 8
4 5

Total states visited: 14
Solution found!
Moves: U L D R R U L D R
Number of moves: 9
1BM23CS306 Satish G K

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

g(n) = 1, h(n) = 8, f(n) = g(n) + h(n) = 9

Move 2: L
1 2 3

 6 8
4 7 5

g(n) = 2, h(n) = 7, f(n) = g(n) + h(n) = 9

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

g(n) = 3, h(n) = 6, f(n) = g(n) + h(n) = 9

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

g(n) = 4, h(n) = 5, f(n) = g(n) + h(n) = 9

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

g(n) = 5, h(n) = 4, f(n) = g(n) + h(n) = 9

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

g(n) = 6, h(n) = 3, f(n) = g(n) + h(n) = 9

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

g(n) = 7, h(n) = 2, f(n) = g(n) + h(n) = 9

Move 8: D
1 2 3

4 5 6
7 8

g(n) = 8, h(n) = 1, f(n) = g(n) + h(n) = 9

Move 9: R
1 2 3
4 5 6
7 8

g(n) = 9, h(n) = 0, f(n) = g(n) + h(n) = 9

b) Manhattan Distance

```
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("1BM23CS306 Satish G K\n")

        current_state = start
        g = 0  # initialize cost so far
        for i, move in enumerate(result, 1):
            new_state = move_tile(current_state, move)
            g += 1
            h = manhattan_distance(new_state)
            f = g + h
            print(f"Move {i}: {move}")
            print_state(new_state)
            print(f"g(n) = {g}, h(n) = {h}, f(n) = g(n) + h(n) = {f}\n")
            current_state = new_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.")
```

Output:

```
Enter start state (e.g., 724506831): 123678405
Start state:
1 2 3
6 7 8
4   5

Total states visited: 14
Solution found!
Moves: U L D R R U L D R
Number of moves: 9
1BM23CS306 Satish G K

Move 1: U
1 2 3
```

6 8
4 7 5

g(n) = 1, h(n) = 8, f(n) = g(n) + h(n) = 9

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

g(n) = 2, h(n) = 7, f(n) = g(n) + h(n) = 9

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

g(n) = 3, h(n) = 6, f(n) = g(n) + h(n) = 9

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

g(n) = 4, h(n) = 5, f(n) = g(n) + h(n) = 9

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

g(n) = 5, h(n) = 4, f(n) = g(n) + h(n) = 9

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

g(n) = 6, h(n) = 3, f(n) = g(n) + h(n) = 9

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

g(n) = 7, h(n) = 2, f(n) = g(n) + h(n) = 9

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

g(n) = 8, h(n) = 1, f(n) = g(n) + h(n) = 9

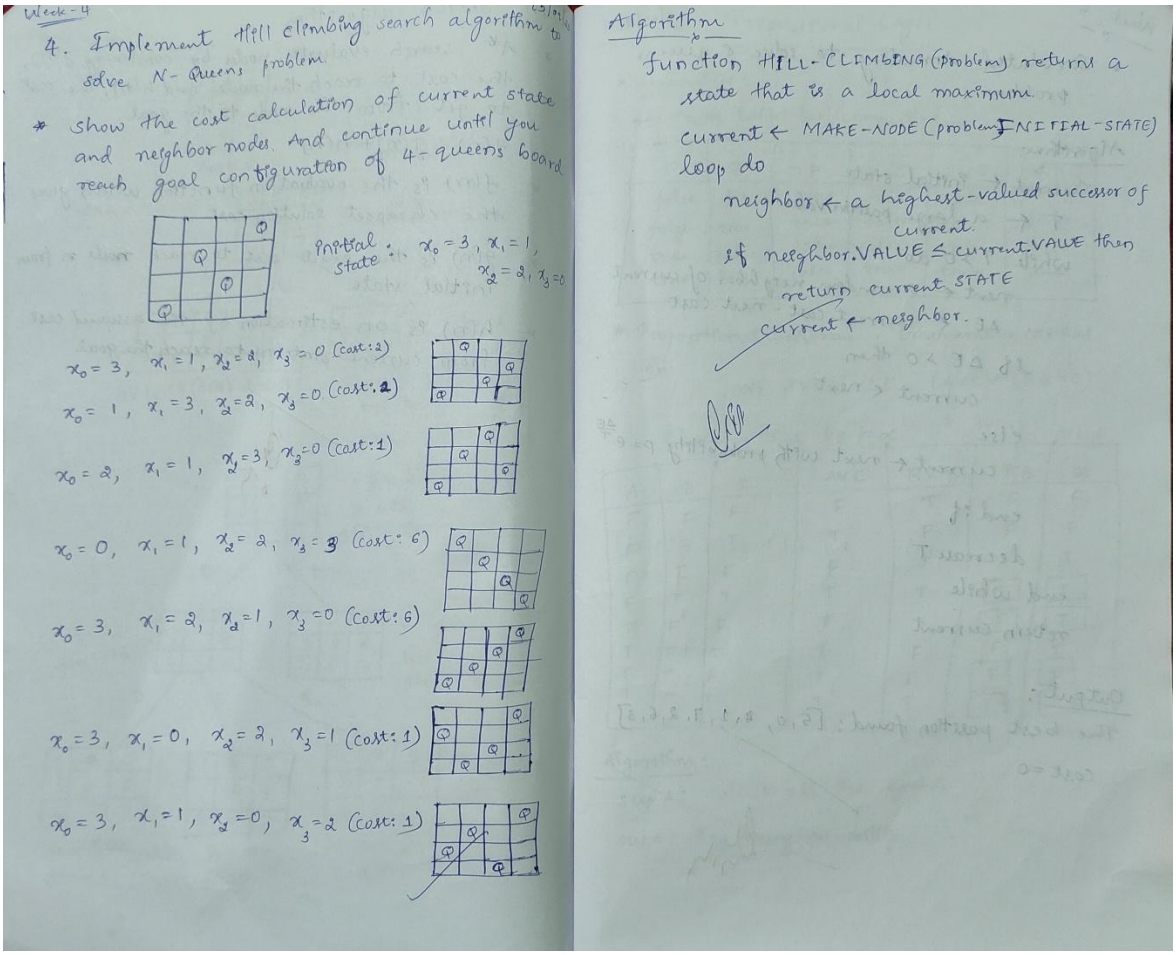
Move 9: R
1 2 3
4 5 6
7 8

g(n) = 9, h(n) = 0, f(n) = g(n) + h(n) = 9

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:



Code:

```
def calculate_cost(state):
    cost = 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):
                cost += 1
    return cost

# Generate neighbors (move one queen in a column to a different row)
def generate_neighbors(state):
    neighbors = []
```

```
    n = len(state)
    for col in range(n):
        for row in range(n):
            if state[col] != row:  # move queen
                new_state = list(state)
                new_state[col] = row
                neighbors.append(new_state)
    return neighbors

def hill_climbing(initial_state):
    current = initial_state
    current_cost = calculate_cost(current)
    step = 0

    print(f"Step {step}: State = {current}, Cost = {current_cost}")

    while True:
        neighbors = generate_neighbors(current)
        neighbor_costs = [(n, calculate_cost(n)) for n in neighbors]

        # Print state space for this step
        print("\nNeighbors and their costs:")
        for n, c in neighbor_costs:
            print(f"   {n} -> Cost = {c}")

        # Pick the best neighbor (lowest cost)
        best_neighbor, best_cost = min(neighbor_costs, key=lambda x: x[1])

        if best_cost >= current_cost:
            print("\nNo better neighbor found. Algorithm stops.")
            break

        # Move to better state
        step += 1
        current, current_cost = best_neighbor, best_cost
        print(f"\nStep {step}: Move to {current}, Cost = {current_cost}")

        if current_cost == 0:
            print("\nGoal reached! Solution found.")
            break

def get_user_initial_state(n):
    """
    Get initial state input from user.
```

```
    """
    while True:
        user_input = input(f"Enter the initial state as {n} integers (0 to {n-1}) separated by spaces:\n")
        parts = user_input.strip().split()
        if len(parts) != n:
            print(f"Error: Please enter exactly {n} integers.")
            continue

        try:
            state = [int(x) for x in parts]
        except ValueError:
            print("Error: Please enter valid integers.")
            continue

        if any(row < 0 or row >= n for row in state):
            print(f"Error: Each integer must be between 0 and {n-1}.")
            continue

        return state

if __name__ == "__main__":
    n = int(input("Enter the number of queens (N): "))
    initial_state = get_user_initial_state(n)
    hill_climbing(initial_state)

    print("\nSatish G K - 1BM23CS306")
```

Output:

```
Enter the number of queens (N): 4
Enter the initial state as 4 integers (0 to 3) separated by spaces:
2 0 3 1
Step 0: State = [2, 0, 3, 1], Cost = 0

Neighbors and their costs:
  [0, 0, 3, 1] -> Cost = 1
  [1, 0, 3, 1] -> Cost = 3
  [3, 0, 3, 1] -> Cost = 1
  [2, 1, 3, 1] -> Cost = 2
  [2, 2, 3, 1] -> Cost = 2
  [2, 3, 3, 1] -> Cost = 3
  [2, 0, 0, 1] -> Cost = 3
  [2, 0, 1, 1] -> Cost = 2
  [2, 0, 2, 1] -> Cost = 2
```

[2, 0, 3, 0] -> Cost = 1
[2, 0, 3, 2] -> Cost = 3
[2, 0, 3, 3] -> Cost = 1

No better neighbor found. Algorithm stops.

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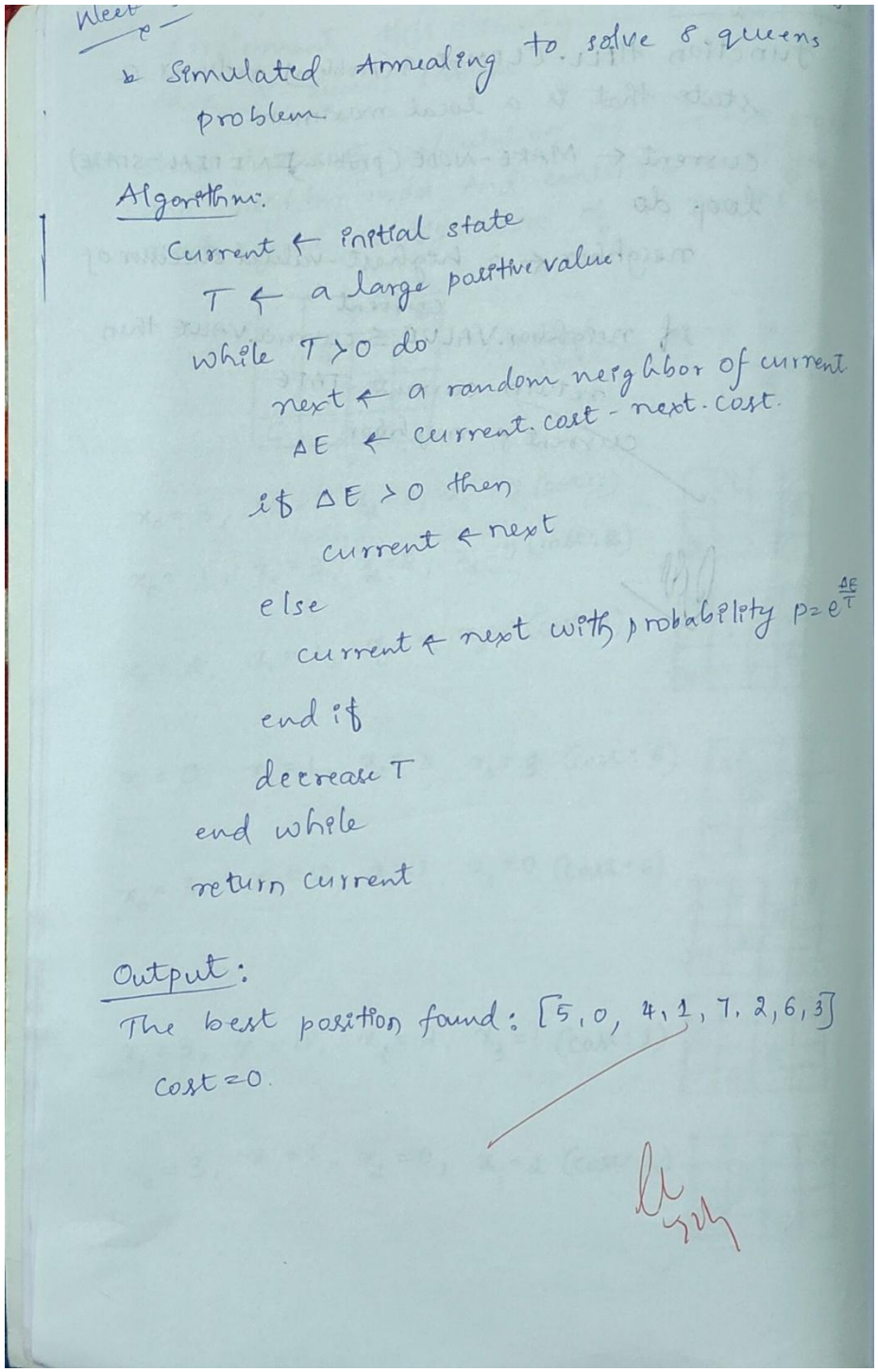
Program 5

Simulated Annealing to Solve 8-Queens problem

Algorithm:



Week 2

Simulated Annealing to solve 8 queens problem

Algorithm:

```
Current ← initial state
T ← a large positive value
while T > 0 do
    next ← a random neighbor 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:

The best position found: [5, 0, 4, 1, 7, 2, 6, 3]

cost = 0

Code:

```
import random
import math

# Heuristic: number of attacking pairs
def calculate_cost(state):
    cost = 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):
                cost += 1
    return cost

# Generate a random neighbor
def get_random_neighbor(state):
    n = len(state)
    new_state = list(state)
    col = random.randint(0, n - 1)   # pick random column
    row = random.randint(0, n - 1)   # new row
    new_state[col] = row
    return new_state

def simulated_annealing(n=8, max_iterations=10000, initial_temp=100.0, cooling_rate=0.99):
    # start with a random state
    current = [random.randint(0, n - 1) for _ in range(n)]
    current_cost = calculate_cost(current)
    best = current
    best_cost = current_cost
    temperature = initial_temp

    for _ in range(max_iterations):
        if current_cost == 0:
            break  # found solution

        neighbor = get_random_neighbor(current)
        neighbor_cost = calculate_cost(neighbor)
        delta = neighbor_cost - current_cost

        # Decide whether to accept the neighbor
        if delta < 0 or random.random() < math.exp(-delta / temperature):
            current, current_cost = neighbor, neighbor_cost

            # Update best if improved
```

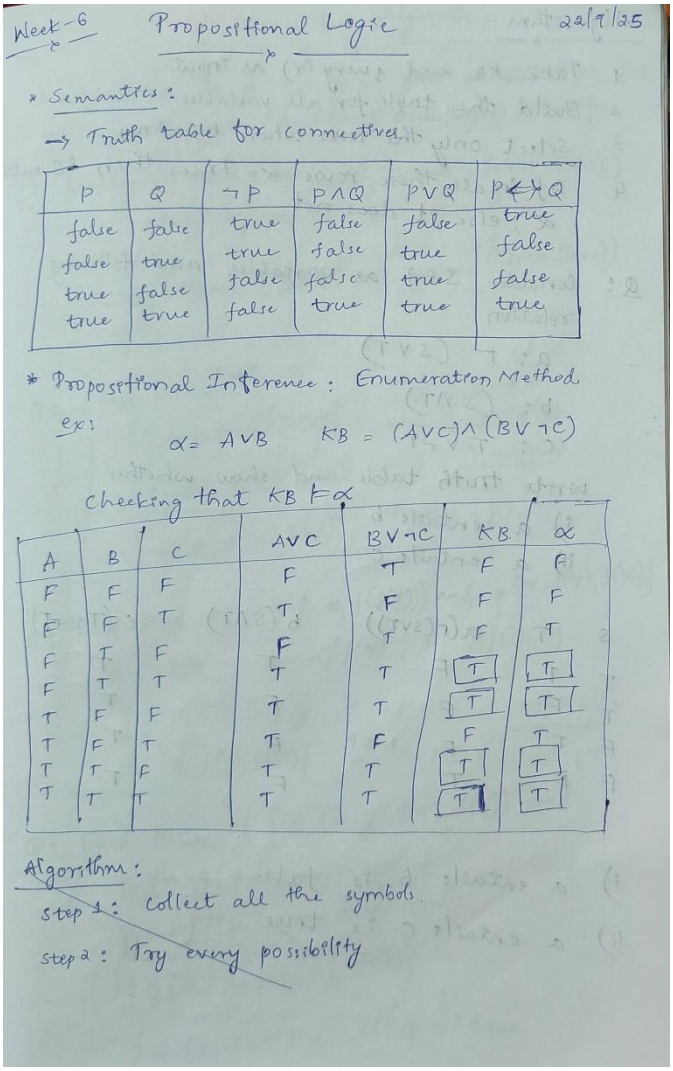
```
            if current_cost < best_cost:
                best, best_cost = current, current_cost

        temperature *= cooling_rate
        if temperature < 1e-6:
            break

    return best, best_cost

# Run simulated annealing for 8 queens
best_state, best_cost = simulated_annealing()

print("The best position found:", best_state)
print("cost =", best_cost)

print("Satish G K - 1BM23CS306")
```

Output:
The best position found: [5, 0, 4, 1, 7, 2, 6, 3]
cost = 0
Satish G K - 1BM23CS306

Program 6

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

Algorithm:



Week-6 Propositional Logic 22/9/25

* Semantics:

→ Truth table for connectives

P	Q	¬P	P∧Q	P∨Q	P⟷Q
false	false	true	false	false	true
false	true	true	false	true	false
true	false	false	false	true	false
true	true	false	true	true	true

* Propositional Inference: Enumeration Method.

ex: $\alpha = A \vee B$ $KB = (A \vee C) \wedge (B \vee \neg C)$

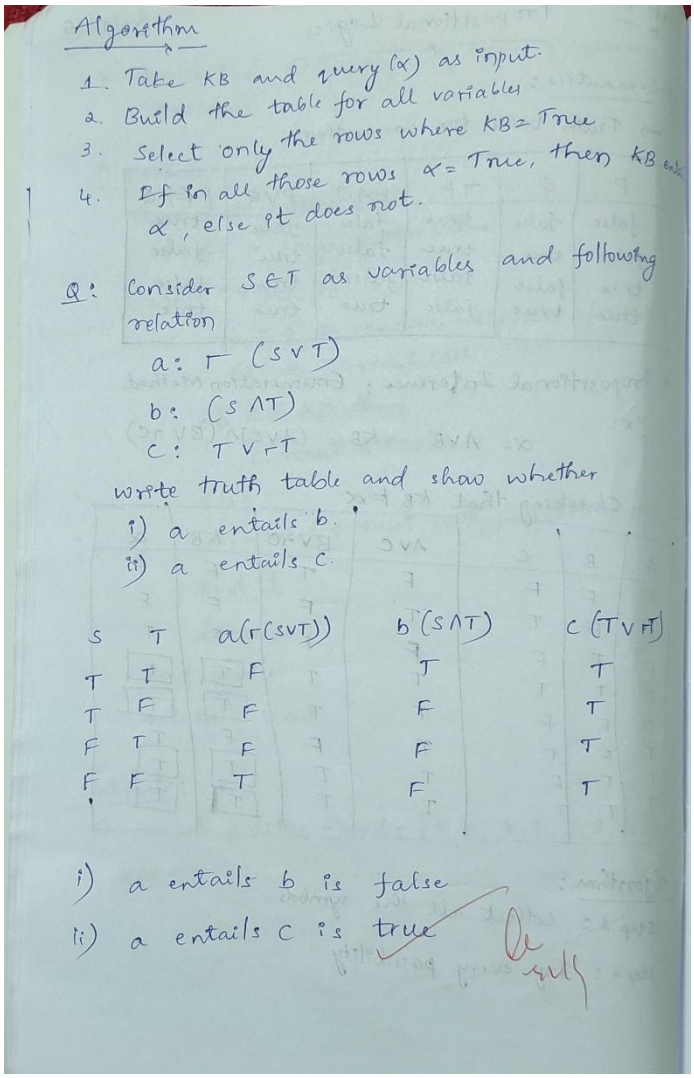
Checking that $KB \models \alpha$

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

Algorithm:

step 1: Collect all the symbols.

step 2: Try every possibility



Algorithm

1. Take KB and query (α) as input.
2. Build the table for all variables
3. Select only the rows where KB = True
4. If in all those rows α = True, then KB entails α, else it does not.

Q: Consider S & T as variables and following relation

a: ¬ (S ∨ T)

b: (S ∧ T)

c: T ∨ ¬T

write truth table and show whether

i) a entails b.

ii) a entails c.

S	T	a(¬(S∨T))	b (S∧T)	c (T∨¬T)
T	T	F	T	T
T	F	F	F	T
F	T	F	F	T
F	F	T	F	T

i) a entails b is false

ii) a entails c is true

Code:

```
 import itertools
import pandas as pd
from tabulate import tabulate
import re

# Helper: convert booleans to T/F
def tf(val):
    return "T" if val else "F"

# Replace logical symbols (V, Λ, ¬) with Python equivalents
def translate(expr: str) -> str:
    return (
        expr.replace("V", " or ")
            .replace("Λ", " and ")
            .replace("¬", " not ")
    )

# === Take KB and α (query) from user ===
kb_expr = input("Enter your Knowledge Base (use Λ, V, ¬): ")
alpha_expr = input("Enter your α (query) (use Λ, V, ¬): ")

# Translate to Python syntax
kb_py = translate(kb_expr)
alpha_py = translate(alpha_expr)

# === Detect variables dynamically (any single letter, uppercase/lowercase)
===
vars_in_expr = sorted(set(re.findall(r"\b[a-zA-Z]\b", kb_expr +
alpha_expr)))

if not vars_in_expr:
    raise ValueError("No variables detected. Please use single letters like
A, b, C...")

# Generate truth table
rows = []
for values in itertools.product([False, True], repeat=len(vars_in_expr)):
    local_vars = dict(zip(vars_in_expr, values))
    kb_val = eval(kb_py, {}, local_vars)
    alpha_val = eval(alpha_py, {}, local_vars)

    row = {var: tf(val) for var, val in local_vars.items()}
    row["KB"] = tf(kb_val)
    row[f"α = {alpha_expr}"] = tf(alpha_val)
    rows.append(row)
```

```
# Convert to DataFrame
df = pd.DataFrame(rows)

# Full truth table
print("\n=== Full Truth Table ===")
print(tabulate(df, headers="keys", tablefmt="fancy_grid", showindex=False))

# Filtered truth table (only KB = T)
filtered_df = df[df["KB"] == "T"]

print("\n=== Rows where KB is True ===")
if not filtered_df.empty:
    print(tabulate(filtered_df, headers="keys", tablefmt="fancy_grid",
showindex=False))
else:
    print("No rows where KB is True (KB is unsatisfiable).")

# Entailment check
query_col = f"α = {alpha_expr}"
entails = all(filtered_df[query_col] == "T") if not filtered_df.empty else
True
print(f"\nDoes KB entail α ({alpha_expr})? ->", "Yes" if entails else "No")
print("Satish G K - 1BM23CS306\n")
```

Output:

```
Enter your Knowledge Base (use ∧, ∨, ¬): (a or c) and (b or not c)
Enter your α (query) (use ∧, ∨, ¬): a or b

=== Full Truth Table ===
```

a	b	c	KB	α = a or b
F	F	F	F	F
F	F	T	F	F
F	T	F	F	T
F	T	T	T	T
T	F	F	T	T
T	F	T	F	T
T	T	F	T	T

T	T	T	T	T

```
=== Rows where KB is True ===
```

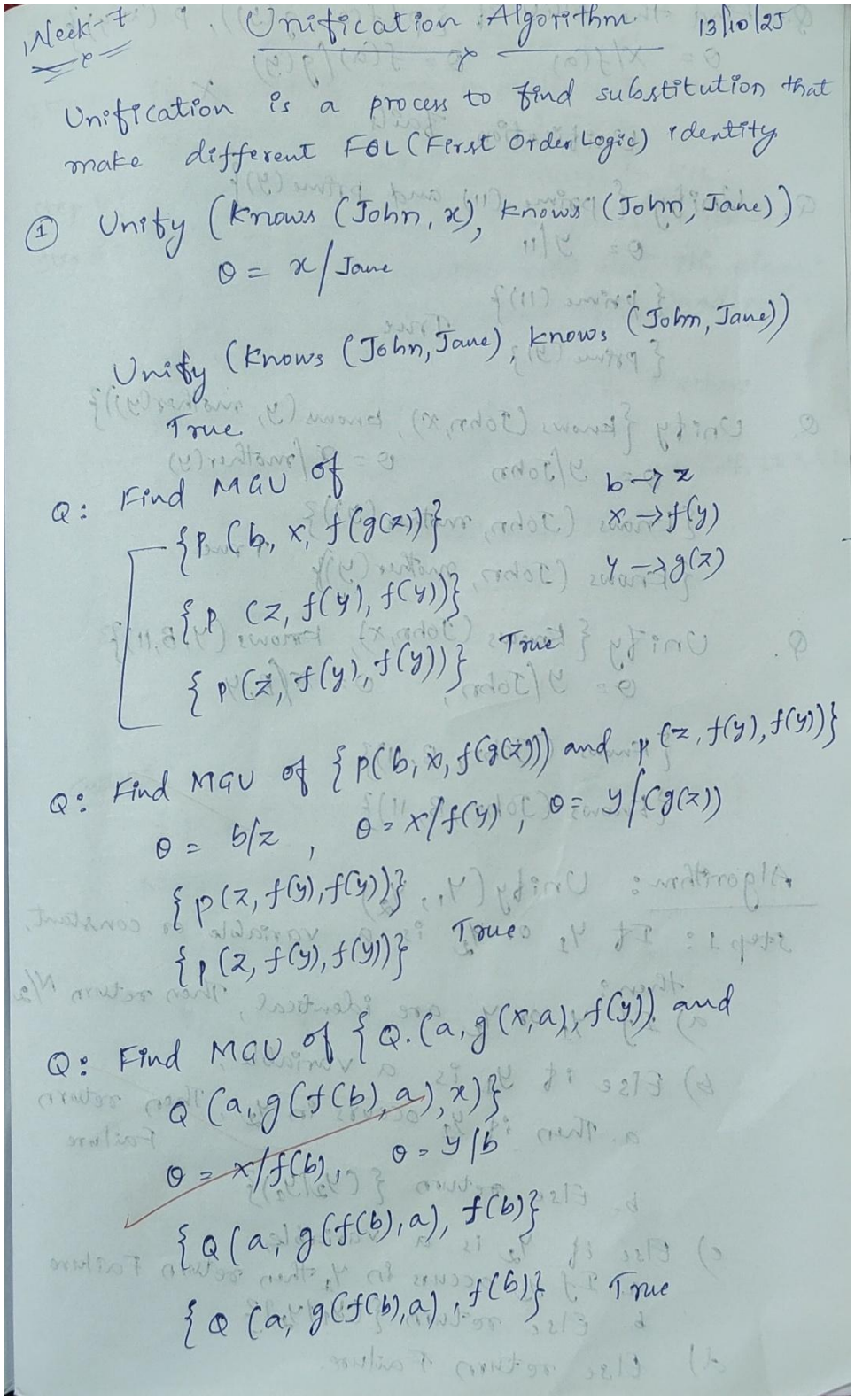
a	b	c	KB	α = a or b
F	T	T	T	T
T	F	F	T	T
T	T	F	T	T
T	T	T	T	T

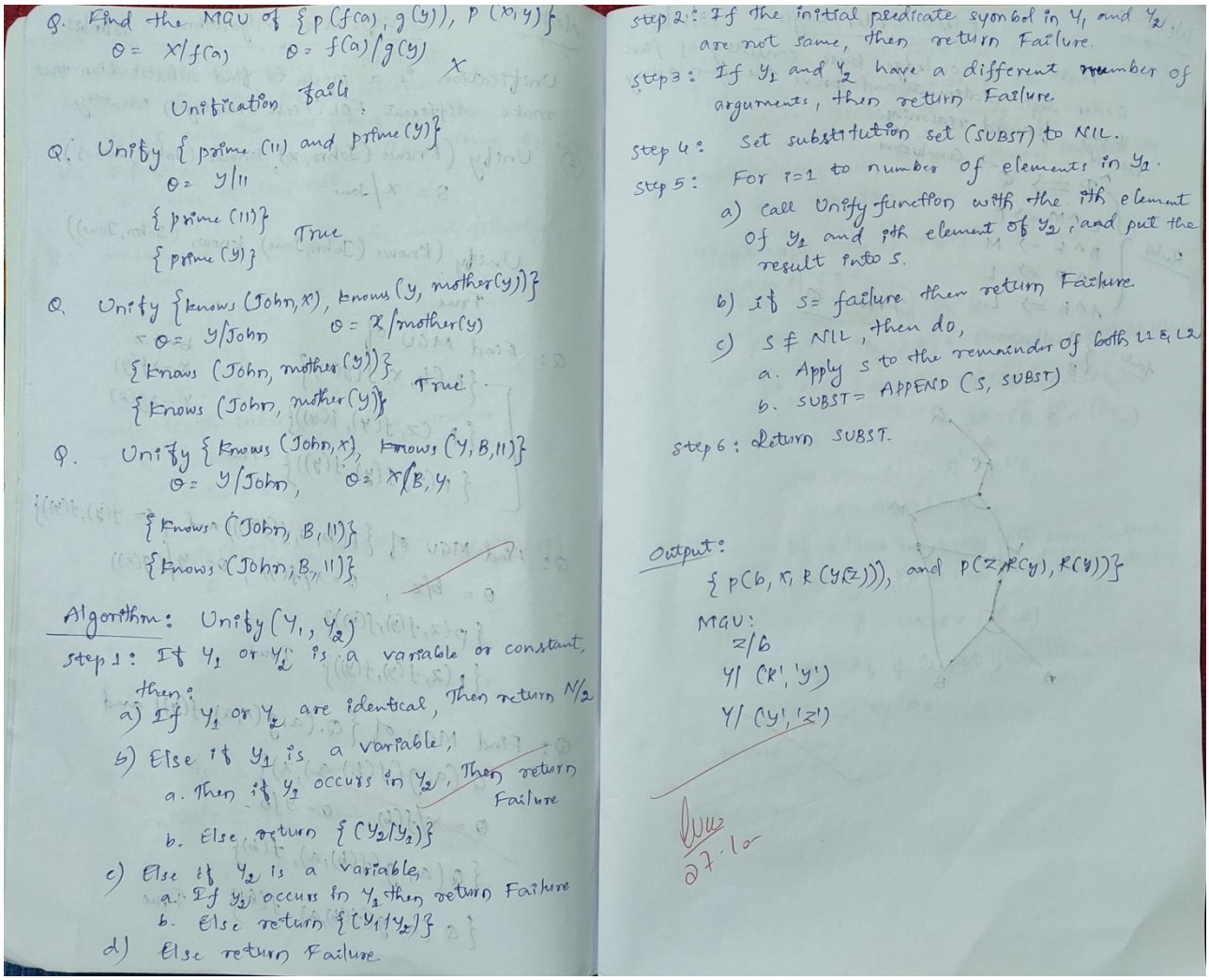
```
Does KB entail α (a or b)? -> Yes
Satish G K - 1BM23CS306
```

Program 7

Implement unification in first order logic

Algorithm:





Code:

```
class UnificationError(Exception):
    pass

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

def unify(term1, term2, substitutions=None):
```

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

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

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

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

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

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

        return substitutions
```

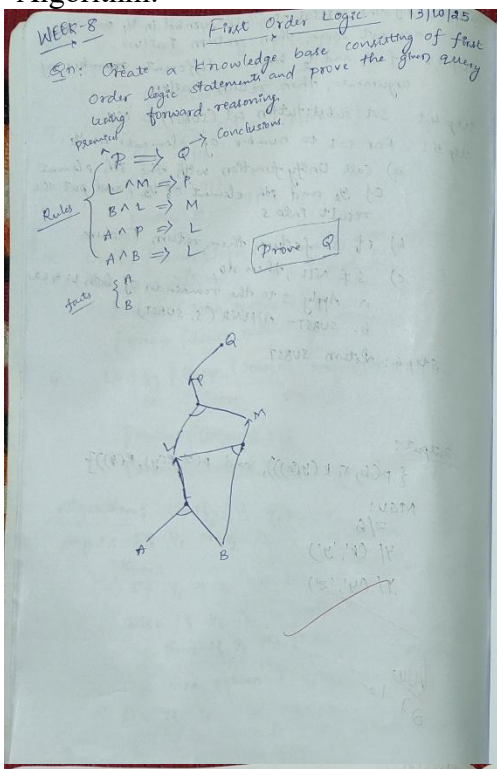
```
    else:
        raise UnificationError(f"Cannot unify: {term1} with {term2}")

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

try:
    # Find the MGU
    result = unify(term1, term2)
    print("Most General Unifier (MGU):")
    print(result)
except UnificationError as e:
    print(f"Unification failed: {e}")
finally:
    print("1BM23CS306 SATISH G K")
```

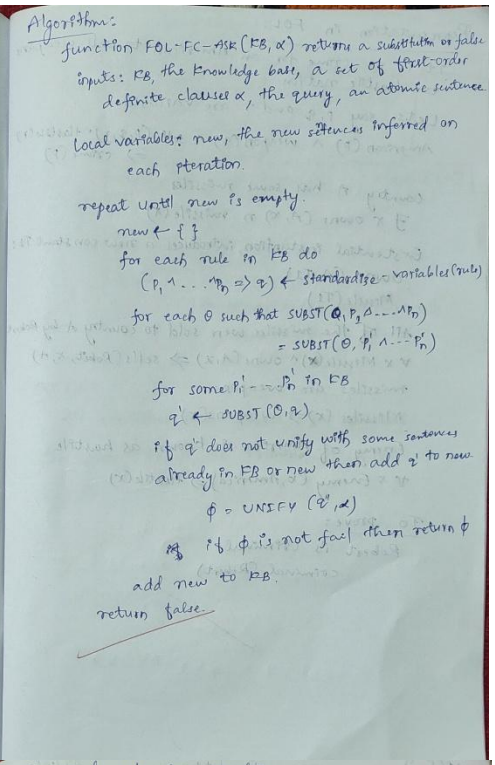
Output:
Most General Unifier (MGU):
{'Z': 'b', 'X': ('f', 'Y'), 'Y': ('g', 'Z')}
1BM23CS306 SATISH G K

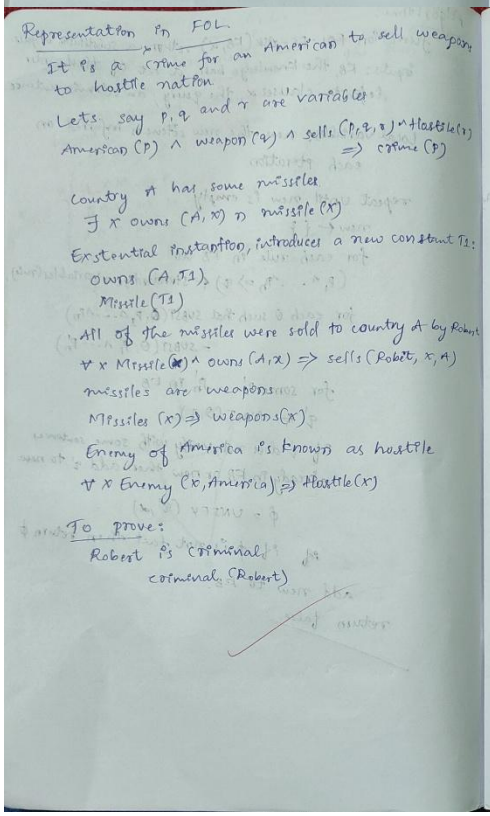
Program 8

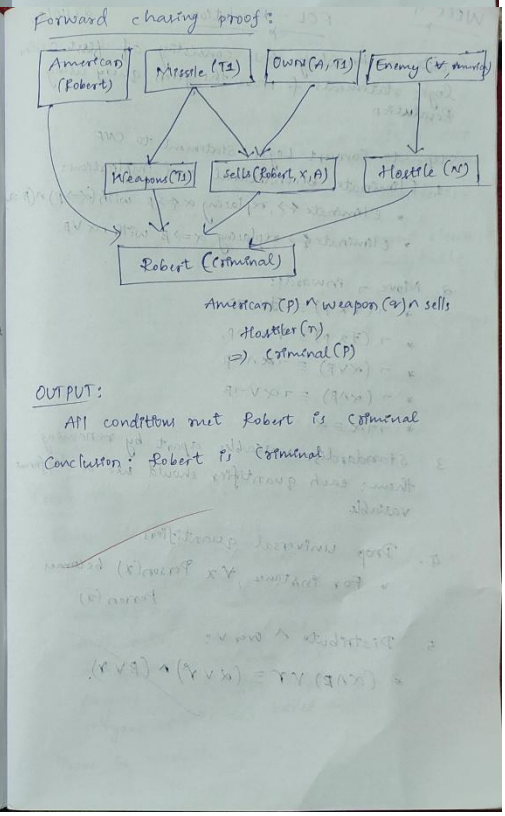
Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning.

Algorithm:









Code:

Code :

```
# Define the knowledge base
facts = {
    'American(Robert)': True,  # Robert is an American
    'Hostile(A)': True,        # Country A is hostile to America
    'Sells_Weapons(Robert, A)': True  # Robert sold weapons to Country A
}

# Define the law/rule: If American(X) and Hostile(Y) and Sells_Weapons(X, Y), then Crime(X)
def forward_reasoning(facts):
    # Apply the rule: If American(X) and Hostile(Y) and Sells_Weapons(X, Y), then Crime(X)
    if facts.get('American(Robert)', False) and facts.get('Hostile(A)', False) and
facts.get('Sells_Weapons(Robert, A)', False):
        facts['Crime(Robert)'] = True  # Robert is a criminal

# Perform forward reasoning to see if we can deduce that Robert is a criminal
forward_reasoning(facts)

# Output the result based on the fact derived
if facts.get('Crime(Robert)', False):
    print("Robert is a criminal.")
    print("Satish G K 1BM23CS306")
else:
    print("Robert is not a criminal.")
```

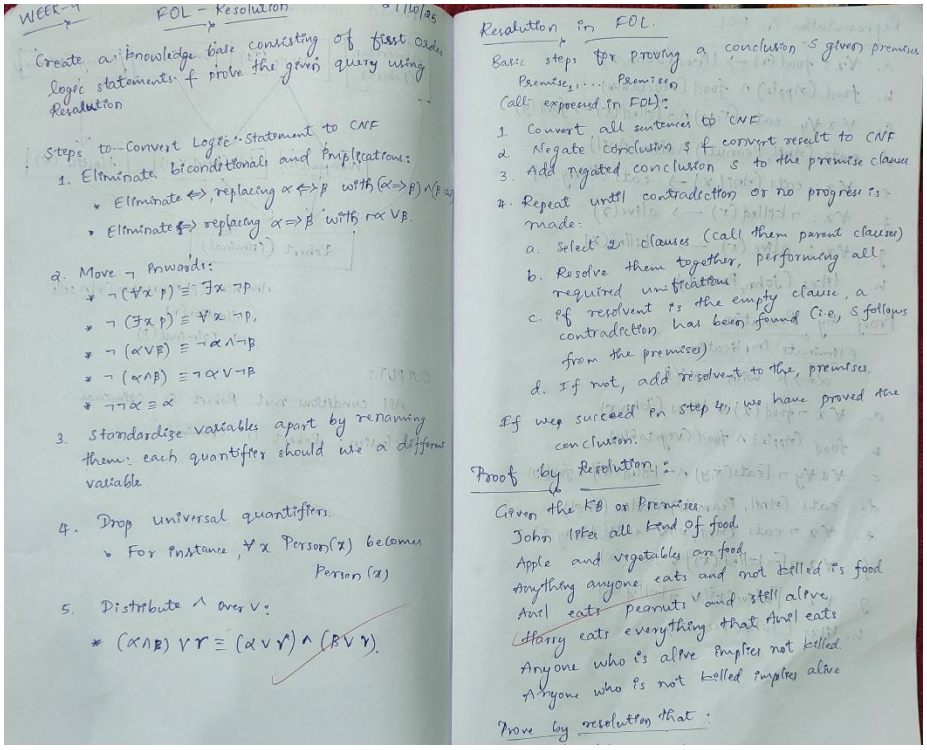
Output:

```
Robert is a criminal.
Satish G K 1BM23CS306
```

Program 9

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

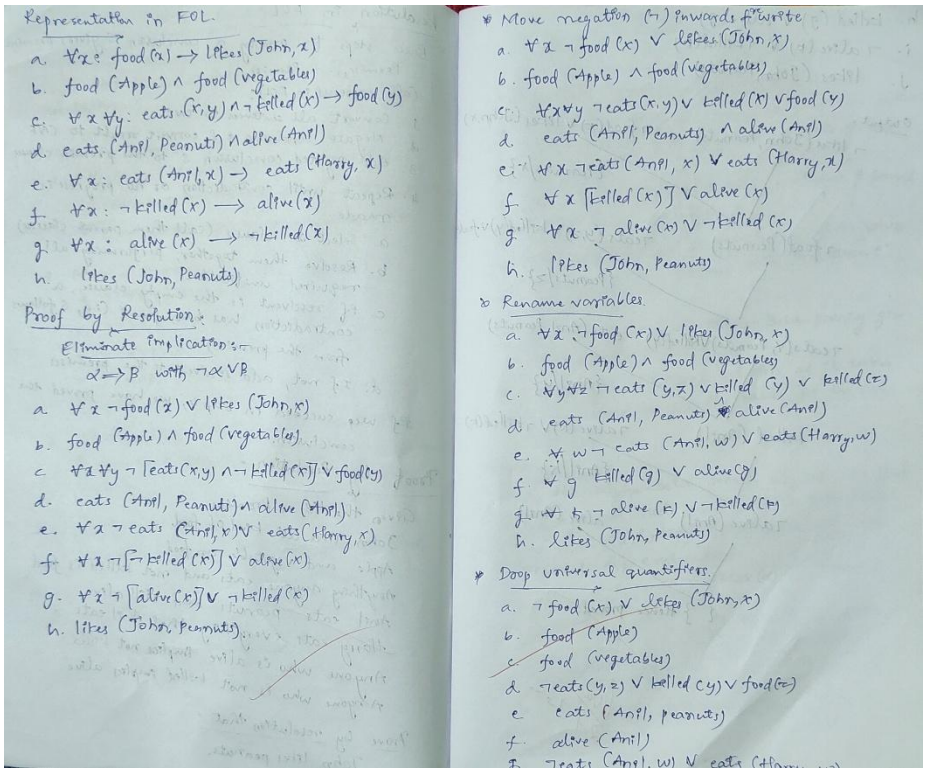
Algorithm:

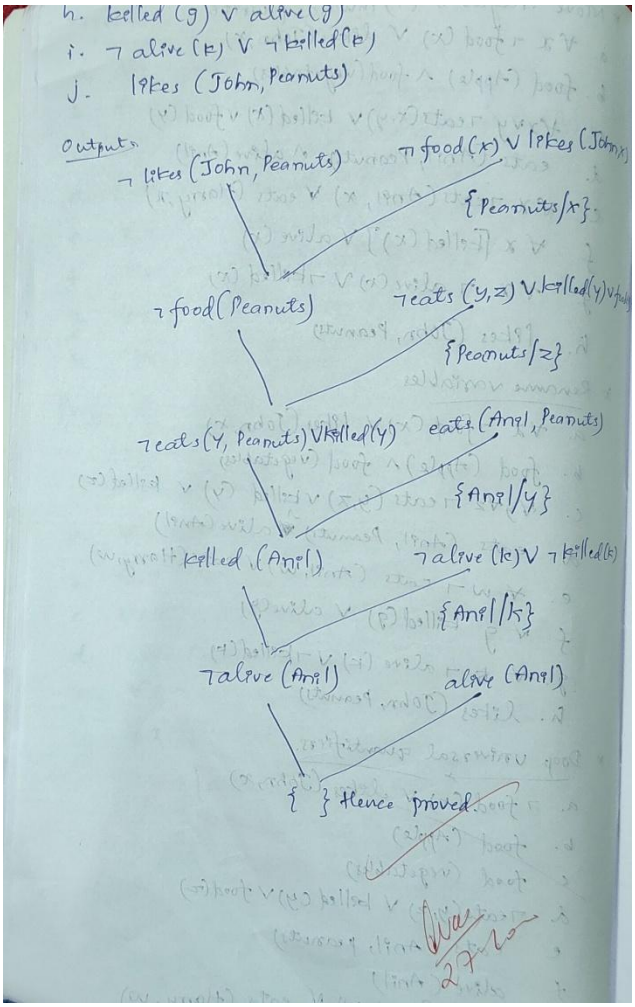


Resolution in FOL.

Basic steps for proving a conclusion S given premises Premise$_1$, ..., Premise$_n$

Code:





Code:

```
import re
import itertools


def remove_implications(expr):
    expr = re.sub(r'\(([^()]*)->([^()]*)\)', r'(¬\1V\2)', expr)
    return expr.replace('->', 'V')

def move_negations(expr):
    expr = expr.replace('¬(¬', '(')
    expr = expr.replace('¬(∀', '∃¬')
    expr = expr.replace('¬(∃', '∀¬')
    expr = expr.replace('¬(A∧B)', '(¬A∨¬B)')
    expr = expr.replace('¬(A∨B)', '(¬A∧¬B)')
    return expr
```

```
def drop_quantifiers(expr):
    return re.sub(r'[∀∃][a-z]\.', '', expr)

def distribute(expr):
    changed = True
    while changed:
        new_expr = re.sub(r'\(([^()]*)∨\(([^()]*)∧([^()]*)\)\)',
                          r'((\1∨\2)∧(\1∨\3))', expr)
        new_expr = re.sub(r'\(\(([^()]*)∧([^()]*)\)∨([^()]*)\)',
                          r'((\1∨\3)∧(\2∨\3))', new_expr)
        changed = new_expr != expr
        expr = new_expr
    return expr

def to_cnf(expr):
    expr = remove_implications(expr)
    expr = move_negations(expr)
    expr = drop_quantifiers(expr)
    expr = distribute(expr)
    return expr


KB = [
    "∀x.(Food(x) -> Likes(John,x))",
    "Food(Apple)",
    "Food(Vegetable)",
    "∀x∀y.((Eats(x,y) ∧ ¬Killed(x)) -> Food(y))",
    "(Eats(Anil,Peanuts) ∧ Alive(Anil))",
    "∀x∀y.(Eats(Anil,y) -> Eats(Harry,y))",
    "∀x.(Alive(x) -> ¬Killed(x))",
    "∀x.(¬Killed(x) -> Alive(x))"
]


goal = "Likes(John,Peanuts)"


print("=== Knowledge Base in CNF ===")
CNF_KB = [to_cnf(s) for s in KB]
for clause in CNF_KB:
    print(clause)


neg_goal = f"¬{goal}"
print("\nNegated Goal (for resolution):", neg_goal)
```

```
clauses = set(CNF_KB + [neg_goal])

def resolution(clauses):
    new = set()
    while True:
        pairs = [(c1, c2) for i, c1 in enumerate(clauses)
                 for c2 in list(clauses)[i + 1:]]
        for (ci, cj) in pairs:
            resolvents = resolve(ci, cj)
            if "" in resolvents:
                return True
            new |= set(resolvents)
        if new.issubset(clauses):
            return False
        clauses |= new

def resolve(ci, cj):
    resolvents = set()
    ci_literals = set(ci.replace("(", "").replace(")", "").split("∧"))
    cj_literals = set(cj.replace("(", "").replace(")", "").split("∧"))
    for di in ci_literals:
        for dj in cj_literals:
            if di.strip() == ("¬" + dj.strip()) or dj.strip() == ("¬" +
di.strip()):
                new_clause = (ci_literals | cj_literals) - {di, dj}
                resolvents.add("∧".join(new_clause))
    return resolvents

proved = resolution(clauses)
print("\nCan we prove that John likes peanuts?")
print("Result:", "YES (derived contradiction ⇒ proved)" if proved else "NO
(cannot prove)")
print("Satish G K 1BM23CS306")
```

Output:

=== Knowledge Base in CNF ===
(Food(x) ∨ Likes(John,x))
Food(Apple)
Food(Vegetable)
∀x((Eats(x,y) ∧ ¬Killed(x)) ∨ Food(y))
(Eats(Anil,Peanuts) ∧ Alive(Anil))
∀x(Eats(Anil,y) ∨ Eats(Harry,y))
(Alive(x) ∨ ¬Killed(x))

(¬Killed(x) ∨ Alive(x))

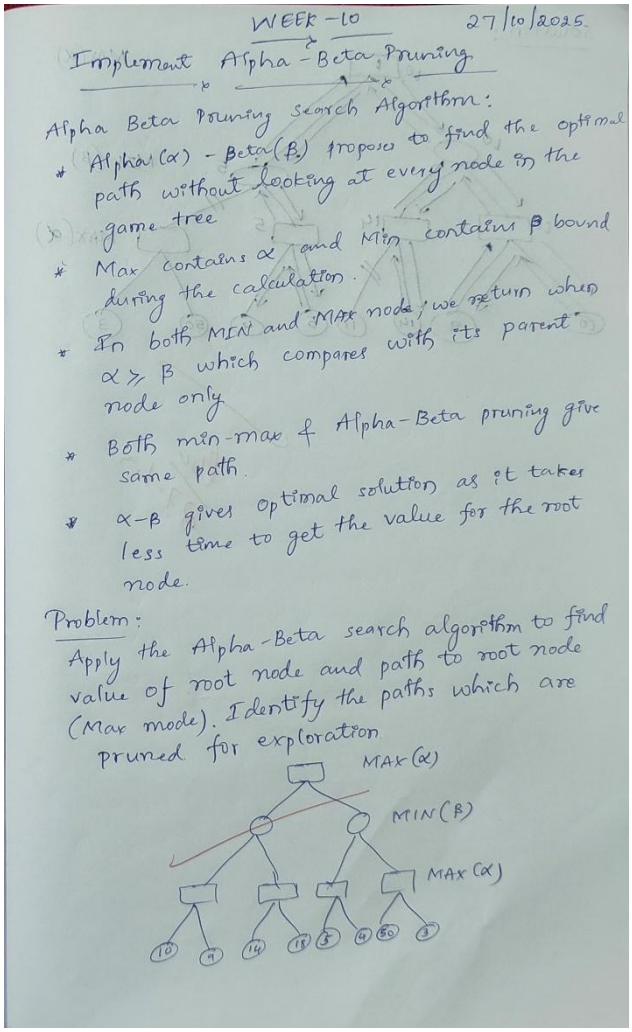
Negated Goal (for resolution): ¬Likes(John,Peanuts)

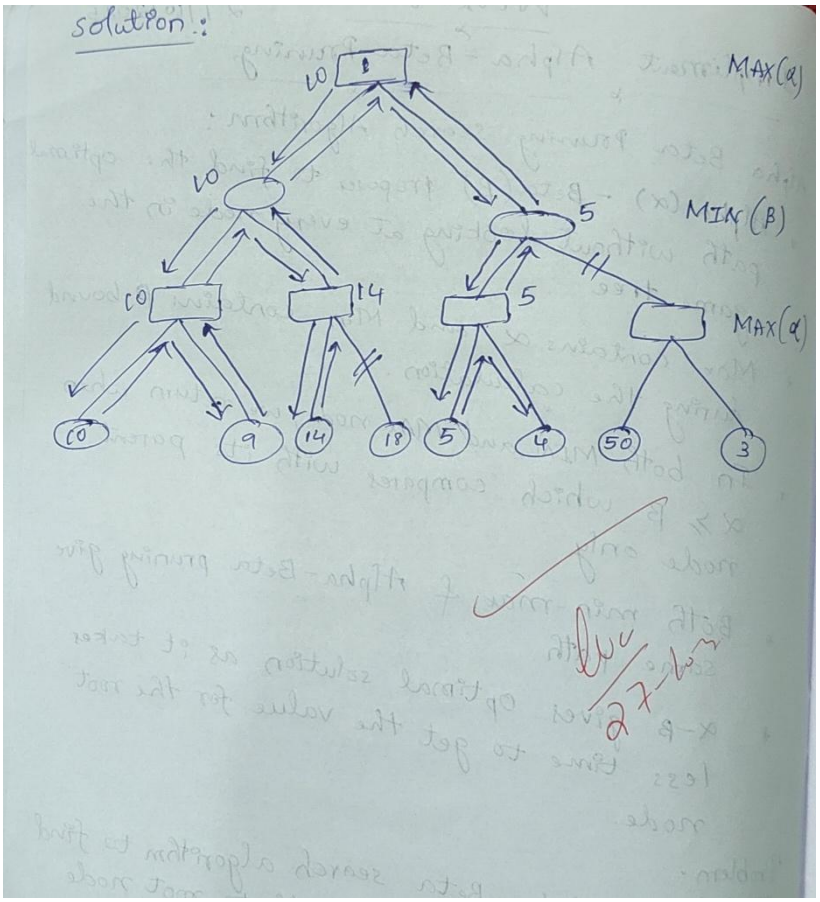
Can we prove that John likes peanuts?
Result: NO (cannot prove)
Satish G K 1BM23CS306

Program 10

Implement Alpha-Beta Pruning.

Algorithm:





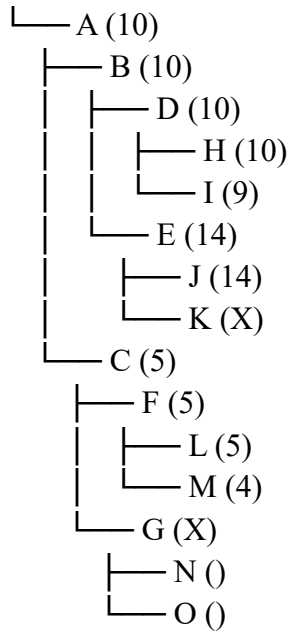
Code :

```
import math

tree = {
    'A': ['B', 'C'],
    'B': ['D', 'E'],
    'C': ['F', 'G'],
    'D': ['H', 'I'],
    'E': ['J', 'K'],
    'F': ['L', 'M'],
    'G': ['N', 'O'],
```

```
    'H': [], 'I': [], 'J': [], 'K': [],
    'L': [], 'M': [], 'N': [], 'O': []
}

# Leaf node values
values = {
    'H': 10, 'I': 9,
    'J': 14, 'K': 18,
    'L': 5, 'M': 4,
    'N': 50, 'O': 3
}

# to store final display values
node_values = {}

def get_children(node):
    return tree.get(node, [])

def is_terminal(node):
    return len(get_children(node)) == 0

def evaluate(node):
    return values[node]

def alpha_beta(node, depth, alpha, beta, maximizing):
    if is_terminal(node) or depth == 0:
        val = evaluate(node)
        node_values[node] = val
        return val

    if maximizing:
        value = -math.inf
        for child in get_children(node):
            val = alpha_beta(child, depth - 1, alpha, beta, False)
            value = max(value, val)
            alpha = max(alpha, val)
            if beta <= alpha:
                # mark remaining children as pruned
                for rem in get_children(node)[get_children(node).index(child)+1:]:
                    node_values[rem] = "X"
                break
```

```
            node_values[node] = value
            return value
        else:
            value = math.inf
            for child in get_children(node):
                val = alpha_beta(child, depth - 1, alpha, beta, True)
                value = min(value, val)
                beta = min(beta, val)
                if beta <= alpha:
                    for rem in get_children(node)[get_children(node).index(child)+1:]:
                        node_values[rem] = "X"
                    break
            node_values[node] = value
            return value

# Run pruning
alpha_beta('A', depth=4, alpha=-math.inf, beta=math.inf, maximizing=True)

def print_tree(node, prefix="", is_last=True):
    connector = " └── " if is_last else " ├── "
    value = node_values.get(node, "")
    print(prefix + connector + f"{node} ({value})")
    children = get_children(node)
    for i, child in enumerate(children):
        new_prefix = prefix + ("    " if is_last else " │  ")
        print_tree(child, new_prefix, i == len(children)-1)

# Display the final tree
print("\nFINAL TREE\n" )
print_tree('A')

print("\n Satish G K - 1BM23CS306")
```

Output:
FINAL TREE



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