VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

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

B.M.S. COLLEGE OF ENGINEERING
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B.M.S. College of Engineering,

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(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 **Shreyash Sinha (1BM22CS273),** 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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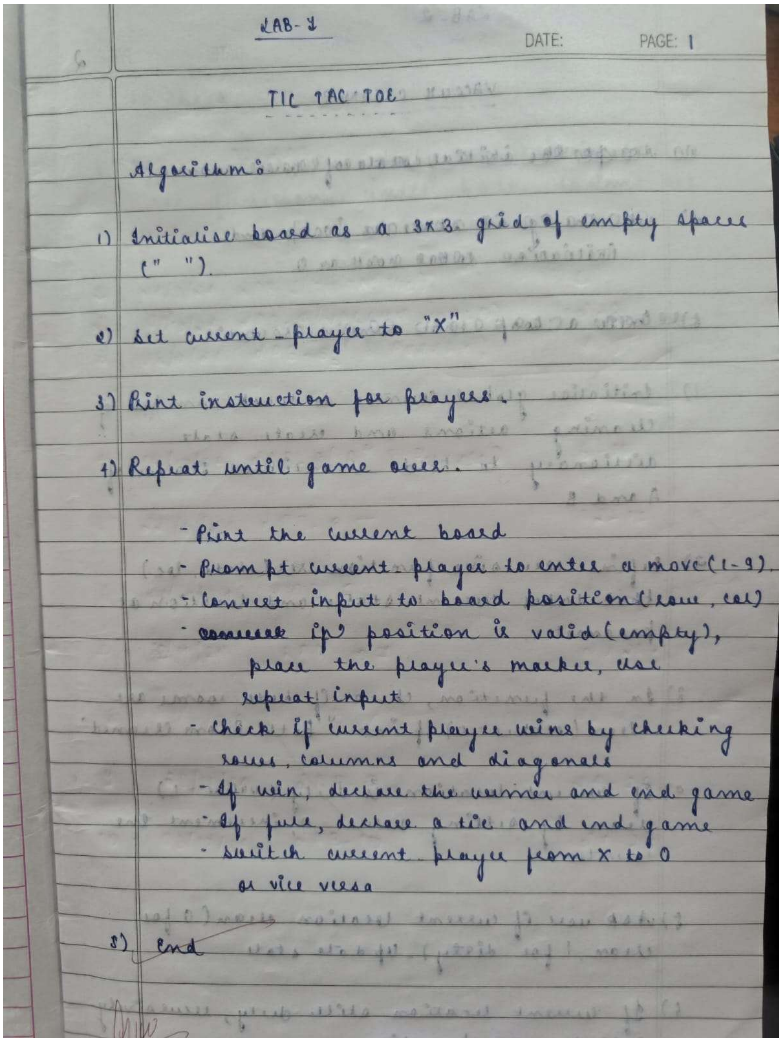
Github Link:https://github.com/shreyashSinha1208/AILab

Program 1
Implement Tic –Tac –Toe Game

Algorithm:



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TIC TAC TOE

Algorithm:

1) Initialise board as a 3x3 grid of empty space (" ").

2) Set current_player to "X"

3) Print instruction for players.

4) Repeat until game over.

- Print the current board
- Prompt current player to enter a move (1-9).
- Convert input to board position (row, col)
- if position is valid (empty), place the player's marker, else repeat input
- Check if current player wins by checking rows, columns and diagonals
- If win, declare the winner and end game
- If full, declare a tie and end game
- Switch current player from X to O or vice versa

5) End

Code:

```
def print_board(board):

    print("\n")

    for row in board:

        print("|".join(row))

        print("-" * 5)
```

```
    print("\n")


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


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


def player_move(board, player):
    while True:
        try:
            move = int(input(f"Player {player}, enter your move (1-9): ")) - 1
            if move < 0 or move >= 9:
                raise ValueError
```

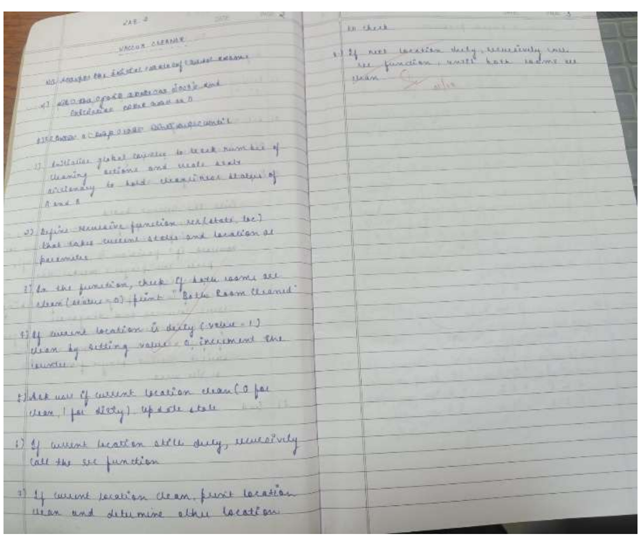
```
            row, col = divmod(move, 3)
            if board[row][col] == ' ':
                board[row][col] = player
                break
            else:
                print("This spot is already taken. Try again.")
        except ValueError:
            print("Invalid input. Enter a number between 1 and 9.")


def play_game():
    board = [[' ' for _ in range(3)] for _ in range(3)]
    current_player = 'X'
    game_over = False
    print("Welcome to Tic Tac Toe!")
    print("Player X goes first.")
    print("Enter a number between 1-9 to make your move (1 is top-left and 9 is bottom-right).")
    print_board(board)
    while not game_over:
        player_move(board, current_player)
        print_board(board)
        if check_winner(board, current_player):
            print(f"Player {current_player} wins!")
            game_over = True
        elif is_board_full(board):
```

```
            print("It's a tie!")

            game_over = True

        else

    current_player = 'O' if current_player == 'X' else 'X'

if __name__ == "__main__":

    play_game()
```

```
Player X, enter your move (1-9):
Invalid input. Enter a number between 1 and 9.
Player X, enter your move (1-9): 6


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


Player O, enter your move (1-9): 7


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


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


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


It's a tie!
```

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


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


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


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


Player X, enter your move (1-9): 7


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


Player X wins!
```

Implement Vaccum Cleaner Agent




```
count = 0
```

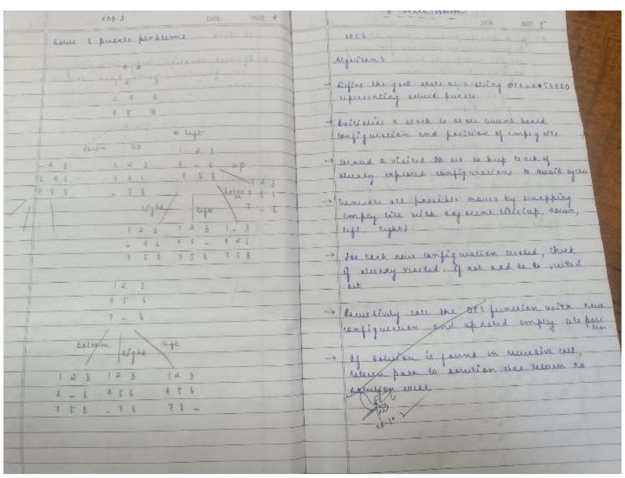
```
def rec(state, loc):
    global count
    if state['A'] == 0 and state['B'] == 0:
        print("Turning vacuum off")
        return

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

```
state = {}

state['A'] = int(input("Enter state of A (0 for clean, 1 for dirty): "))

state['B'] = int(input("Enter state of B (0 for clean, 1 for dirty): "))

loc = input("Enter location (A or B): ")

rec(state, loc)

print("Cost:",count)

print(state)
```

```
Enter state of A (0 for clean, 1 for dirty): 0
Enter state of B (0 for clean, 1 for dirty): 0
Enter location (A or B): A
Turning vacuum off
Cost: 0
{'A': 0, 'B': 0}
```

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)



```
goal_state = [[1, 2, 3],

              [4, 5, 6],

              [7, 8, 0]]
```

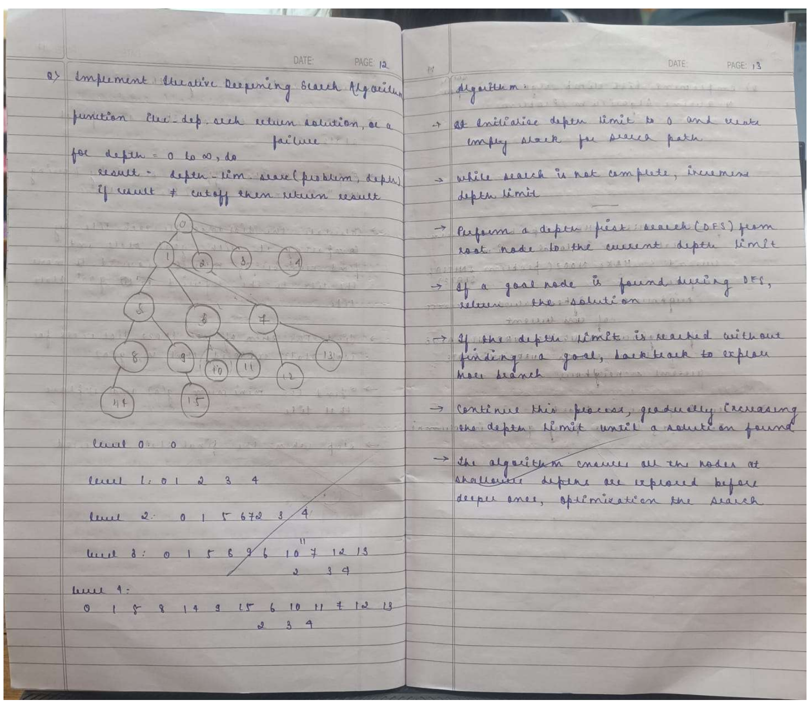
```
def is_goal(state):
    return state == goal_state
def find_blank(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
def swap(state, i1, j1, i2, j2):
    new_state = [row[:] for row in state]
    new_state[i1][j1], new_state[i2][j2] = new_state[i2][j2], new_state[i1][j1]
    return new_state
def get_neighbors(state):
    neighbors = []
    i, j = find_blank(state)
    if i > 0:
        neighbors.append(swap(state, i, j, i - 1, j))
    if i < 2:
        neighbors.append(swap(state, i, j, i + 1, j))
    if j > 0:
        neighbors.append(swap(state, i, j, i, j - 1))
    if j < 2:
        neighbors.append(swap(state, i, j, i, j + 1))
     return neighbors
def dfs(state, visited, path):
```

```
    state_tuple = tuple(tuple(row) for row in state)
    if state_tuple in visited:
        return None
    visited.add(state_tuple)
    if is_goal(state):
        return path
    for neighbor in get_neighbors(state):
        result = dfs(neighbor, visited, path + [neighbor])
        if result is not None:
            return result

    return None


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

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


if solution:
    print("Solution found in", len(solution), "steps:")
    for step in solution:
        for row in step:
```

```
            print(row)
        print()
else:
    print("No solution found.")
```

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

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

Implement Iterative deepening search algorithm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Q) Implement Iterative Deepening Search Algorithm

function iter-dep-srch return solution, or a failure

for depth = 0 to ∞, do
result = depth-lim-searc(problem, depth)
if result ≠ cutoff then return result

level 0: 0

level 1: 0 1 2 3 4

level 2: 0 1 5 6 7 2 3 4

level 3: 0 1 5 8 9 6 10 11 7 12 13 2 3 4

level 4:
0 1 5 8 14 9 15 6 10 11 7 12 13 2 3 4

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Algorithm:

→ Initialise depth limit to 0 and create empty stack for search path

→ while search is not complete, increment depth limit

→ Perform a depth first search (DFS) from root node to the current depth limit

→ If a goal node is found during DFS, return the solution

→ If the depth limit is reached without finding a goal, backtrack to explore more branch

→ Continue this process, gradually increasing the depth limit until a solution found

→ The algorithm ensures all the nodes at shallower depths are explored before deeper ones, optimization the search

```
class PuzzleState:
    def __init__(self, board, moves=0):
        self.board = board
```

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

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

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

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

        return possible_moves

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

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

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

    return None

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

# Example Usage
if __name__ == "__main__":
    initial_board = [2, 8, 3, 1, 6, 4, 7, 0, 5]  # Initial state
```

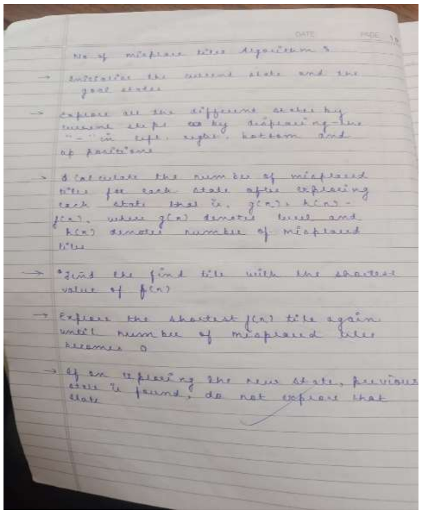
```python
goal_state = [2, 0, 3, 1, 8, 4, 7, 6, 5]  # Final state
initial_state = PuzzleState(initial_board)


solution = iterative_deepening_search(initial_state, goal_state)


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

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

Program 3

Implement A* Search Algorithm

Misplaced Tiles:



No of misplace tiles Algorithm :

→ Initialise the current state and the goal states

→ Explore all the different states by [illegible] steps [illegible] by displacing the "-" in left, right, bottom and up positions

→ Calculate the number of misplaced tiles for each state after exploring each state that is, g(n) + h(n) = f(n), where g(n) denotes level and h(n) denotes number of misplaced tiles

→ Find the final tile with the shortest value of f(n)

→ Explore the shortest f(n) tile again until number of misplaced tiles becomes 0

→ If on exploring the new state, previous state is found, do not explore that state

```
import heapq

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


def findmin(open_list, goal):
    minv = float('inf')
```

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


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

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


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


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

```
        print(' '.join(map(str, row)))
initial_state = [[2, 8, 3], [1, 6, 4], [7, 0, 5]]
goal_state = [[1, 2, 3], [8, 0, 4], [7, 6, 5]]

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

while open_list:
    best_state = findmin(open_list, goal_state)

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

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

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

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

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


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

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

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

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

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

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

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

Goal state reached!

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

Misplaced Tiles:

```
import heapq


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


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


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

    for dx, dy in directions:
        new_x, new_y = x + dx, y + dy
```

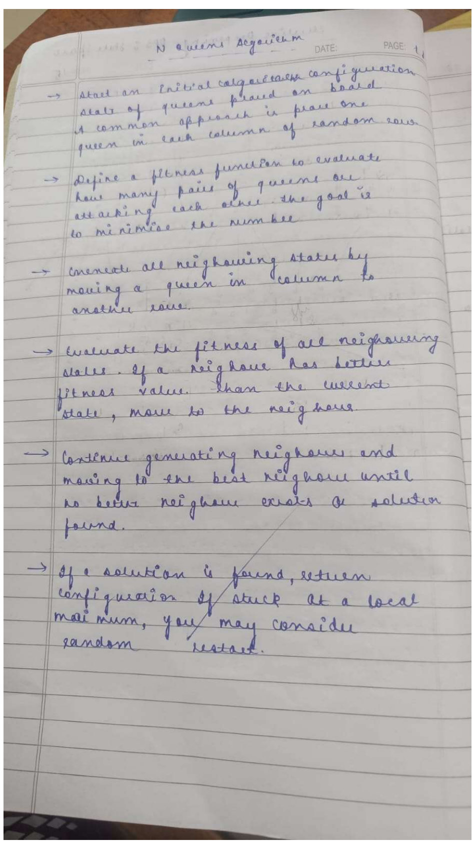
```
        if 0 <= new_x < 3 and 0 <= new_y < 3:
            new_state = [row[:] for row in state]

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


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


def a_star_8_puzzle(start, goal):

    open_list = []

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

    visited = set()

    while open_list:

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

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

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

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

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

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

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

a_star_8_puzzle(start_state, goal_state)
```

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

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

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

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

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

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

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

Goal state reached!
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem.



N Queens Algorithm

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→ Start an initial configuration state of queens placed on board. A common approach is place one queen in each column of random row.

→ Define a fitness function to evaluate how many pairs of queens are attacking each other. The goal is to minimise the number.

→ Generate all neighbouring states by moving a queen in column to another row.

→ Evaluate the fitness of all neighbouring states. If a neighbour has better fitness value than the current state, move to the neighbour.

→ Continue generating neighbours and moving to the best neighbour until no better neighbour exists or solution found.

→ If a solution is found, return configuration. If stuck at a local maximum, you may consider random restart.

```
import random

class NQueens:

    def __init__(self, n):

        self.n = n

        self.board = self.init_board()

    def init_board(self):

        # Randomly place one queen in each column

        return [random.randint(0, self.n - 1) for _ in range(self.n)]



    def fitness(self, board):

        # Count the number of pairs of queens attacking each other

        conflicts = 0

        for col in range(self.n):

            for other_col in range(col + 1, self.n):

                if board[col] == board[other_col] or abs(board[col] - board[other_col]) == abs(col -
other_col):

                    conflicts += 1

        return conflicts

    def get_neighbors(self, board):

        neighbors = []

        for col in range(self.n):

            for row in range(self.n):

                if row != board[col]:  # Move queen to a different row in the same column

                    new_board = board[:]

                    new_board[col] = row
```

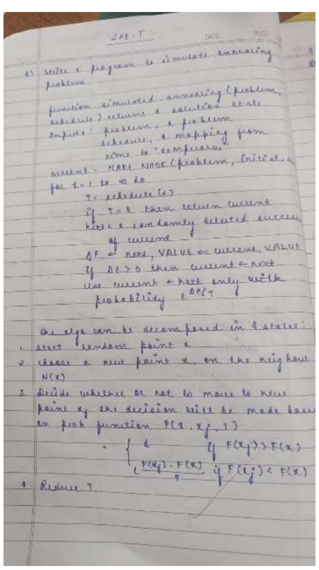
```
            neighbors.append(new_board)
    return neighbors
def hill_climbing(self):
    current_board = self.board
    current_fitness = self.fitness(current_board)

    while current_fitness > 0:
        neighbors = self.get_neighbors(current_board)
        next_board = None
        next_fitness = current_fitness
        for neighbor in neighbors:
            neighbor_fitness = self.fitness(neighbor)
            if neighbor_fitness < next_fitness:
                next_fitness = neighbor_fitness
                next_board = neighbor
        if next_board is None:
            # Stuck at local maximum, can either return or restart
            print("Stuck at local maximum. Restarting...")
            self.board = self.init_board()
            current_board = self.board
            current_fitness = self.fitness(current_board)
        else:
            current_board = next_board
            current_fitness = next_fitness
```

```
        return current_board

# Example usage

if __name__ == "__main__":

    n = 4  # Size of the board (N)

    n_queens_solver = NQueens(n)

    solution = n_queens_solver.hill_climbing()


    print("Solution:")

    for row in solution:

        line = ['Q' if i == row else '.' for i in range(n)]

        print(' '.join(line))
```

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

Program 5

Simulated Annealing to Solve 8-Queens problem.



LAB - 5

Q) Write a program to simulate annealing problem.

function simulated_annealing(problem, schedule) returns a solution state
inputs: problem, a problem
schedule, a mapping from time to "temperature"
current ← MAKE NODE(problem, Initial state)
for t = 1 to ∞ do
T ← schedule(t)
if T = 0 then return current
next ← a randomly selected successor of current
ΔE ← next.VALUE − current.VALUE
if ΔE > 0 then current ← next
else current ← next only with probability $e^{\Delta E/T}$

The algo can be decomposed in 4 states:
1. start random point x
2. choose a new point x_j on the neighbour N(x)
3. Decide whether or not to move to new point x_j; the decision will be made based on prob function P(x, x_j, T)
$= \begin{cases} 1 & \text{if } F(x_j) > F(x) \\ e^{\frac{F(x_j) - F(x)}{T}} & \text{if } F(x_j) < F(x) \end{cases}$
4. Reduce T.

```
import random

import math


def print_board(state):

    size = len(state)

    for i in range(size):

        row = ['.'] * size

        row[state[i]] = 'Q'

        print(' '.join(row))

    print()


def calculate_conflicts(state):

    conflicts = 0

    size = len(state)

    for i in range(size):

        for j in range(i + 1, size):

            if state[i] == state[j] or abs(state[i] - state[j]) == abs(i - j):

                conflicts += 1

    return conflicts


def random_state(size):

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


def neighbor(state):
```

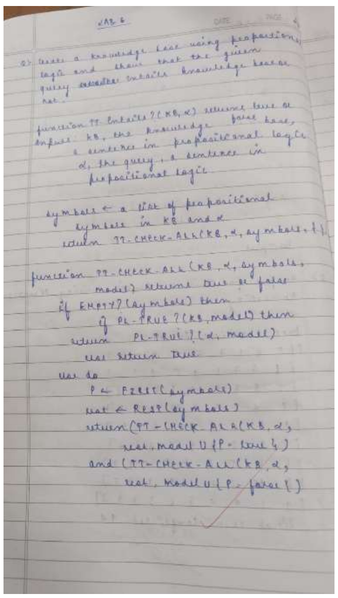
```
    new_state = state[:]
    idx = random.randint(0, len(state) - 1)
    new_state[idx] = random.randint(0, len(state) - 1)
    return new_state


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

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

        # If new state is better, accept it
        if new_conflicts < current_conflicts:
            current_state, current_conflicts = new_state, new_conflicts
        else:
            # Accept with a probability based on temperature
            acceptance_probability = math.exp((current_conflicts - new_conflicts) / temperature)
            if random.random() < acceptance_probability:
                current_state, current_conflicts = new_state, new_conflicts

        temperature *= cooling_rate
```

```
    return current_state


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

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


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

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

Conflicts: 6
```

Program 6

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



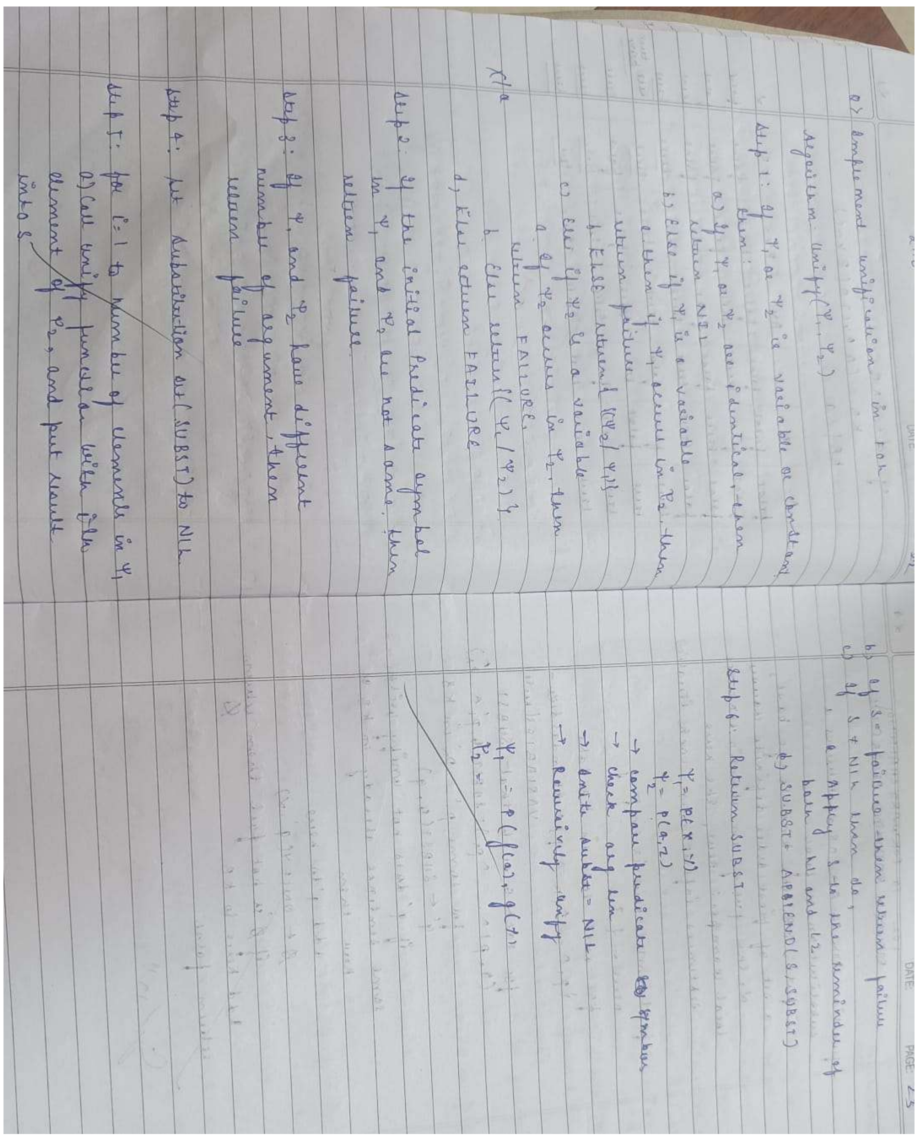

```
def truth_table_entailment():
    print(f"{'A':<7}{'B':<7}{'C':<7}{'A or C':<12}{'B or not C':<15}{'KB':<8}{'alpha':<10}")
    print("-" * 65)
    all_entail = True
    for A in [False, True]:
        for B in [False, True]:
            for C in [False, True]:
                # Calculate individual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

```
            A_or_C = A or C                    # A or C
            B_or_not_C = B or (not C)          # B or not C
            KB = A_or_C and B_or_not_C         # KB = (A or C) and (B or not C)
            alpha = A or B                     # alpha = A or B

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

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

            # Print the results for this row
            print(f"{str(A):<7}{str(B):<7}{str(C):<7}{str(A_or_C):<12}{str(B_or_not_C):<15}{str(KB)
:<8}{str(alpha):<10}")

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

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

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

KB entails alpha for all cases.
```

Program 7

Implement unification in first order logic.



Q) Implement unification in FOL

Algorithm: Unify(Ψ1, Ψ2)

Step 1: If Ψ1 or Ψ2 is variable or constant then:
a) If Ψ1 or Ψ2 are identical, then return NIL
b) Else if Ψ1 is a variable
a. then if Ψ1 occurs in Ψ2, then return failure
b. ELSE return {(Ψ2/ Ψ1)}
c) Else if Ψ2 is a variable
a. If Ψ2 occurs in Ψ1, then return FAILURE.
b. Else return {(Ψ1 / Ψ2)}
d) Else return FAILURE

Step 2: If the initial Predicate symbol in Ψ1 and Ψ2 are not same, then return failure.

Step 3: If Ψ1 and Ψ2 have different number of argument, then return failure

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

Step 5: for i=1 to number of elements in Ψ1
a) Call unify function with ith element of Ψ2, and put result into S
b) If S = failure then return failure
c) If S ≠ NIL then do,
a. Apply S to the reminder of both L1 and L2
b) SUBST = APPEND(S, SUBST)

Step 6: Return SUBST

Ψ1 = P(X, Y)
Ψ2 = P(a, Z)
→ compare predicate symbols
→ check arg len
→ Init subst = NIL
→ Recursively unify

X/a

Ψ1 = P(f(a), g(Y))
Ψ2 =

```
def unify(expr1, expr2, substitution=None):
    """
    Perform unification on two expressions in first-order logic.

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

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

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

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

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

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

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

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

# Case 4: If both are compound expressions (e.g., functions or predicates)
if is_compound(expr1) and is_compound(expr2):
    if expr1[0] != expr2[0] or len(expr1) != len(expr2):
        print(f"Failure: Predicate names or arity mismatch {expr1[0]} != {expr2[0]}")
        return None  # Function names or arity mismatch
    for arg1, arg2 in zip(expr1[1:], expr2[1:]):
        substitution = unify(arg1, arg2, substitution)
        if substitution is None:
            print(f"Failure: Could not unify arguments {arg1} and {arg2}")
            return None
    return substitution
```

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


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

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

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

```
    else:
        substitution[var] = expr
        print(f"Substitution added: {var} -> {expr}")
        return substitution

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

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

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

def is_variable(expr):
    """Checks if the expression is a variable."""
```

```
    return isinstance(expr, str) and expr[0].islower()


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


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


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


    Returns:
        The updated expression with substitutions applied.
    """
    if is_variable(expr) and expr in substitution:
        return apply_substitution(substitution[expr], substitution)
    elif is_compound(expr):
        return [apply_substitution(arg, substitution) for arg in expr]
    return expr


# Example Usage:
```

expr1 = ['P', 'X', 'Y']

expr2 = ['P', 'a', 'Z']

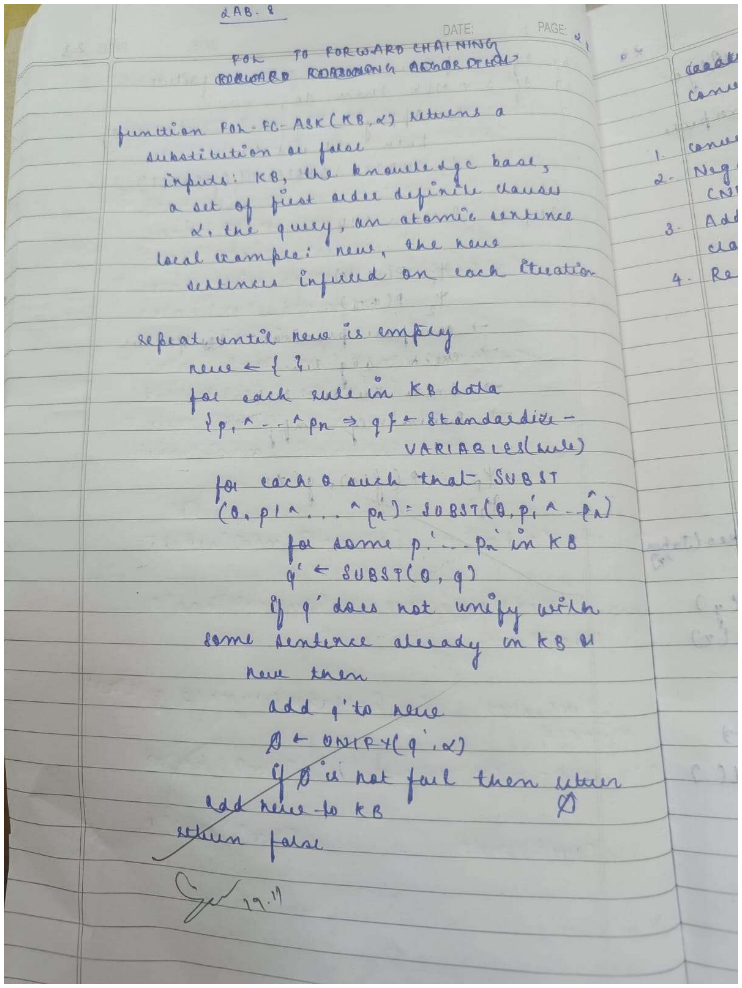
result = unify(expr1, expr2)

print("Unification Result:", result)

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

Program 8

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



LAB. 8

FOL TO FORWARD CHAINING

FORWARD REASONING ALGORITHM

function FOL-FC-ASK(KB, α) returns a substitution or false
inputs: KB, the knowledge base, a set of first order definite clauses
α, the query, an atomic sentence
local examples: new, the new sentences inferred on each iteration

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

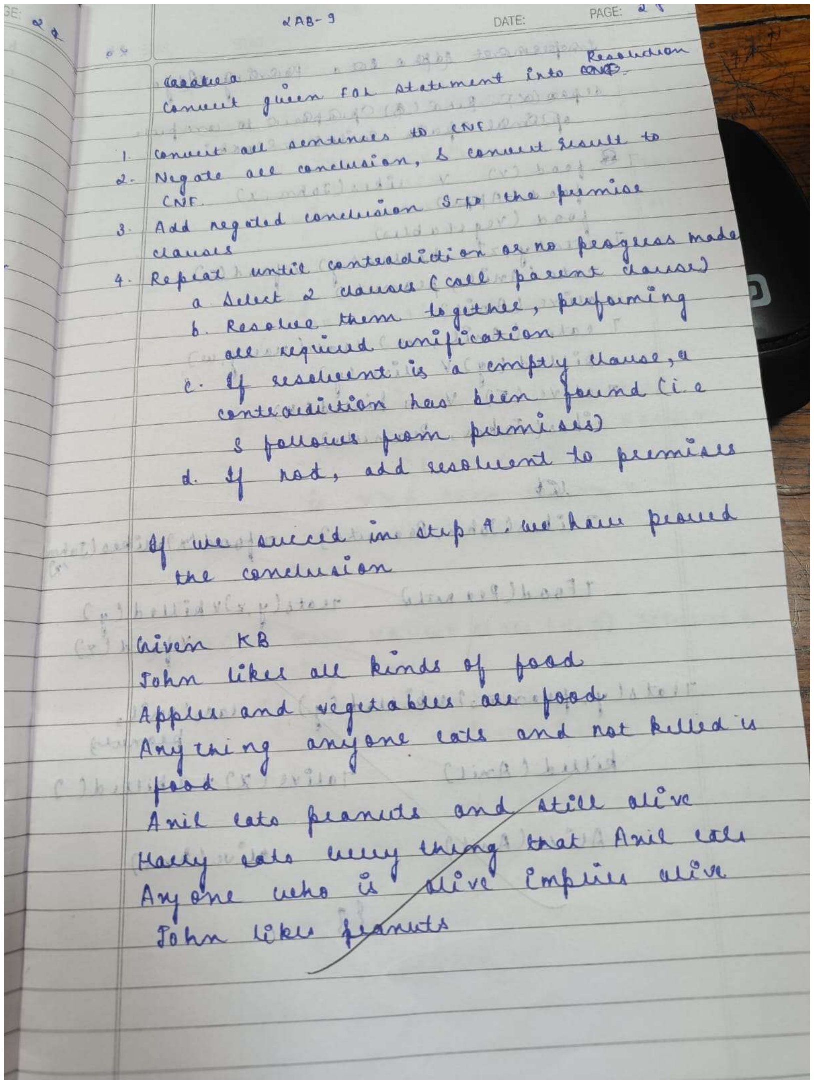
```
class ForwardReasoning:
    def __init__(self, rules, facts):
        self.rules = rules  # List of rules (condition -> result)
        self.facts = set(facts)  # Known facts

    def infer(self):
        applied_rules = True

        while applied_rules:
            applied_rules = False
            for rule in self.rules:
                condition, result = rule
                if condition.issubset(self.facts) and result not in self.facts:
                    self.facts.add(result)
                    applied_rules = True
```

```
            print(f"Applied rule: {condition} -> {result}")
        return self.facts


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

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

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

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

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

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

Program 9

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



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Convert given FOL statement into CNF. Resolution

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

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

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

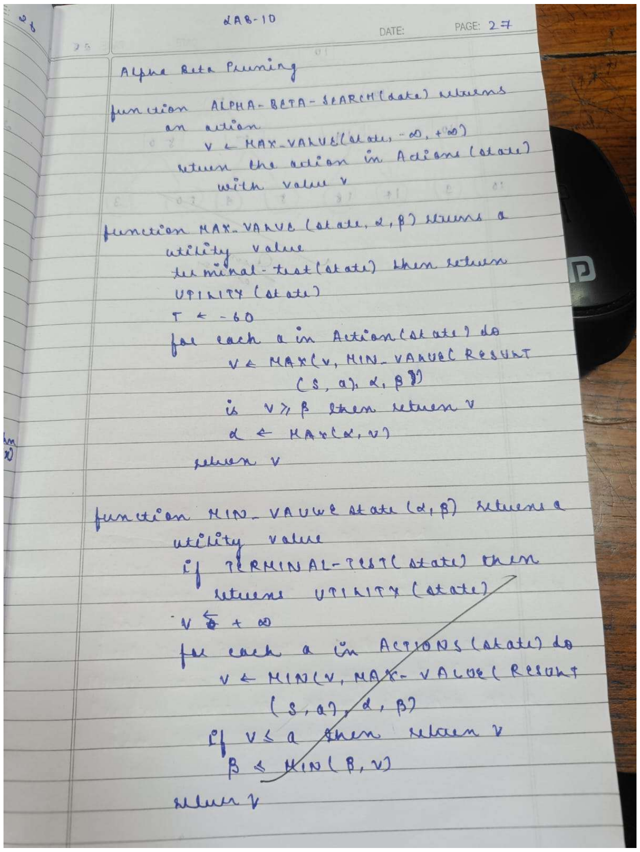
```
# Define the knowledge base (KB) as a set of facts
KB = set()
# Premises based on the provided FOL problem
KB.add('American(Robert)')
KB.add('Enemy(America, A)')
KB.add('Missile(T1)')
KB.add('Owns(A, T1)')
# Define inference rules
def modus_ponens(fact1, fact2, conclusion):
""" Apply modus ponens inference rule: if fact1 and fact2 are true, then conclude conclusion
"""
if fact1 in KB and fact2 in KB:
KB.add(conclusion)
```

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

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

Program 10

Implement Alpha-Beta Pruning.


LAB-10

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Alpha Beta Pruning

function ALPHA-BETA-SEARCH(state) returns
an action
v ← MAX_VALUE(state, -∞, +∞)
return the action in Actions(state)
with value v

function MAX-VALUE (state, α, β) returns a
utility value
terminal-test(state) then return
UTILITY (state)
v ← -∞
for each a in Action(state) do
v ← MAX(v, MIN-VALUE(RESULT
(s, a), α, β))
if v ≥ β then return v
α ← MAX(α, v)
return v

function MIN-VALUE state (α, β) returns a
utility value
if TERMINAL-TEST(state) then
returns UTILITY (state)
v ← +∞
for each a in ACTIONS (state) do
v ← MIN(v, MAX-VALUE(RESULT
(s, a), α, β)
if v ≤ α then return v
β ← MIN(β, v)
return v

```
# Alpha-Beta Pruning Implementation
def alpha_beta_pruning(node, alpha, beta, maximizing_player):
# Base case: If it's a leaf node, return its value (simulating evaluation of the node)
if type(node) is int:
return node
# If not a leaf node, explore the children
if maximizing_player:
max_eval = -float('inf')
for child in node: # Iterate over children of the maximizer node
eval = alpha_beta_pruning(child, alpha, beta, False)
max_eval = max(max_eval, eval)
alpha = max(alpha, eval) # Maximize alpha
if beta <= alpha: # Prune the branch
break
return max_eval
```

```
else:
min_eval = float('inf')
for child in node: # Iterate over children of the minimizer node
eval = alpha_beta_pruning(child, alpha, beta, True)
min_eval = min(min_eval, eval)
beta = min(beta, eval) # Minimize beta
if beta <= alpha: # Prune the branch
1
break
return min_eval
# Function to build the tree from a list of numbers
def build_tree(numbers):
# We need to build a tree with alternating levels of maximizers and minimizers
# Start from the leaf nodes and work up
current_level = [[n] for n in numbers]
while len(current_level) > 1:
next_level = []
for i in range(0, len(current_level), 2):
if i + 1 < len(current_level):
next_level.append(current_level[i] + current_level[i + 1]) # Combine two nodes
else:
next_level.append(current_level[i]) # Odd number of elements, just carry forward
current_level = next_level
return current_level[0] # Return the root node, which is a maximizer
# Main function to run alpha-beta pruning
def main():
# Input: User provides a list of numbers
numbers = list(map(int, input("Enter numbers for the game tree (space-separated): ").split()))
2
# Build the tree with the given numbers
tree = build_tree(numbers)
# Parameters: Tree, initial alpha, beta, and the root node is a maximizing player
alpha = -float('inf')
beta = float('inf')
maximizing_player = True # The root node is a maximizing player
# Perform alpha-beta pruning and get the final result
result = alpha_beta_pruning(tree, alpha, beta, maximizing_player)
```

```
print("Final Result of Alpha-Beta Pruning:", result)
if __name__ == "__main__":
main()
```

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