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
(Autonomous Institution under VTU)
BENGALURU-560019
Aug-2025 to Dec-2025

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 **Aprameya S J (1BM23CS048),** 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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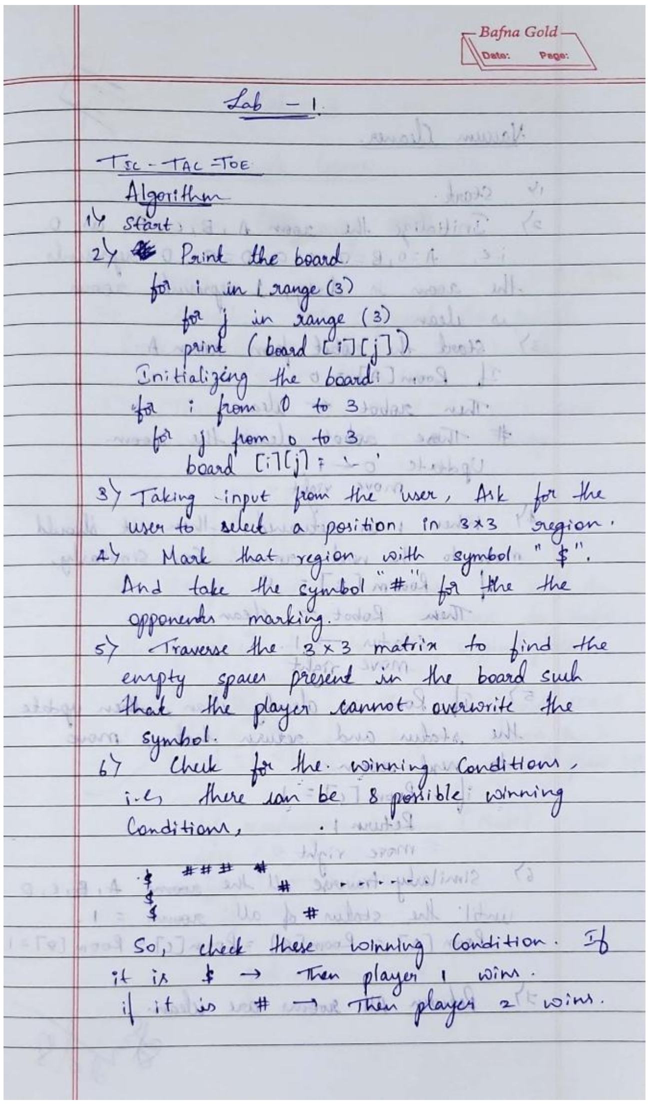
Github Link:

https://github.com/APRAMEYA10/AI-LAB

Program 1

Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

Algorithm for Tic-Tac-Toe:



Lab – 1.

TIC - TAC - TOE

Algorithm

1) Start.

2) Print the board

    for i in range (3)
        for j in range (3)
        print (board [i][j])

   Initializing the board

    for i from 0 to 3
      for j from 0 to 3
        board [i][j] = ' '

3) Taking input from the user, Ask for the user to select a position in 3×3 region.

4) Mark that region with symbol "$". And take the symbol "#" for the the opponents marking.

5) Traverse the 3×3 matrix to find the empty spaces present in the board such that the player cannot overwrite the symbol.

6) Check for the winning conditions, i.e there can be 8 possible winning conditions,

    $ ###   #
    $ #
    $ #

So, check these winning condition. If it is $ → Then player 1 wins.
if it is # → Then player 2 wins.

Code for 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
```

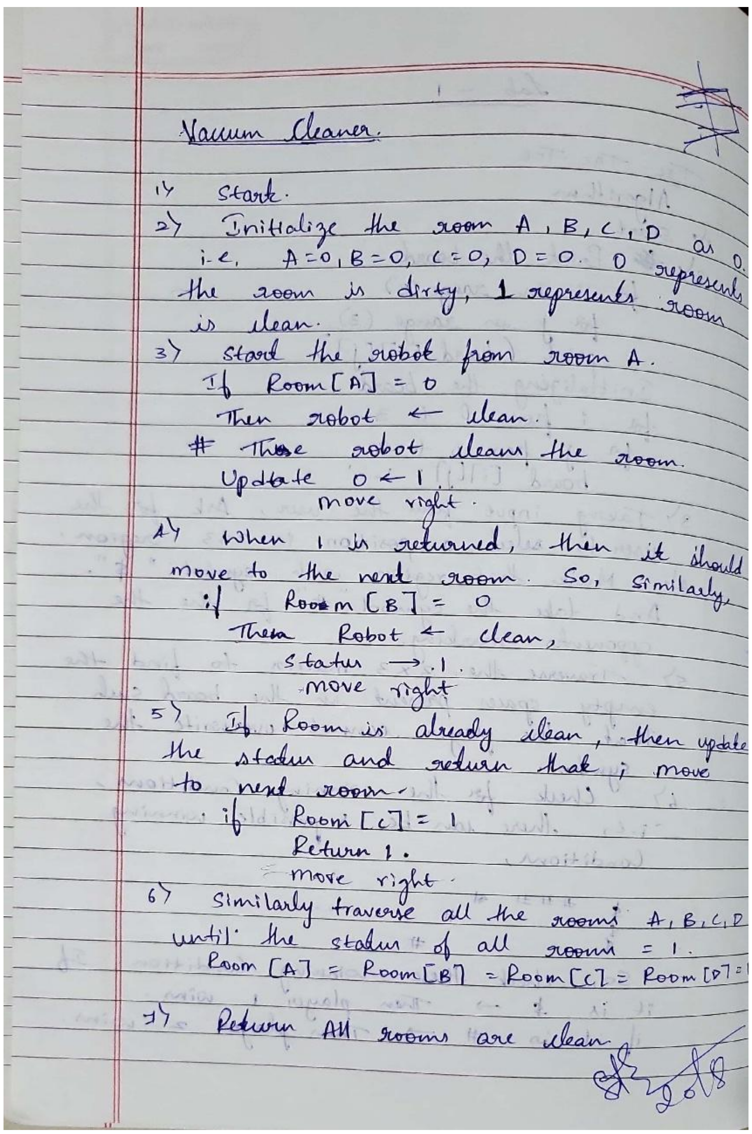
```
def insertLetter(letter, position):
  if (spaceFree(position)):
      board[position] = letter
      printBoard(board)


      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()
```

Algorithm for Vacuum Cleaner Agent:



Vacuum Cleaner.

1) Start.

2) Initialize the room A, B, C, D as 0. i.e, A=0, B=0, C=0, D=0. 0 represents the room is dirty, 1 represents room is clean.

3) Start the robot from room A.
   If Room[A] = 0
   Then robot ← clean.
   # The robot cleans the room.
   Update 0 ← 1
   move right.

4) When 1 is returned, then it should move to the next room. So, similarly,
   if Room [B] = 0
   Then Robot ← clean,
   status → 1.
   move right

5) If Room is already clean, then update the status and return that; move to next room.
   if Room [C] = 1
   Return 1.
   move right.

6) Similarly traverse all the rooms A, B, C, D until the status of all rooms = 1.
   Room [A] = Room[B] = Room[C] = Room [D] = 1

7) Return All rooms are clean.

```
def vacuum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    location_input = input("Enter Location of Vacuum: ")
    status_input = input("Enter status of " + location_input + ": ")
    status_input_complement = input("Enter status of other room: ")

    print("Initial Location Condition: " + str(goal_state))

    if location_input == 'A':

        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")

            goal_state['A'] = '0'
            cost += 1
            print("Cost for CLEANING A: " + str(cost))
            print("Location A has been Cleaned.")

            if status_input_complement == '1':

                print("Location B is Dirty.")
                print("Moving right to Location B.")
```

```
            cost += 1
            print("COST for moving RIGHT: " + str(cost))


            goal_state['B'] = '0'
            cost += 1
            print("COST for SUCK: " + str(cost))
            print("Location B has been Cleaned.")
        else:
            print("Location B is already clean. No action.")
    else:
        print("Location A is already clean.")
        if status_input_complement == '1':
            print("Location B is Dirty.")
            print("Moving right to Location B.")
            cost += 1
            print("COST for moving RIGHT: " + str(cost))


            goal_state['B'] = '0'
            cost += 1
            print("Cost for SUCK: " + str(cost))
            print("Location B has been Cleaned.")
        else:
            print("Location B is already clean. No action.")
```

```
else:
    print("Vacuum is placed in Location B")

    if status_input == '1':
        print("Location B is Dirty.")

        goal_state['B'] = '0'
        cost += 1
        print("COST for CLEANING B: " + str(cost))
        print("Location B has been Cleaned.")

        if status_input_complement == '1':

            print("Location A is Dirty.")
            print("Moving left to Location A.")
            cost += 1
            print("COST for moving LEFT: " + str(cost))

            goal_state['A'] = '0'
            cost += 1
            print("COST for SUCK: " + str(cost))
            print("Location A has been Cleaned.")
        else:
            print("Location A is already clean. No action.")
```

```
        else:
            print("Location B is already clean.")
            if status_input_complement == '1':
                print("Location A is Dirty.")
                print("Moving left to Location A.")
                cost += 1
                print("COST for moving LEFT: " + str(cost))

                goal_state['A'] = '0'
                cost += 1
                print("Cost for SUCK: " + str(cost))
                print("Location A has been Cleaned.")
            else:
                print("Location A is already clean. No action.")



    print("GOAL STATE: ")
    print(goal_state)
    print("Performance Measurement: " + str(cost))



vacuum_world()
```

Program 2 :

Implement 8 puzzle problems using Depth First Search (DFS)

Implement Iterative deepening search algorithm

8 – puzzle usig DFS :

Algorithm :

3/9/25.

Lab - 2.

8 - Puzzle Game.

Algorithm.

1) Start.

2) Initially, we represent the puzzle state using 0, 1, 2, 3, 4, 5, 6, 7, 8. 1-D list.
where 0 ← blank tile.

3) There will be a 3×3 grid and we need to arrange in ordered way.

0	1	2
3	4	5
6	7	8

4) Using Manhattan distance, we need to calculate the minimum distance to shift the displaced tile to it's original place.

i.e,

6	1	2
4	0	5
3	7	8

So, 6 should move 2 places down & 3 should move 1 place up

```
def manhattan_distance (state):
dist = 0
for i ← v (state),
  if v == 0:
    Continue.
  goal_index = v - 1.
```

```
N = 3
class PuzzleState:
    def __init__(self, board, x, y, depth):
        self.board = board
        self.x = x
        self.y = y
        self.depth = depth
row = [0, 0, -1, 1]
col = [-1, 1, 0, 0]
def is_goal_state(board):
    goal = [[1, 2, 3], [4, 5, 6], [7, 8, 0]]
    return board == goal
def is_valid(x, y):
    return 0 <= x < N and 0 <= y < N
def print_board(board):
    for row in board:
        print(' '.join(map(str, row)))
    print("--------")
def solve_puzzle_dfs(start, x, y):
    stack = []
    visited = set()
    stack.append(PuzzleState(start, x, y, 0))
    visited.add(tuple(map(tuple, start)))
```

```
    while stack:
        curr = stack.pop()
        print(f'Depth: {curr.depth}')
        print_board(curr.board)
        if is_goal_state(curr.board):
            print(f'Goal state reached at depth {curr.depth}')
            return
        for i in range(4):
            new_x = curr.x + row[i]
            new_y = curr.y + col[i]
            if is_valid(new_x, new_y):
                new_board = [row[:] for row in curr.board]
                new_board[curr.x][curr.y], new_board[new_x][new_y] = new_board[new_x][new_y], new_board[curr.x][curr.y]
                board_tuple = tuple(map(tuple, new_board))
                if board_tuple not in visited:
                    visited.add(board_tuple)
                    stack.append(PuzzleState(new_board, new_x, new_y, curr.depth + 1))
    print('No solution found (DFS Brute Force reached depth limit)')
if __name__ == '__main__':
    start = [[1, 2, 3], [4, 0, 5], [6, 7, 8]]
    x, y = 1, 1
    print('Initial State:')
    print_board(start)
```

solve_puzzle_dfs(start, x, y)

8-puzzle for IDS :

Pseudocode.

1) Start.

2) Initialize A* function,

```
function A_star (start, goal):
    open_set = priority queue().
    open_set.push(start, priority = heuristics(start))

3) While open_set is non-empty,
        current = open_set.pop().

    if curr = goal:
        return solution_path

4) (g)  for neighbour in neighbour(current):
            tentative_g = g_score [current] + 1.

5) If neighbour not in g_score,

    g_score [neighbour] = tentative_g.
        f = tentative_g + heuristic(neighbour).

    open_set.push(neighbour, priority = f).

    return no solution
```

6) Now arrange all the popped elements in the order way to get solution

```
N = 3
class PuzzleState:
    def __init__(self, board, x, y, depth):
        self.board = board
        self.x = x
        self.y = y
self.depth = depth

row_moves = [0, 0, -1, 1]
col_moves = [-1, 1, 0, 0]
def is_goal_state(board):
    goal = [[1,2,3],[4,5,6],[7,0,8]]
    return board == goal
def is_valid(x, y):
    return 0 <= x < N and 0 <= y < N
def print_board(board):
    for r in board:
        print(' '.join(map(str, r)))
    print("--------")
def dfs_with_depth_limit(start, x, y, depth_limit):
    stack = []
```

```
    visited = set()
    stack.append(PuzzleState(start, x, y, 0))
    visited.add(tuple(map(tuple, start)))
    while stack:
        curr = stack.pop()
        print(f'Depth: {curr.depth}')
        print_board(curr.board)

        if is_goal_state(curr.board):

            print(f'Goal state reached at depth {curr.depth}')
            return True

        if curr.depth == depth_limit:
            continue

        for i in range(4):
            new_x = curr.x + row_moves[i]
            new_y = curr.y + col_moves[i]

            if is_valid(new_x, new_y):
                new_board = [row[:] for row in curr.board]
                    new_board[curr.x][curr.y], new_board[new_x][new_y] = new_board[new_x][new_y],
new_board[curr.x][curr.y]
```

```
                board_tuple = tuple(map(tuple, new_board))
                if board_tuple not in visited:
                    visited.add(board_tuple)
                    stack.append(PuzzleState(new_board, new_x, new_y, curr.depth + 1))
        return False
    def iterative_deepening_search(start, x, y, max_depth=50):
        for depth in range(max_depth):
            print(f"Trying depth limit: {depth}")
            found = dfs_with_depth_limit(start, x, y, depth)
            if found:
          print(f"Solved at depth {depth}!")
return
        print("No solution found within max depth limit.")
    if _name___== '_main_':
        start = [[1, 2, 3], [4, 0, 5], [6, 7, 8]]
        x, y = 1, 1
        print('Initial State:')
        print_board(start)
        iterative_deepening_search(start, x, y)
```

Pseudocode.

1) function IDDFS (root, goal):
   depth = 0.
   found = DLS (root, goal, depth).
   return true.
loop → while true.

2) function DLS (node, goal, limit):
   if node is null,
   return false.

   if node == goal:
   return true

   if limit == 0:
   return false.

3) for each child in children (node)
   if DLS (child, goal, limit-1) == true:
   return true.
   return false

Path → A → C → F → K.

4) max-depth (src){
   if (src == null){
   return 0
   }
   L = max-depth (src.left);
   R = max-depth (src.right).

Problem 3:

Implement A* search algorithm

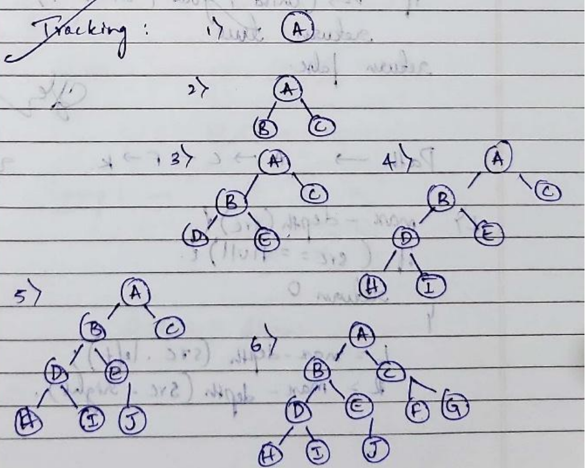
Algorithm:

Algorithm
Consider,
1) bool DLS (src, target, limit):
   if (src == target)
      return true.

2) If not, then in,
   for src ← i:
   if (DLS(i, target, limit))
      return true.
   return false.

3) bool IDDFS(src, target, max_deep).
   for limit 0 to max_depth.
   if DLS (src, target, max-limit).
      ~~return false.~~
   ~~return 1 + max (l, r).~~

Tracking :



Code :

from copy import deepcopy

import heapq

```
GOAL_STATE = [
    [1, 2, 3],
    [4, 5, 6],
    [7, 8, 0]
]
DIRECTIONS = {
    'up': (-1, 0),
    'down': (1, 0),
    'left': (0, -1),
    'right': (0, 1)
}
def print_state(state):
    for row in state:
        print(row)
    print('-' * 10)
def state_to_tuple(state):
    return tuple(tuple(row) for row in state)
def find_zero(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j
def move(state, direction):
```

```
    x, y = find_zero(state)
    dx, dy = DIRECTIONS[direction]
    nx, ny = x + dx, y + dy
    if 0 <= nx < 3 and 0 <= ny < 3:
        new_state = deepcopy(state)
        new_state[x][y], new_state[nx][ny] = new_state[nx][ny], new_state[x][y]
        return new_state
    return None
def manhattan_distance(state):
    distance = 0
    for i in range(3):
        for j in range(3):
            value = state[i][j]
            if value != 0:
                goal_x = (value - 1) // 3
                goal_y = (value - 1) % 3
                distance += abs(i - goal_x) + abs(j - goal_y)
    return distance
def a_star(start_state, goal_state):
    open_list = []
    g_score = {state_to_tuple(start_state): 0}
    f_score = {state_to_tuple(start_state): manhattan_distance(start_state)}
    heapq.heappush(open_list, (f_score[state_to_tuple(start_state)], start_state, []))
    visited = set()
```

```
    iteration = 0
    print("\nStarting A* Search...\n")
    while open_list:
        iteration += 1
        _, current_state, path = heapq.heappop(open_list)
        print(f"Iteration {iteration}:")
        print_state(current_state)
        print(f"g(n): {len(path)}, h(n): {manhattan_distance(current_state)}, f(n): {len(path) + manhattan_distance(current_state)}")
        state_key = state_to_tuple(current_state)
        if state_key in visited:
            continue
        visited.add(state_key)
        if current_state == goal_state:
            print("Goal state reached!\n")
            return path + [current_state]
        for direction in DIRECTIONS.keys():
            new_state = move(current_state, direction)
            if new_state:
                new_key = state_to_tuple(new_state)
                if new_key not in visited:
                    new_g = len(path) + 1
                    new_f = new_g + manhattan_distance(new_state)
                    heapq.heappush(open_list, (new_f, new_state, path + [current_state]))
```

```
    print("No solution found.")
    return None
if __name__ == "__main__":
    print("Enter the initial 3x3 puzzle state (use 0 for the blank):")
    initial_state = []
    for i in range(3):
        row = input(f"Row {i+1} (space-separated): ").strip().split()
        initial_state.append([int(num) for num in row])
    solution_path = a_star(initial_state, GOAL_STATE)

    if solution_path:
        print("Solution Path (step-by-step):")
        for idx, state in enumerate(solution_path):
            print(f"Step {idx}:")
            print_state(state)
        print(f"Puzzle Solved in {len(solution_path) - 1} moves!")
    else:
        print("Could not find a solution.")
```

Problem 4:

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm:

8/10/25.

Hill Climbing Algorithm.

1) Start with a random board i.e, one queen per column, random row.

2) Then we need to compute heuristics. ($h(n)$) i.e, the number of attacking queen.

$f(n) = h(n) + g(n)$.

where: $h(n)$ = attacking queen.

$g(n)$ = number of iterations / steps.

3) find / get best neighbour after generating the neighbours.

calculate attack :
    n = len (board)
    for i from 0 to n
    board [i] == board [j]
        attacks += 1.
    return attack.

4) Evaluate the neighbours value to move to next position.

i.e,
    if h < best_h :
        best_h = h.
        best_board = best_h
    else
        return h.

Code :

```
import random

def calculate_conflicts(state):

    conflicts = 0
```

```
    N = len(state)
    for i in range(N):
        for j in range(i + 1, N):
            if state[i] == state[j]:
                conflicts += 1
            if abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts
def get_neighbors(state):
    neighbors = []
    N = len(state)
    for col in range(N):
        for row in range(N):
            if state[col] != row:
                new_state = state.copy()
                new_state[col] = row
                neighbors.append(new_state)
    return neighbors
def print_board(state):
    N = len(state)
    board = [["." for _ in range(N)] for _ in range(N)]
    for col in range(N):
        board[state[col]][col] = "Q"
    for row in board:
```

```
        print(" ".join(row))
    print()


def hill_climbing_nqueens(N=4):
    current_state = [random.randint(0, N - 1) for _ in range(N)]
    current_cost = calculate_conflicts(current_state)
    print_board(current_state)
    while True:
        if current_cost == 0:
            return current_state
        neighbors = get_neighbors(current_state)
        best_neighbor = min(neighbors, key=calculate_conflicts)
        best_cost = calculate_conflicts(best_neighbor)
        if best_cost >= current_cost:
            return current_state
        else:
            current_state, current_cost = best_neighbor, best_cost
            print_board(current_state)
solution = hill_climbing_nqueens(4)
print("Final Solution:", solution)
print("Conflicts:", calculate_conflicts(solution))
```

Problem 5:

Simulated Annealing to Solve 8-Queens problem

Algorithm:

8/10/2025.

Simulated Annealing.

1) Start.

2) Initialize current_state & initial state.
Check for the temperature T.

Simulated annealing().
current ← initial_state.
T ← a large positive ~~state~~ value.

3) while T > 0
do,
next ← a random neighbour of current.

ΔE ← current_cost − next_cost.

4) if $\Delta E > 0$
current ← next.
else
current ← next with
probability = $p \cdot e^{\Delta E / T}$.

decrease T.

return current.

5) End / terminate.

8/10/25

Code :

```
import random

import math

def random_state(n=8):

    """Generate a random board: list of row positions for each column."""

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

```
def conflicts(state):
    """
    Number of attacking pairs of queens.
    Lower is better. A solution has 0.
    """
    h = 0
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            if state[i] == state[j]:
                h += 1
            if abs(state[i] - state[j]) == abs(i - j):
                h += 1
    return h
def random_neighbor(state):
    """
    Create a neighbor by moving a queen in one random column
    to a random row.
    """
    n = len(state)
    new_state = state.copy()
    col = random.randint(0, n - 1)
    row = random.randint(0, n - 1)

    new_state[col] = row
```

```
    return new_state
def simulated_annealing(max_steps=100000, n=8):
    current = random_state(n)
    current_cost = conflicts(current)
    T = 1.0
    cooling = 0.0001
    for step in range(max_steps):
        if current_cost == 0:
            return current, step
        T = max(T * math.exp(-cooling * step), 0.0001)
        next_state = random_neighbor(current)
        next_cost = conflicts(next_state)
        delta = current_cost - next_cost
        if delta > 0 or random.random() < math.exp(delta / T):
            current = next_state
            current_cost = next_cost
    return None, max_steps
solution, steps = simulated_annealing()
if solution:
    print(f"Solution found in {steps} steps:")
    print("State:", solution)
    print("Conflicts:", conflicts(solution))
else:
    print("No solution found.")
```

Problem 6:

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

Algorithm :

15/10/25.

LAB - 6.

Create a knowledge Base (KB) using propositional logic & show that the given query entails the KB (or) not.

1> Start.

2> We need to convert all sentences in KB to CNF i.e, the normal form.
function TT-Entails? (KB, α) symbols ← (KB, α)
return true / false.

3> Input should be the set of propositional sentences i.e, KB, α, the query & a sentence in propositional logic.

4> Negate the query α and convert ¬α to CNF, add ¬α to the KB.
function TT-Check-All (KB, α, symbols, model)
return true / false
if Empty? (symbols) then,
if PL-True? (KB, model)
return PL-True?(α, model).
else
return true.

5> else do
P ← First (symbols).
rest ← REST (symbols).
return (TT-Check-All (KB, α, rest, model)
P = true.

Code :

```python
import itertools

class Formula:

    def __init__(self, symbols, expr):

        self.symbols = set(symbols)
```

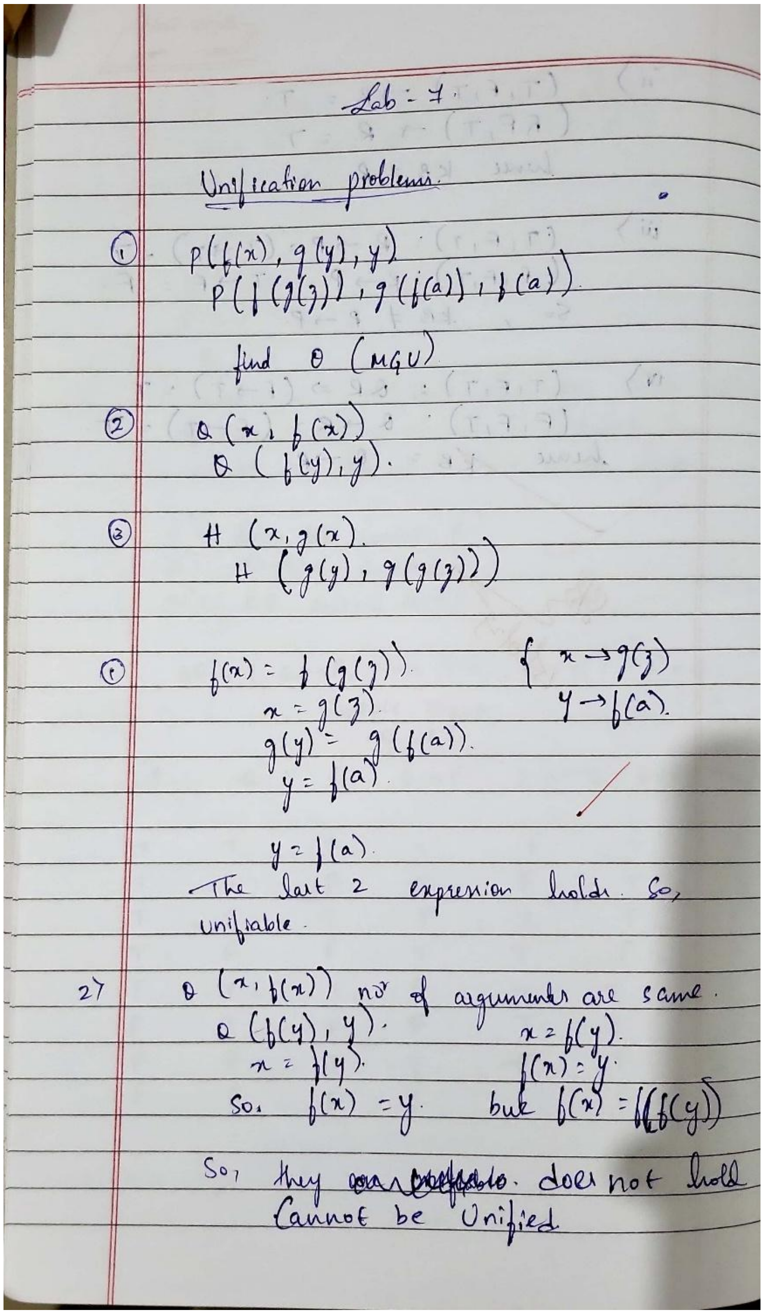
```
        self.expr = expr
    def evaluate(self, model):
        return self.expr(model)
def get_all_symbols(kb, query):
    symbols = set()
    for f in kb + [query]:
        symbols |= f.symbols
    return sorted(symbols)
def entails(kb, query):
    symbols = get_all_symbols(kb, query)
    for values in itertools.product([False, True], repeat=len(symbols)):
        model = dict(zip(symbols, values))
        if all(f.evaluate(model) for f in kb):
            if not query.evaluate(model):
                print("Counterexample found:", model)
                return False
    return True
R_implies_W = Formula({"R", "W"}, lambda m: (not m["R"]) or m["W"])
S_implies_W = Formula({"S", "W"}, lambda m: (not m["S"]) or m["W"])
W_implies_L = Formula({"W", "L"}, lambda m: (not m["W"]) or m["L"])
C_implies_R = Formula({"C", "R"}, lambda m: (not m["C"]) or m["R"])
S_or_C = Formula({"S", "C"}, lambda m: m["S"] or m["C"])
```

```
S_equiv_D = Formula({"S", "D"}, lambda m: m["S"] == m["D"])


Query_L = Formula({"L"}, lambda m: m["L"])



KB = [
    R_implies_W,
    S_implies_W,
    W_implies_L,
    C_implies_R,
    S_or_C,
    S_equiv_D
]
result = entails(KB, Query_L)
print("\nDoes KB entail L (grass is slippery)? →", result)
```

Program 7:

Implement unification in first order logic

Algorithm:



Lab - 7

Unification problems.

① $P(f(x), g(y), y)$
$P(f(g(z)), g(f(a)), f(a))$

find θ (MGU)

② $Q(x, f(x))$
$Q(f(y), y)$.

③ $H(x, g(x))$
$H(g(y), g(g(z)))$

① $f(x) = f(g(z))$
$x = g(z)$
$g(y) = g(f(a))$
$y = f(a)$

$\{ x \to g(z)$
$y \to f(a)$

$y = f(a)$
The last 2 expression holds. So, unifiable.

2) $Q(x, f(x))$ no of arguments are same.
$Q(f(y), y)$.
$x = f(y)$
So, $f(x) = y$.

$x = f(y)$
$f(x) = y$
but $f(x) = f(f(y))$

So, they ~~can~~ does not hold
Cannot be Unified

Code :

```
def occurs_check(var, expr):

    if var == expr:
```

```
    return True
elif isinstance(expr, list):
```

```
        return any(occurs_check(var, subexpr) for subexpr in expr)
    return False



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

    if isinstance(x, str) and x.islower():
        if x in subst:
            return unify(subst[x], y, subst)
        elif occurs_check(x, y):
            return None
        else:
            subst[x] = y
            return subst

    elif isinstance(y, str) and y.islower():
        if y in subst:
            return unify(x, subst[y], subst)
        elif occurs_check(y, x):
            return None
        else:
            subst[y] = x
```

```
            return subst

    elif x == y:
        return subst

    elif isinstance(x, list) and isinstance(y, list):
        if len(x) != len(y):
            return None
        for xi, yi in zip(x, y):
            subst = unify(xi, yi, subst)
            if subst is None:
                return None
        return subst

    else:
        return None



expr1 = ["Knows", "John", "x"]
expr2 = ["Knows", "y", "Mary"]

print("Expression 1:", expr1)
print("Expression 2:", expr2)
```

```
result = unify(expr1, expr2)

if result:

    for k, v in result.items():

        print(f"{k} / {v}")

else:

    print("Unification failed.")
```

Program 8:

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

Code :

```
from copy import deepcopy
def occurs_check(var, expr):
    if var == expr:
        return True
```

```
    elif isinstance(expr, list):
        return any(occurs_check(var, subexpr) for subexpr in expr)
    return False


def substitute(expr, subst):
    if isinstance(expr, str):
        return subst.get(expr, expr)
    elif isinstance(expr, list):
        return [substitute(e, subst) for e in expr]
    return expr
def unify(x, y, subst=None):
    if subst is None:
        subst = {}
    if subst is None:
        return None
    if x == y:
        return subst
    elif isinstance(x, str) and x.islower():
        if x in subst:
            return unify(subst[x], y, subst)
        elif occurs_check(x, y):
            return None
        else:
            subst[x] = y
            return subst
    elif isinstance(y, str) and y.islower():
```

```
        return unify(y, x, subst)
    elif isinstance(x, list) and isinstance(y, list) and len(x) == len(y):
        for a, b in zip(x, y):
            subst = unify(a, b, subst)
            if subst is None:
                return None
        return subst
    else:
        return None

def parse_sentence(sentence):
    """Parse sentence like 'Parent(John, x)' → ['Parent', 'John', 'x']"""
    sentence = sentence.strip()
    if '(' in sentence and ')' in sentence:
        pred = sentence[:sentence.index('(')]
        args = sentence[sentence.index('(') + 1:sentence.index(')')].split(',')
        args = [a.strip() for a in args]
        return [pred] + args
    else:
        return [sentence]

def to_string(expr):
    if len(expr) == 1:
        return expr[0]
    else:
        return f"{expr[0]}({', '.join(expr[1:])})"
```

```
def fol_fc_ask(KB, query):
    print("FORWARD CHAINING START ")
    print("Initial Knowledge Base:")
    for fact in KB:
        print("   ", fact)
    print("Query:", query)



    iteration = 0
    new = set()

    while True:
        iteration += 1
        print(f"\n--- Iteration {iteration} ---")
        n_new = set()

        for rule in KB.copy():
            if "=>" in rule:
                premise, conclusion = rule.split("=>")
                premise = premise.strip()
                conclusion = conclusion.strip()
                premises = [p.strip() for p in premise.split("^")]

                print(f"\nChecking rule:  {rule}")

                substitutions = []
```

```
        for fact in KB:
            if "=>" not in fact:
                for p in premises:
                    s = unify(parse_sentence(p), parse_sentence(fact))
                    if s is not None:
                        print(f"  Premise '{p}' unified with fact '{fact}' using {s}")
                        substitutions.append(s)



        for s in substitutions:
            new_fact = to_string(substitute(parse_sentence(conclusion), s))
            if new_fact not in KB and new_fact not in n_new:
                print(f"  => New fact inferred: {new_fact}")
                n_new.add(new_fact)
                phi = unify(parse_sentence(new_fact), parse_sentence(query))
                if phi is not None:
                    print("\n Query proved!")
                    print(f"Substitution set: {phi}")
                    return phi

    if not n_new:
        print("\nNo new inferences. Forward chaining ends.")
        print("Query cannot be proved.")
        return False
```

```
        print("\nNewly inferred facts this iteration:")
        for fact in n_new:
            print("    ", fact)

        KB |= n_new
        print("\nUpdated Knowledge Base:")
        for fact in KB:
            print("    ", fact)

KB = {
    "Parent(John, Mary)",
    "Parent(Mary, Alice)",
    "Parent(x, y) ^ Parent(y, z) => Grandparent(x, z)"
}

query = "Grandparent(John, Alice)"

result = fol_fc_ask(deepcopy(KB), query)
```

Program 9:

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

Algorithm :

12/11/25

First Order Logic.

Resolution is a theorem proving technique that proceeds by building refutation proofs i.e, by contradiction

1. Eliminate biconditional and implication:
   i.e, replacing $(\alpha \to \beta) \wedge (\beta \to \alpha) = \alpha \Leftrightarrow \beta$
   Eliminate $\to$, replacing $\alpha \to \beta$ with $\neg\alpha \vee \beta$.

2. Move $\neg$ inwards:
   i.e, $\neg(\forall x\, p) \equiv \exists x\, \neg p$,
   $\neg(\exists x\, p) \equiv \forall x\, \neg p$;
   $\neg(\alpha \vee \beta) \equiv \neg\alpha \wedge \neg\beta$,
   $\neg(\alpha \wedge \beta) \equiv \neg\alpha \vee \neg\beta$,
   $\neg\neg\alpha \equiv \alpha$.

3. Standardize variables apart by renaming them i.e, each quantifier should use a different variable.

4. Skolemize each existential variable is replaced by a skolem constant (or) skolem constant/function of the enclosing universally quantified variables.

5. Drop Universal quantifiers.

6. Distribute $\wedge$ over $\vee$:
   $(\alpha \wedge \beta) \vee \gamma \equiv (\alpha \vee \gamma) \wedge (\beta \vee \gamma)$

Code :

```
import copy

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

```python
def unify(x, y, theta=None):
    if theta is None:
        theta = {}
    if theta == "FAIL":
        return "FAIL"
    elif x == y:
        return theta
    elif is_variable(x):
        return unify_var(x, y, theta)
    elif is_variable(y):
        return unify_var(y, x, theta)
    elif isinstance(x, list) and isinstance(y, list) and len(x) == len(y):
        return unify(x[1:], y[1:], unify(x[0], y[0], theta))
    else:
        return "FAIL"


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:
        if occurs_check(var, x, theta):
            return "FAIL"
        theta_copy = theta.copy()
```

```
        theta_copy[var] = x
        return theta_copy


def occurs_check(var, x, theta):
    if var == x:
        return True
    elif isinstance(x, list):
        return any(occurs_check(var, arg, theta) for arg in x)
    elif isinstance(x, str) and x in theta:
        return occurs_check(var, theta[x], theta)
    return False



def substitute(theta, clause):
    new_clause = []
    for pred in clause:
        name = pred[0]
        args = pred[1]
        new_args = [(theta[arg] if arg in theta else arg) for arg in args]
        new_clause.append([name, new_args])
    return new_clause



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

```
    for pi in ci:
        for pj in cj:

            if pi[0] == "~" + pj[0] or pj[0] == "~" + pi[0]:
                theta = unify(pi[1], pj[1], {})
                if theta != "FAIL":

                    ci_new = substitute(theta, [x for x in ci if x != pi])
                    cj_new = substitute(theta, [x for x in cj if x != pj])

                    resolvent = []
                    for term in ci_new + cj_new:
                        if term not in resolvent:
                            resolvent.append(term)

                    resolvents.append(resolvent)

    return resolvents


def clause_to_hashable(clause):
    """
    clause = [["Pred", ["a","b"]], ["~Q", ["x"]]]
    → (("Pred", ("a","b")), ("~Q", ("x",)))
    """
    return tuple((pred[0], tuple(pred[1])) for pred in clause)
```

```python
def hashable_to_clause(tup):
    """ reverse conversion """
    return [[pred, list(args)] for pred, args in tup]




def resolution_algorithm(KB, query):

    KB = copy.deepcopy(KB)

    neg_query = []
    for q in query:
        if q[0].startswith("~"):
            neg_query.append([q[0][1:], q[1]])
        else:
            neg_query.append(["~" + q[0], q[1]])
    KB.append(neg_query)

    print("\nInitial KB + neg(query):")
    for c in KB:
        print(c)

    new = set()
```

```
while True:

    pairs = [(KB[i], KB[j]) for i in range(len(KB)) for j in range(i+1, len(KB))]

    for (ci, cj) in pairs:
        resolvents = resolve(ci, cj)

        for r in resolvents:

            if r == []:
                print("\n! Contradiction found → QUERY PROVED.\n")
                return True

            r_hash = clause_to_hashable(r)

            if r_hash not in new:
                new.add(r_hash)

    if all(hashable_to_clause(r) in KB for r in new):
        print("\nNo new clauses → QUERY NOT PROVED.\n")
        return False
```

```
        for r in new:
            clause = hashable_to_clause(r)
            if clause not in KB:
                KB.append(clause)
KB = [
    [["Parent", ["x", "y"]], ["~Mother", ["x", "y"]]],
    [["Mother", ["Mary", "John"]]]
]
query = [["Parent", ["Mary", "John"]]]
print("Trying to prove:", query)
resolution_algorithm(KB, query)
```

Program 10:

Implement Alpha-Beta Pruning.

Algorithm :

Adversial Search.

function Alpha-beta-(state).
return an action.
u ← max-value (state, -∞, +∞)
return the action in actions (state) with
values v.

function max-value (state; α, β) return α
utility value.
If terminal-test (state) then return utility (state).
v ← -∞.

for each a in Actions (state) do
v ← max (v, min-val (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 val
if Terminal-test (state).
return Utility (state).
v ← -∞.
for each α in Action (state) do
v ← MAX (v, Min-Value (Result (s, a), α, β))

if v ≤ α then return v.
β ← Min (β, v)
return v.

Code :

```
import math


def alphabeta(node, depth, alpha, beta, maximizingPlayer):
```

```
if depth == 0 or isinstance(node, int):
    return node

if maximizingPlayer:
    value = -math.inf
    for child in node:
        value = max(value, alphabeta(child, depth - 1, alpha, beta, False))
        alpha = max(alpha, value)
        if beta <= alpha:
            print(f"Pruned in MAX node: alpha={alpha}, beta={beta}")
            break
    return value

else:
    value = math.inf
    for child in node:
        value = min(value, alphabeta(child, depth - 1, alpha, beta, True))
        beta = min(beta, value)
        if beta <= alpha:
            print(f"Pruned in MIN node: alpha={alpha}, beta={beta}")
            break
    return value
```

```
game_tree = [
    [3, 5, 6],
    [1, 2, 4],
    [7, 9, 8]
]


result = alphabeta(game_tree, 2, -math.inf, math.inf, True)
print("\nFinal Result (Best value for Max):", result)
```