**VISVESVARAYA TECHNOLOGICAL UNIVERSITY**

**“JnanaSangama”, Belgaum -590014, Karnataka.**

**LAB REPORT**
**on**

# Artificial Intelligence (23CS5PCAIN)

***Submitted by***

**BISWAJEET (1BM23CS069)**

***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,**

**Bull Temple Road, Bangalore 560019**

(Affiliated To Visvesvaraya Technological University, Belgaum)

**Department of Computer Science and Engineering**

## CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by biswajeet behera**(1BM23CS069),** 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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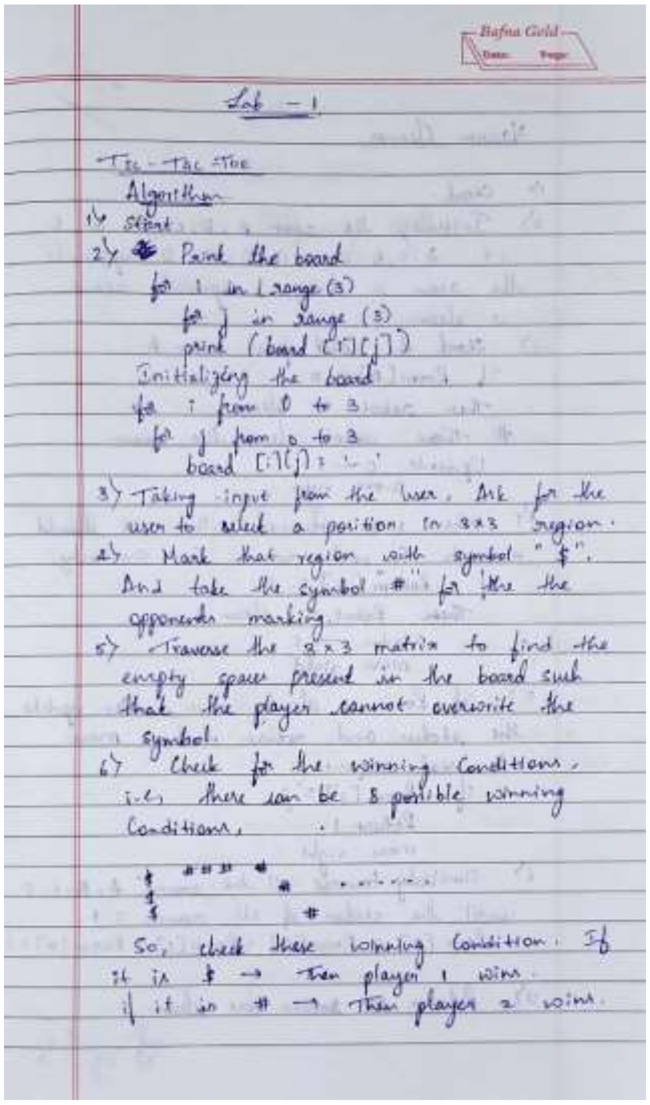

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Lab – 1

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 3x3 region.
4) Mark that region with symbol "$".
   And take the symbol "#" for the the
   opponents marking
5) Traverse the 3x3 matrix to find the
   empty space 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):
```

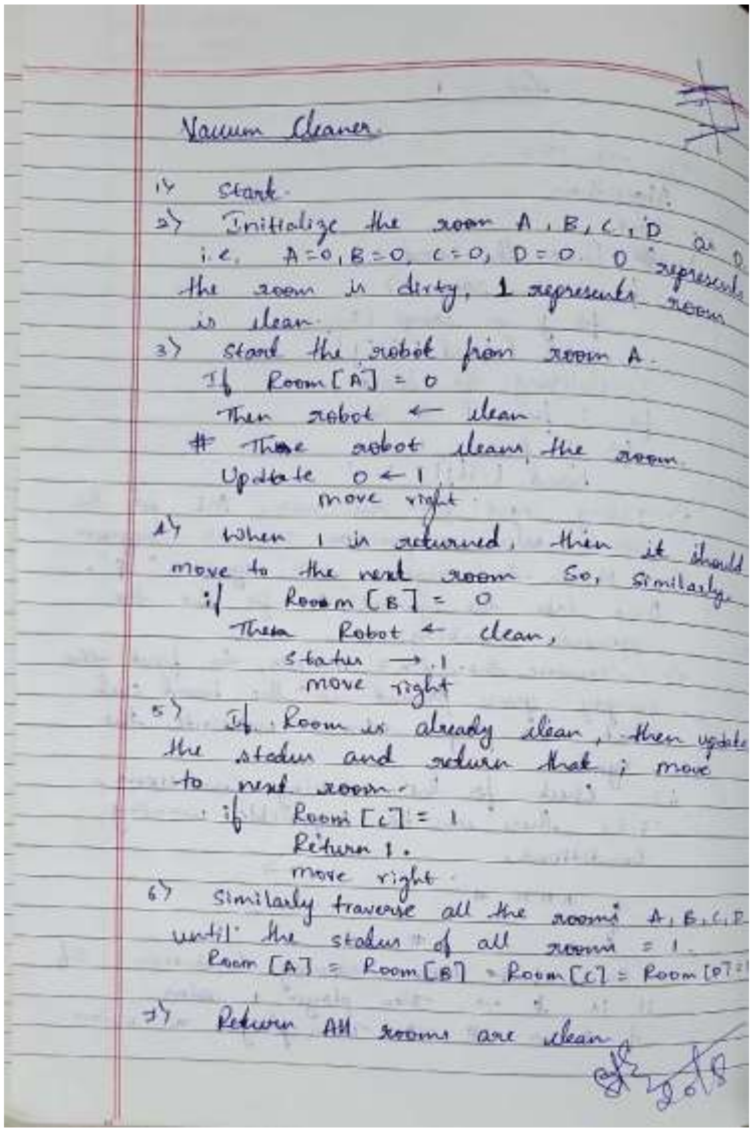
```
    if (board[1]==board[2] and board[1]==board[3] and board[1] ==move):
        return True
    elif (board[4]==board[5] and board[4]==board[6] and board[4] ==move):
        return True
    elif (board[7]==board[8] and board[7]==board[9] and board[7] ==move):
        return True
    elif (board[1]==board[5]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

7) Return All rooms are clean.

[illegible]
2018

```
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()
```

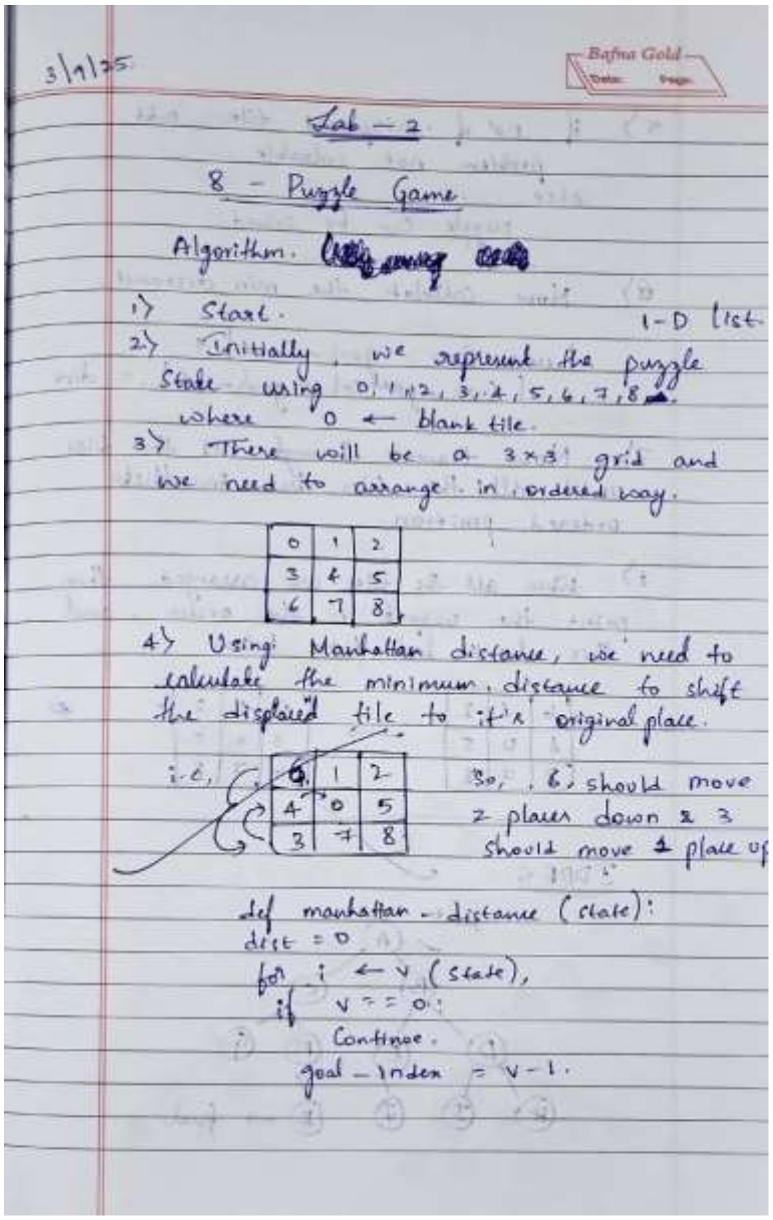
**Program 2 :**

Implement 8 puzzle problems using Depth First Search (DFS)

Implement Iterative deepening search algorithm

8 – puzzle usig DFS :

Algorithm :



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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 |

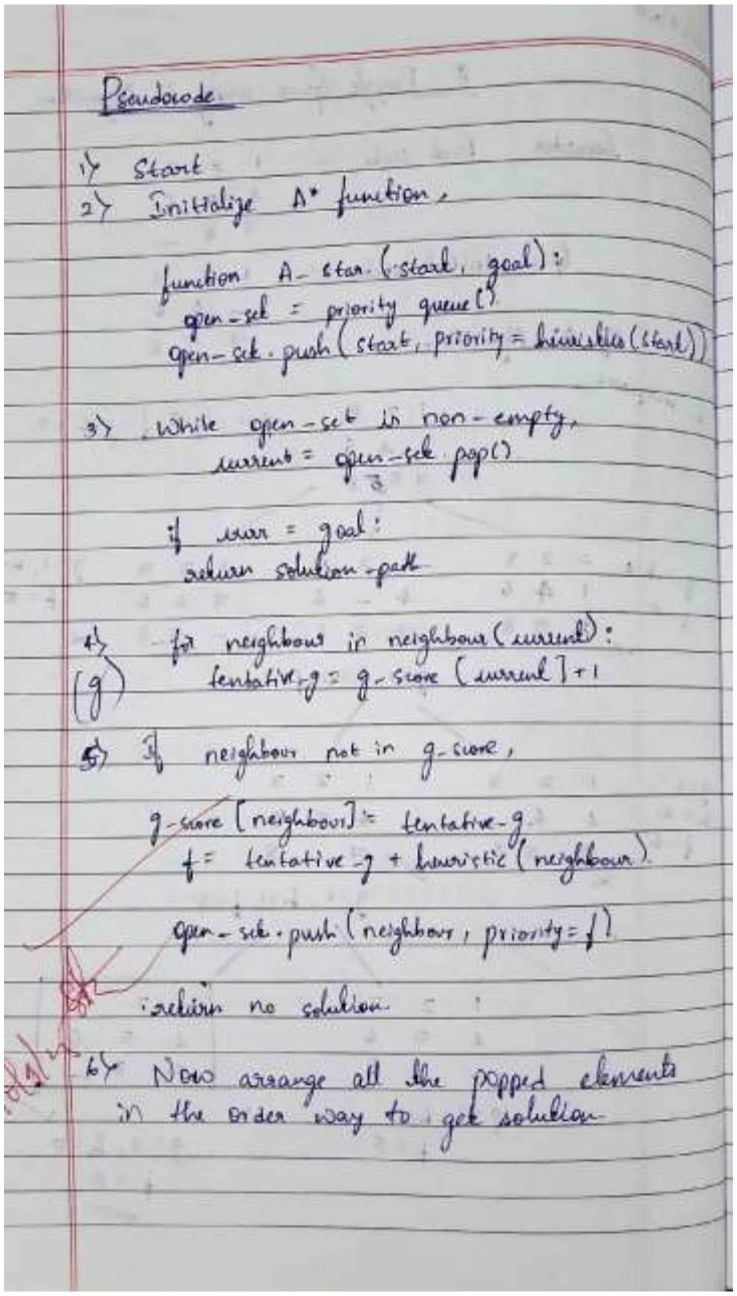
So, 6, should move 2 places down & 3 should move 1 place up

```
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 :

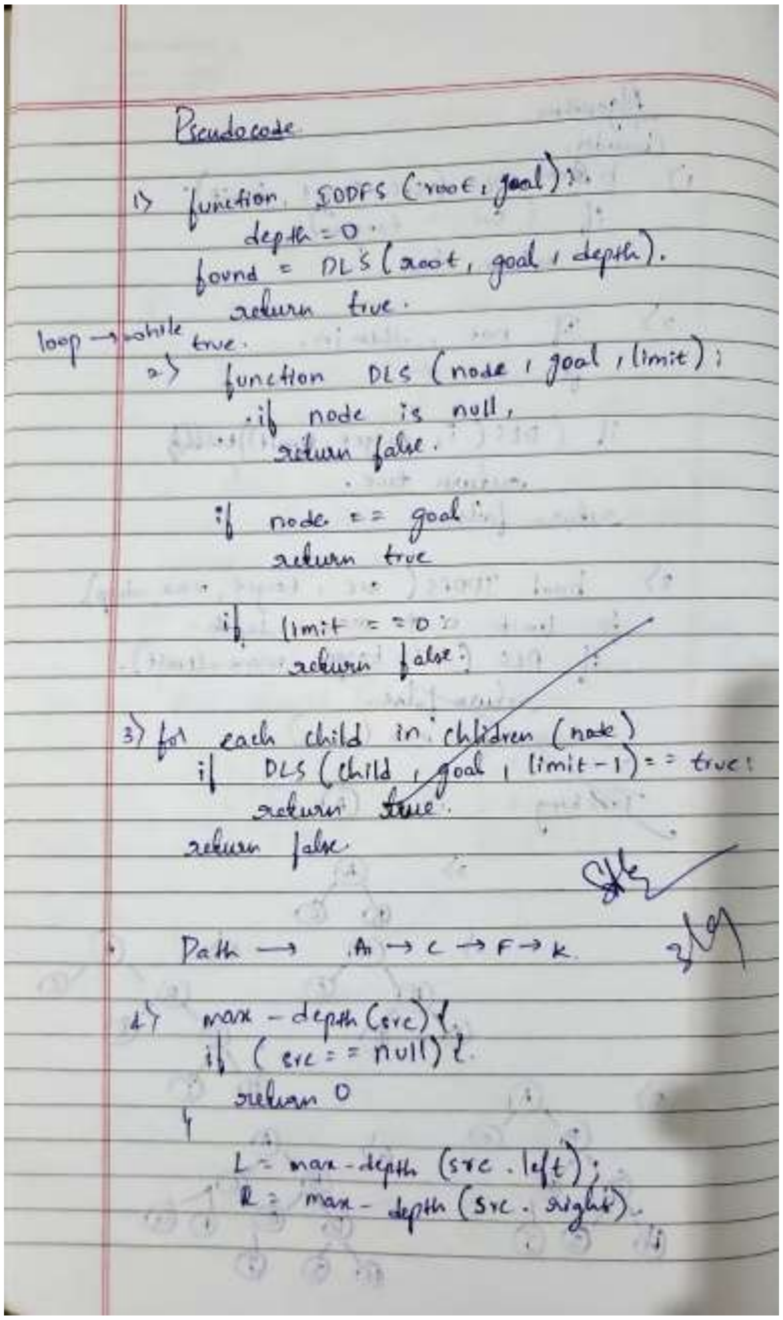


Pseudocode

```
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>   for neighbour in neighbour(current):
(g)      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

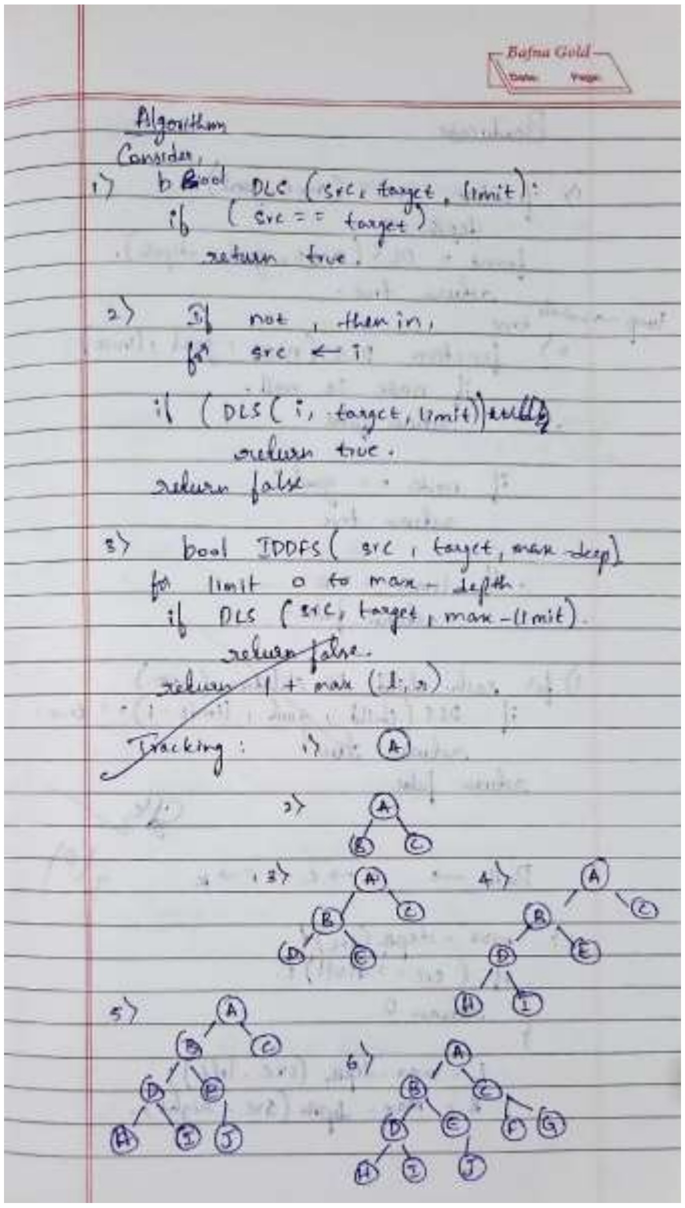
```
1> function IDDFS (root, goal):
      depth = 0.
   found = DLS (root, goal, depth).
      return true.
loop → while true.
  2> function DLS (node, goal, limit):
       if node is null,
         return false.

     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).
```

[illegible]

**Problem 3:**

Implement A* search algorithm

Algorithm:



Algorithm

Consider,

```
1)  b ~~Bool~~ DLC (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 : 1) 2) 3) 4) 5) 6)

A
A B C
A B C D E
A B C D E H I
A B C D E H I J
A B C D E F G H I J

Code :

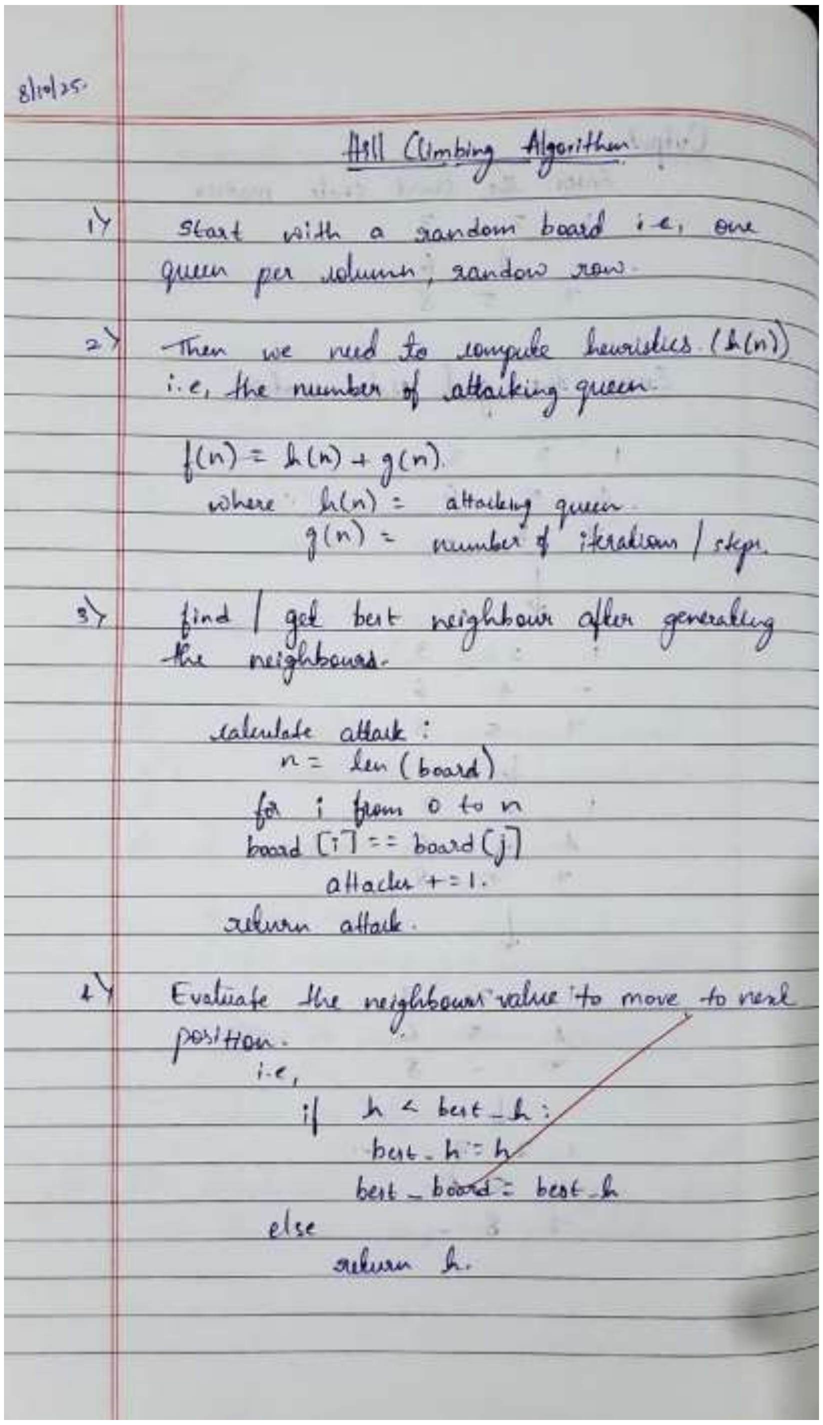
```
from copy import deepcopy

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:



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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 :

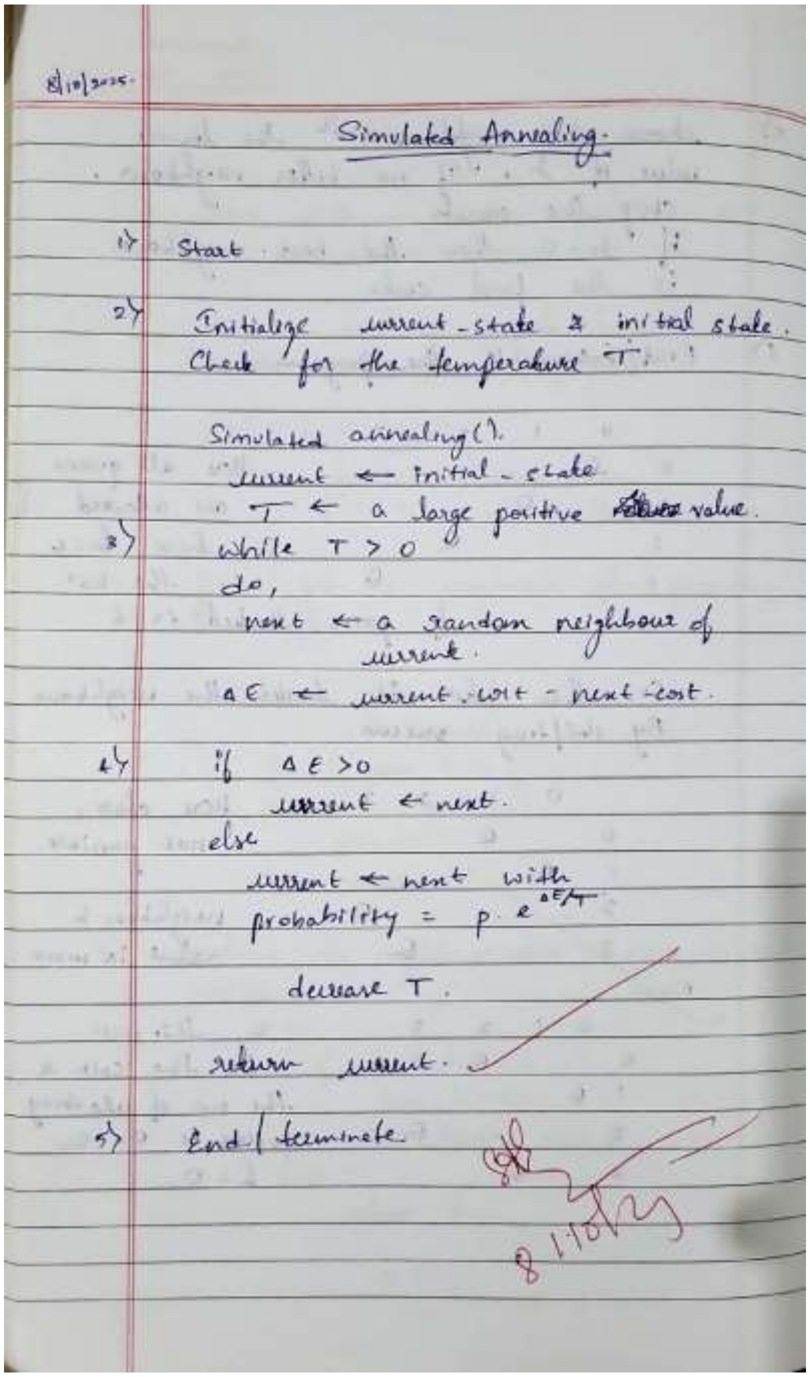
```
import random
def calculate_conflicts(state):
    conflicts = 0
    N = len(state)

    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 ~~[illegible]~~ value.
3)   while T > 0
     do,
       next ← a random neighbour of
              current.
       ΔE ← current_cost - next_cost.

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

         decrease T.

     return current.

5) End / terminate.
```

[illegible]
8/10/25

Code :

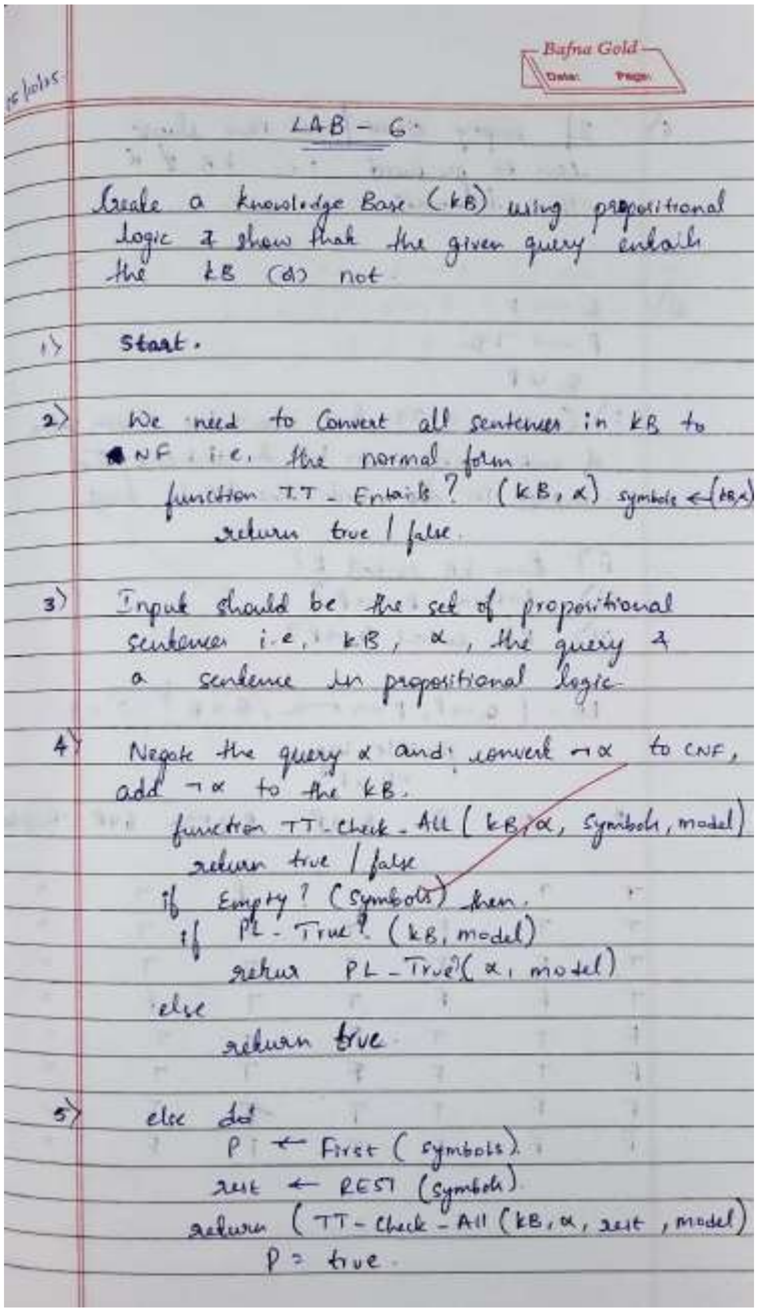
```
import random import math

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 :



15/01/25

Bafna Gold

Date: Page:

LAB - 6.

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

1) Start.

2) We need to Convert all sentences in KB to NF 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 :

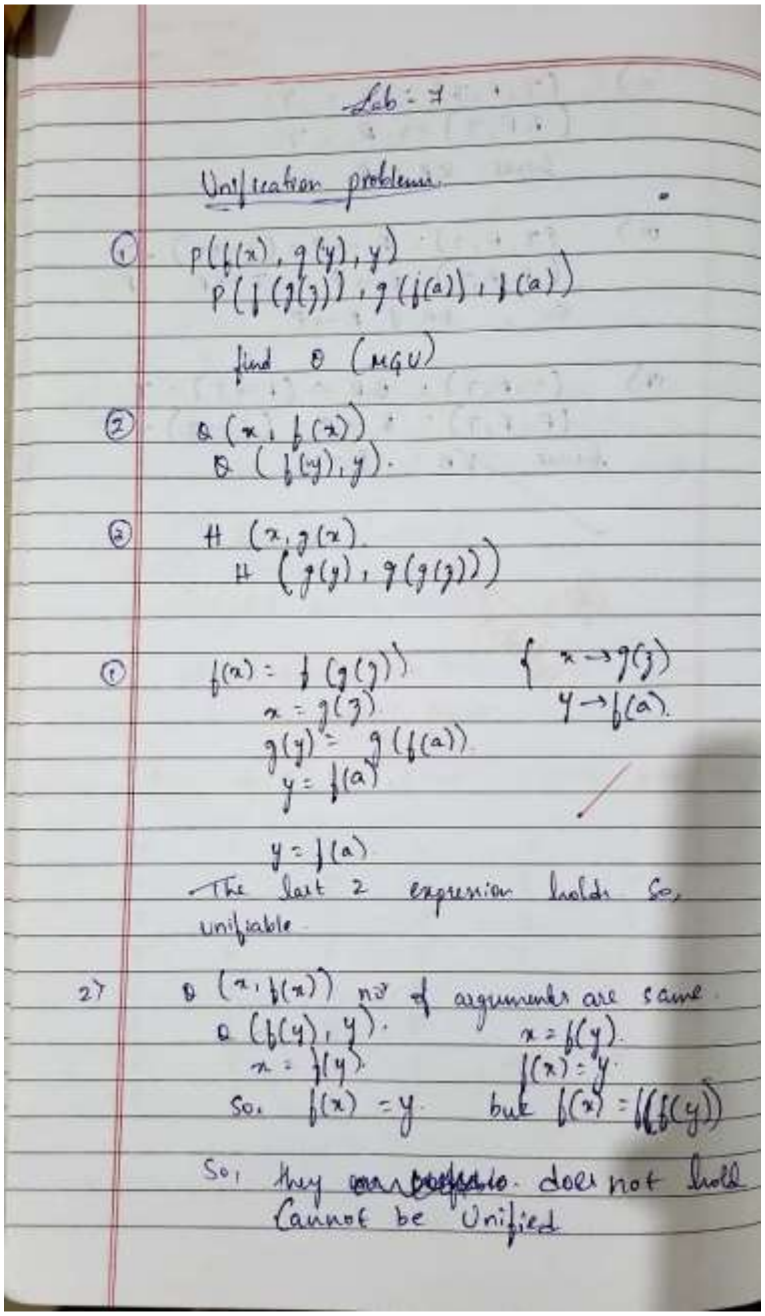
```
import itertools

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 $\theta$ (MGU)

② $Q(x, f(x))$

$Q(f(y), y)$.

③ $H(x, g(x))$

$H(g(y), g(g(z)))$

① $f(x) = f(g(z))$ $\left\{ x \to g(z) \right.$

$x = g(z)$ $y \to f(a)$.

$g(y) = g(f(a))$.

$y = f(a)$

$y = f(a)$.

The last 2 expression holds So, unifiable.

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

$Q(f(y), y)$. $x = f(y)$.

$x = f(y)$. $f(x) = y$.

So, $f(x) = y$. but $f(x) = f(f(y))$

So, they ~~can~~ ~~[illegible]~~ 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
```

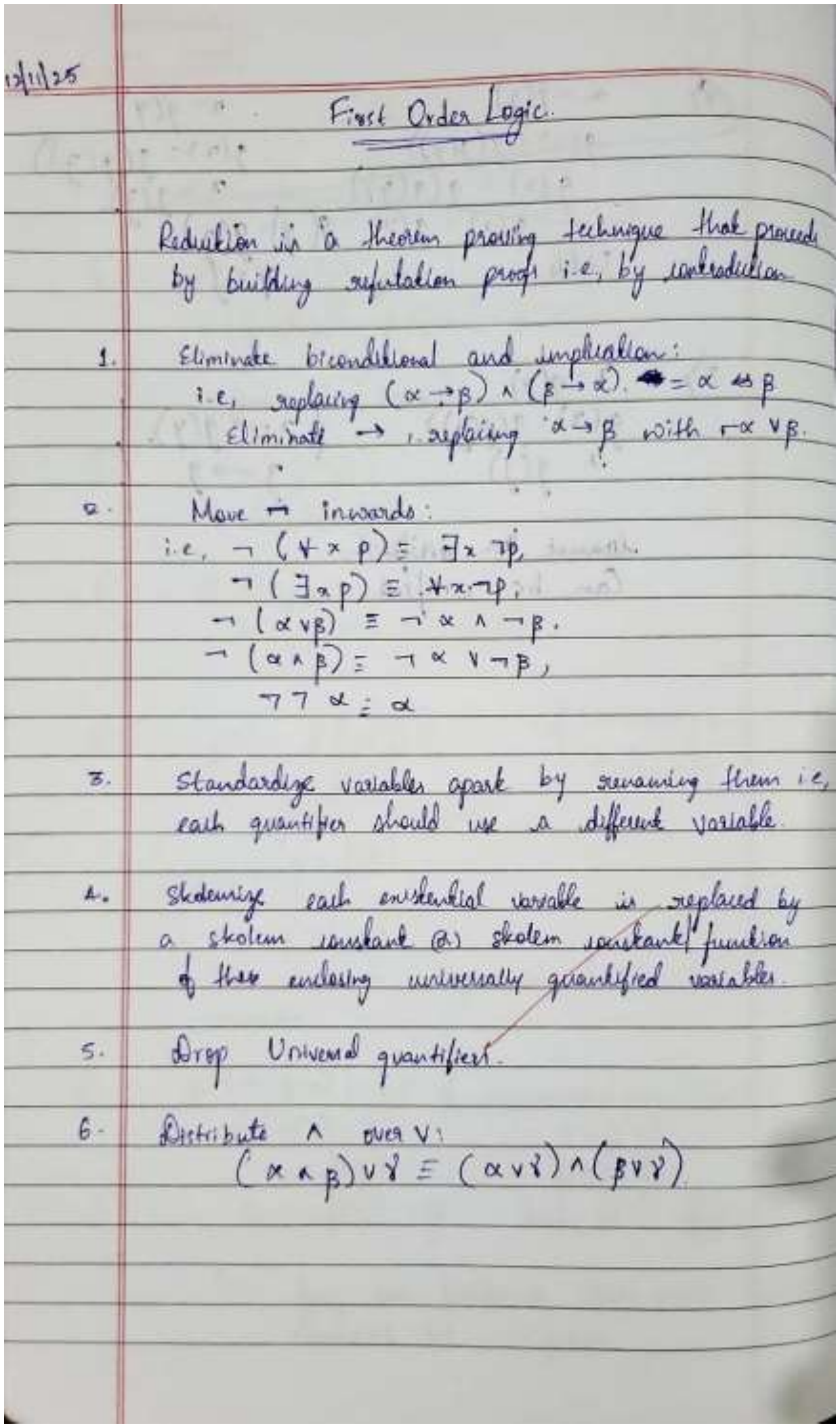
```
elif isinstance(expr, list):
        return any(occurs_check(var, subexpr) for subexpr in expr)
    return False


 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.

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

1. Eliminate biconditional and implication:
   i.e, replacing $(\alpha \rightarrow \beta) \wedge (\beta \rightarrow \alpha) = \alpha \Leftrightarrow \beta$
   Eliminate $\rightarrow$, replacing $\alpha \rightarrow \beta$ 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()
```

```
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)
```

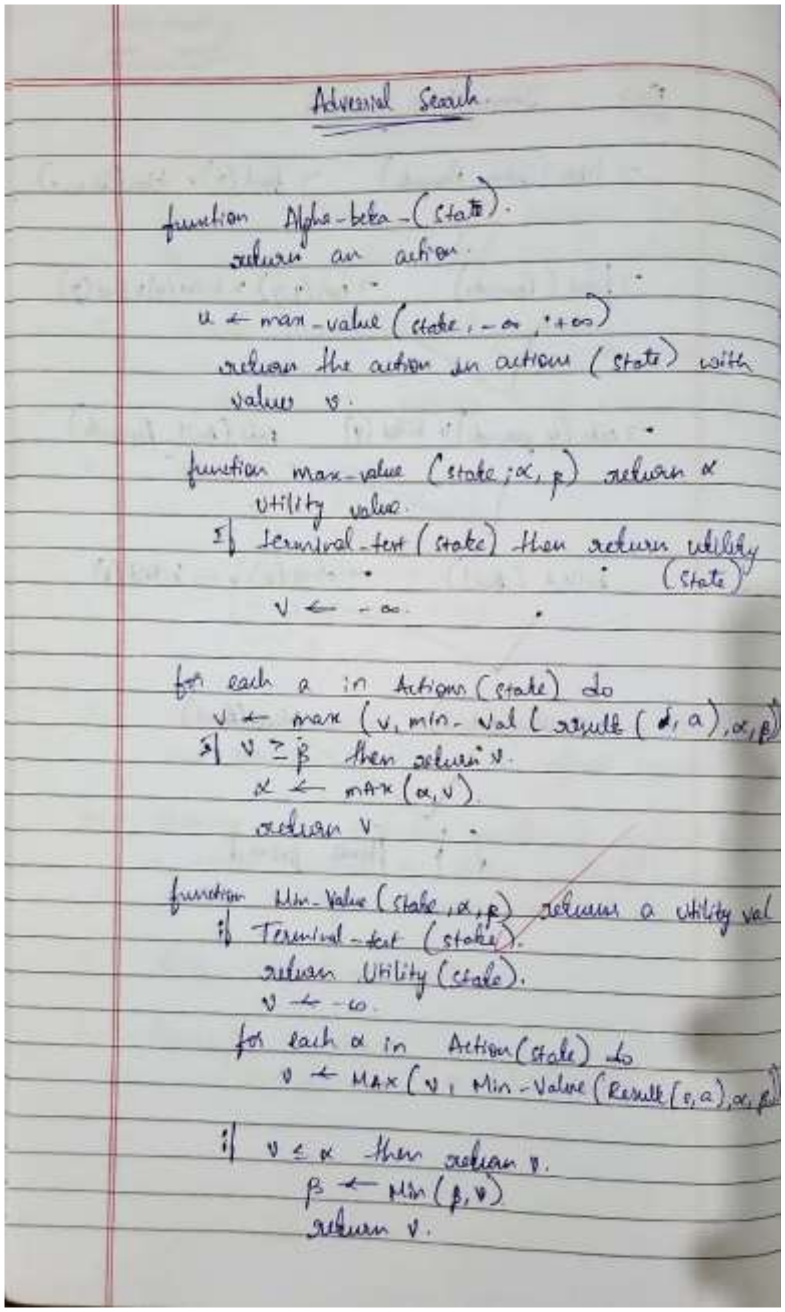
```
                        def hashable_to_clause(tup):
                          """ reverse conversion """
    return [[pred, list(args)] for pred, args in tup]




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.
    v ← max_value (state, $-\infty$, $+\infty$)
    return the action in actions (state) with
    value v.

function max-value (state, $\alpha$, $\beta$) return a
    utility value.
    If terminal-test (state) then return utility
                                              (state)
        v ← $-\infty$.

for each a in Actions (state) do
    v ← max (v, min-Val ( result (s, a), $\alpha$, $\beta$)
    If v $\geq \beta$ then return v.
        $\alpha$ ← max ($\alpha$, v).
        return v

function Min-Value (state, $\alpha$, $\beta$) returns a utility val
    if Terminal-test (state).
        return Utility (state).
        v ← $-\infty$.
    for each a in Action(state) do
        v ← MAX (v, Min-Value (Result (s, a), $\alpha$, $\beta$)

    if v $\leq \alpha$ then return v.
        $\beta$ ← Min ($\beta$, 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)
```