VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT on

Artificial Intelligence (23CS5PCAIN)

Submitted by

Harsh C Kavediya(1BM23CS370)

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 **Sep-2024 to Jan-2025**

B.M.S. College of Engineering,

Bull Temple Road, Bangalore 560019

(Affiliated To Visvesvaraya Technological University, Belgaum)

Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Harsh C Kavediya(1BM23CS370),** 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.

Sandhya A Kulkarni Assistant Professor Department of CSE, BMSCE	**Dr. Kavitha Sooda** Professor & HOD Department of CSE, BMSCE

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Github Link:
https://github.com/Harshkavediya17/AI

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Program 1

Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

Tic-Tac-Toe

Algorithm

20/8/25

LAB-1

Tic Tac Toe

Pseudocode

constraints:

```
Human ← 'X'
AI ← 'O'
Empty ← ' '

Function create_board():
    Return 3x3 list filled with Empty

Function print_board(board):
    for each row in board:
        print elements of row separated by '|'
        print '---'

Function check_winner(board):
    for i ← 0 to 2:
        if board[i][0] == board[i][1] == board[i][2] != Empty:
            return board[i][0] // Row win
        if board[0][i] == board[1][i] == board[2][i] != Empty:
            return board[0][i] // Column win
    if board[0][0] == board[1][1] == board[2][2] != Empty:
        return board[0][0] //diagonal win
    if board[0][2] == board[1][1] == board[2][0] != Empty:
        return board[0][2] //diagonal win
    return None

Function is_board_full(board):
    for each row in board:
        for each cell in row:
            if cell == Empty:
                return False
    return True
```

Function get_available_moves(board):
    moves ← empty list
    for i from 0 to 2:
        for j from 0 to 2:
            if board[i][j] == Empty:
                append (i, j) to moves
    return moves

Function minimax(board, depth, is_maximizing):
    winner ← check_board(board)
    if winner == AI:
        return 1
    if winner == Human:
        return -1
    else if is_board_full(board):
        return 0

    if is_maximizing:
        best_score ← -inf
        for each (i,j) in get_available_moves(board):
            board[i][j] ← AI
            score ← minimax(board, depth+1, False)
            board[i][j] = Empty
            best_score = max(score, best_score)
        return best_score
    else:
        best_score ← inf
        for each (i,j) in get_available_moves(board):
            board[i][j] = Human
            score ← minimax(board, depth+1, False)
            board[i][j] = Empty
            best_score = min(score, best_score)
        return best_score

```
function best_move(board):
    best_score ← -inf
    move ← None
    for each (i, j) in get_available_moves(board):
        board[i][j] ← AI
        score ← minimax(board, 0, False)
        board[i][j] ← Empty
        if score > best_score:
            best_score ← score
            move ← (i, j)
    return move

function play_game():
    board ← create_board()
    print "Welcome to Tic Tac Toe!"
    print_board(board)

    while True:
        while True:
            print "Enter row (0-2): " → row
            print "Enter col (0-2): " → col
            if board[row][col] == Empty:
                board[row][col] ← Human
                break
            else "cell is already occupied!"
        print_board(board)

        winner ← check_winner(board)
        if winner is not None:
            print winner + " wins!"
            break
        if is_board_full(board):
            print "Draw"
            break
```

```
move ← best_move(board)
if board is not None:
    board[move[0]][move[1]] ← AI
print_board(board)

winner ← check_winner(board)
if winner is not None:
    print winner + " wins!"
    break
if is_board_full(board):
    print 'Draw!"
    break

Main:
    call play_game()
```

Output:

Welcome to Tic Tac Toe!

Enter row (0-2): 0
Enter col (0-2): 0

X		

X		O

Enter row (0-2): 1
Enter col (0-2): 1

X		O
	X	

X		O
	X	
O		

Enter row (0-2): 2
Enter col (0-2): 2

X		O
	X	
O		X

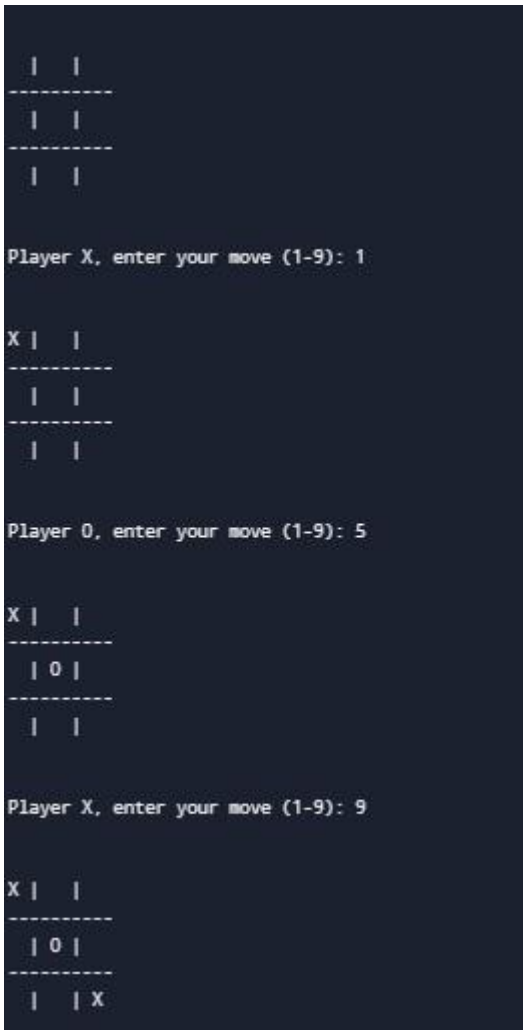
X wins!

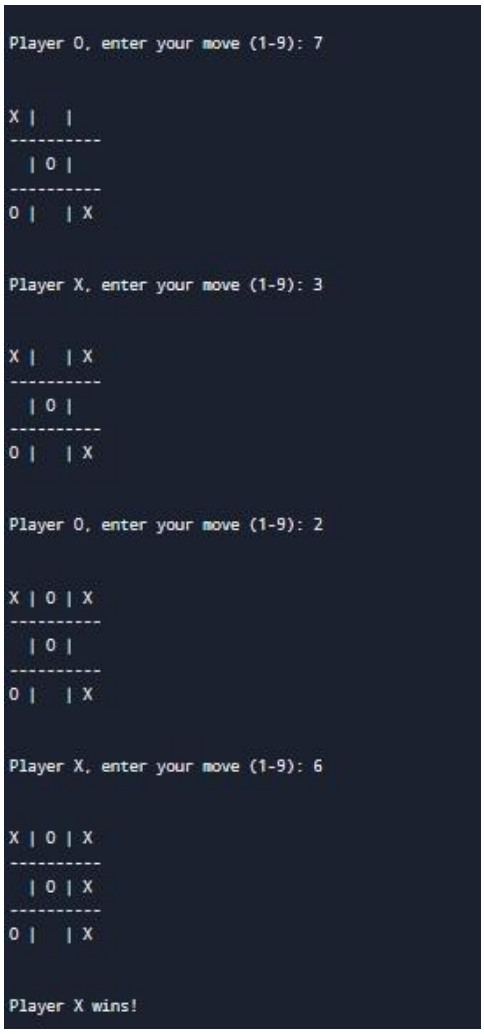
Code

```
def print_board(board):
   print("\n")     for
i in range(3):
       print(" | ".join(board[i*3:(i+1)*3]))
if i < 2:             print("-" * 10)
   print("\n")

def check_winner(board, player):
win_conditions = [
       [0, 1, 2], [3, 4, 5], [6, 7, 8],
       [0, 3, 6], [1, 4, 7], [2, 5, 8],
       [0, 4, 8], [2, 4, 6]
   ]
   for combo in win_conditions:
       count=0         for pos in
combo:             if
board[pos]==player:
               count+=1
if count==3:
return True
   return False

board = [" "] * 9 current_player
= "X"
print_board(board)

while True:
while True:
       pos = int(input(f"Player {current_player}, enter your move (1-9): ")) - 1
if 0 <= pos <= 8 and board[pos] == " ":
           board[pos] = current_player
           break
else:
           print("Invalid move. Try again.")

   print_board(board)

   if check_winner(board, current_player):
print(f"Player {current_player} wins!")
break     if " " not in board:         print("It's a
draw!")         break
```

```
# Switch players
current_player = "O" if current_player == "X" else "X"
```

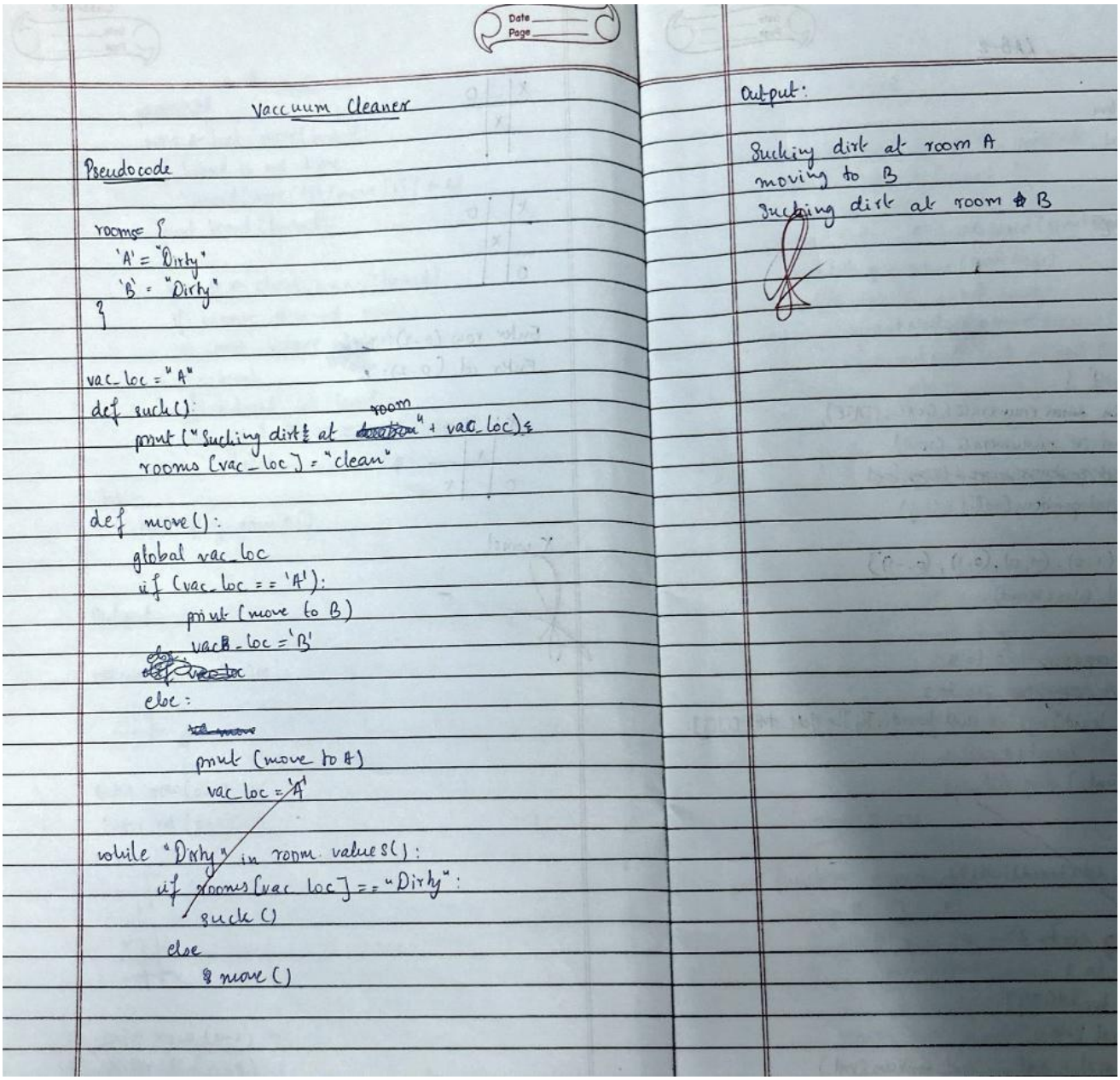
Output





Vacuum Cleaner

Algorithm



Code

```
import random rooms=[1,1,1,1] botpos
=(int(input("Enter Initial Position"))-1)
cleanedpos=[] cost=0

def movebot(pos):

   while True:
      n= random.randint(0,3)        if n !=
pos and n not in cleanedpos:
```

```
            pos = n
break     return pos

while True:
print(str(rooms))
   print(botpos+1)

   if rooms[botpos]==1:

       rooms[botpos]=0
cleanedpos.append(botpos)
cost+=1         if len(cleanedpos)
== 4:           break
       botpos=movebot(botpos)

   elif rooms[botpos]==0:
cleanedpos.append(botpos)         if
len(cleanedpos) == 4:
break
       botpos = movebot(botpos)

print("cost="+str(cost))
```

Output

```
Enter Initial Position2
[1, 1, 1, 1]
2
[1, 0, 1, 1]
3
[1, 0, 0, 1]
1
[0, 0, 0, 1]
4
cost=4
```

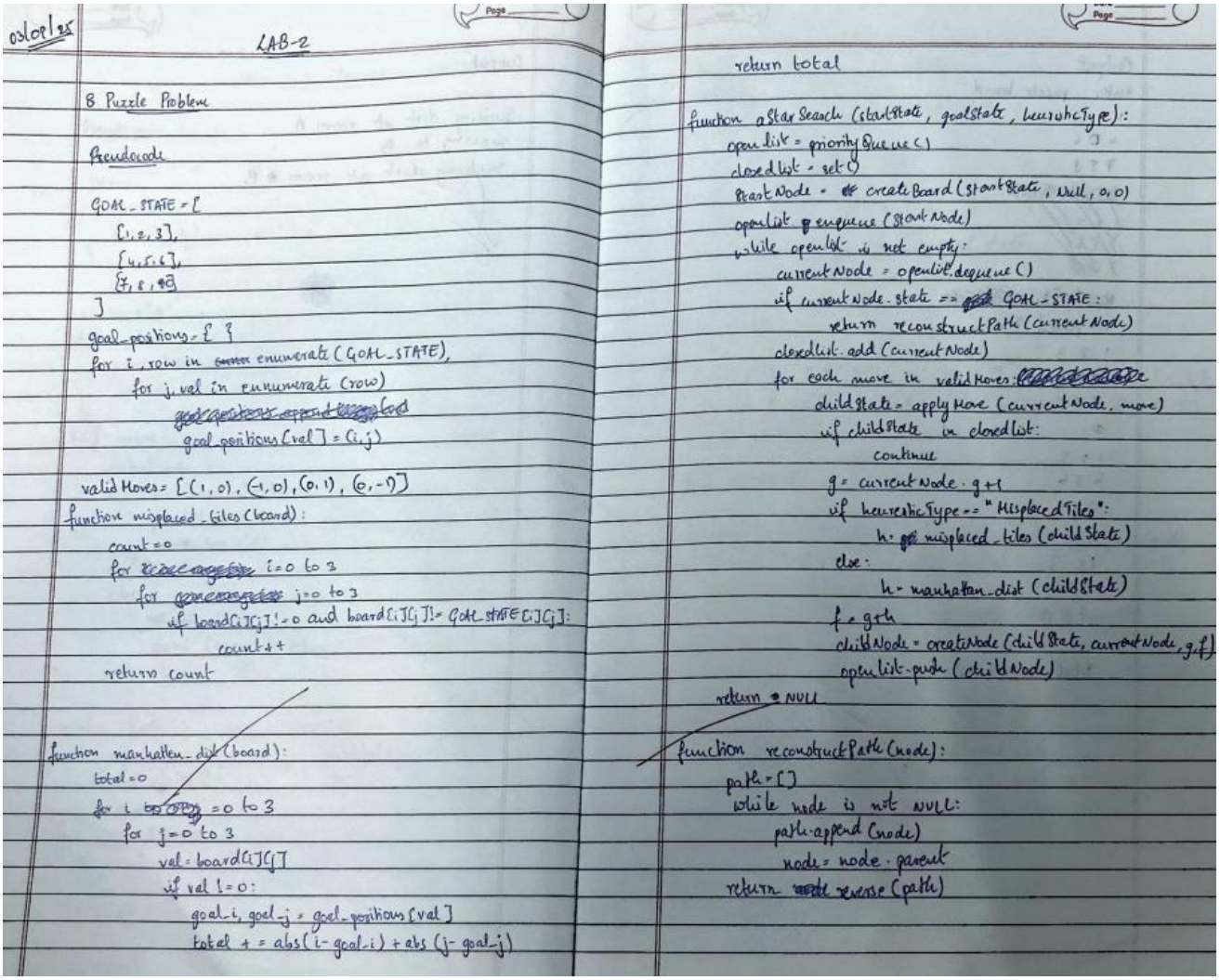
Program 2

Implement 8 puzzle problems using Depth First Search (DFS)

Implement Iterative deepening search algorithm

8 Puzzle Problem

Algorithm

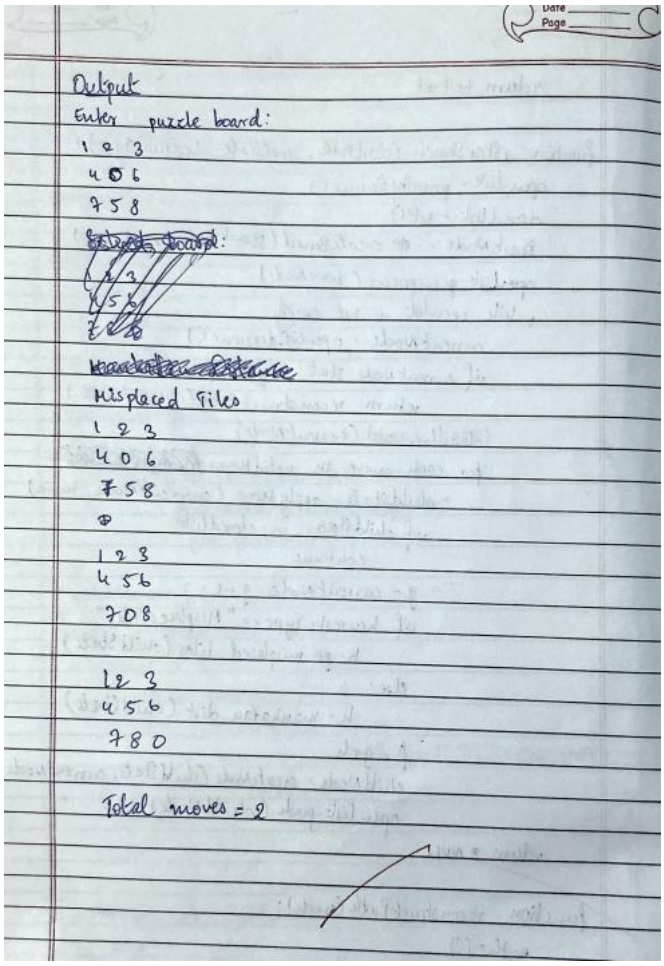


LAB-2

8 Puzzle Problem

Pseudocode

```
GOAL_STATE = [
  [1, 2, 3],
  [4, 5, 6],
  [7, 8, 0]
]
goal_positions = {}
for i, row in enumerate(GOAL_STATE):
    for j, val in enumerate(row)
        goal_positions[val] = (i, j)

valid_moves = [(1, 0), (-1, 0), (0, 1), (0, -1)]
function misplaced_tiles(board):
    count = 0
    for i = 0 to 3
        for j = 0 to 3
            if board[i][j] != 0 and board[i][j] != GOAL_STATE[i][j]:
                count++
    return count

function manhattan_dist(board):
    total = 0
    for i = 0 to 3
        for j = 0 to 3
            val = board[i][j]
            if val != 0:
                goal_i, goal_j = goal_positions[val]
                total += abs(i - goal_i) + abs(j - goal_j)
    return total

function aStarSearch(startState, goalState, heuristicType):
    openList = priorityQueue()
    closedList = set()
    startNode = createBoard(startState, Null, 0, 0)
    openList.enqueue(startNode)
    while openList is not empty:
        currentNode = openList.dequeue()
        if currentNode.state == GOAL_STATE:
            return reconstructPath(currentNode)
        closedList.add(currentNode)
        for each move in validMoves:
            childState = applyMove(currentNode, move)
            if childState in closedList:
                continue
            g = currentNode.g + 1
            if heuristicType == "MisplacedTiles":
                h = misplaced_tiles(childState)
            else:
                h = manhattan_dist(childState)
            f = g + h
            childNode = createNode(childState, currentNode, g, f)
            openList.push(childNode)
    return NULL

function reconstructPath(node):
    path = []
    while node is not NULL:
        path.append(node)
        node = node.parent
    return reverse(path)
```



Code

```
import time

def find_possible_moves(state):
index = state.index('_')     moves
= {
        0: [1, 3],
        1: [0, 2, 4],
        2: [1, 5],
        3: [0, 4, 6],
        4: [1, 3, 5, 7],
        5: [2, 4, 8],
        6: [3, 7],
        7: [6, 8, 4],
        8: [5, 7],
    }
    return moves.get(index, [])
```

```
def dfs(initial_state, goal_state, max_depth=50):
   stack = [(initial_state, [], 0)]
visited = {tuple(initial_state)}
states_explored = 0
   printed_depths = set()

   while stack:
      current_state, path, depth = stack.pop()

      if depth > max_depth:
         continue

      if depth not in printed_depths:
print(f"\n--- Depth {depth} ---")
         printed_depths.add(depth)

      states_explored += 1        print(f"State
#{states_explored}: {current_state}")

      if current_state == goal_state:           print(f"\n Goal reached at depth {depth} after
exploring {states_explored} states.\n")           return path, states_explored

      possible_moves_indices = find_possible_moves(current_state)

      for move_index in reversed(possible_moves_indices):  # Reverse for DFS order
next_state = list(current_state)           blank_index = next_state.index('_')
next_state[blank_index], next_state[move_index] = next_state[move_index],
next_state[blank_index]

         if tuple(next_state) not in visited:
visited.add(tuple(next_state))               stack.append((next_state,
path + [next_state], depth + 1))

   print(f"\n Goal state not reachable within depth {max_depth}. Explored {states_explored}
states.\n")     return None, states_explored


# ----------------- TEST ----------------- initial_state
= [1, 2, 3,
             4, 8, '_',
             7, 6, 5]

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

```
            4, 5, 6,
            7, 8, '_']

# Measure execution time start_time = time.time() solution_path,
explored = dfs(initial_state, goal_state, max_depth=50) end_time =
time.time()

if solution_path is None:
print("No solution found.") else:
   print("Solution path:")     for step, state in
enumerate(solution_path, start=1):
       print(f"Step {step}: {state}")

print("\nExecution time: {:.6f} seconds".format(end_time - start_time))
print("Total states explored:", explored)
```

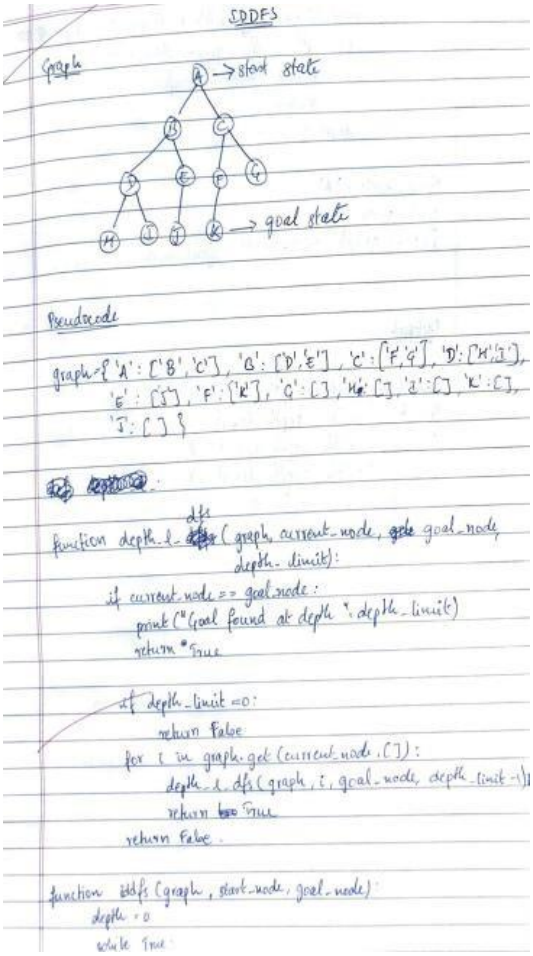
Output

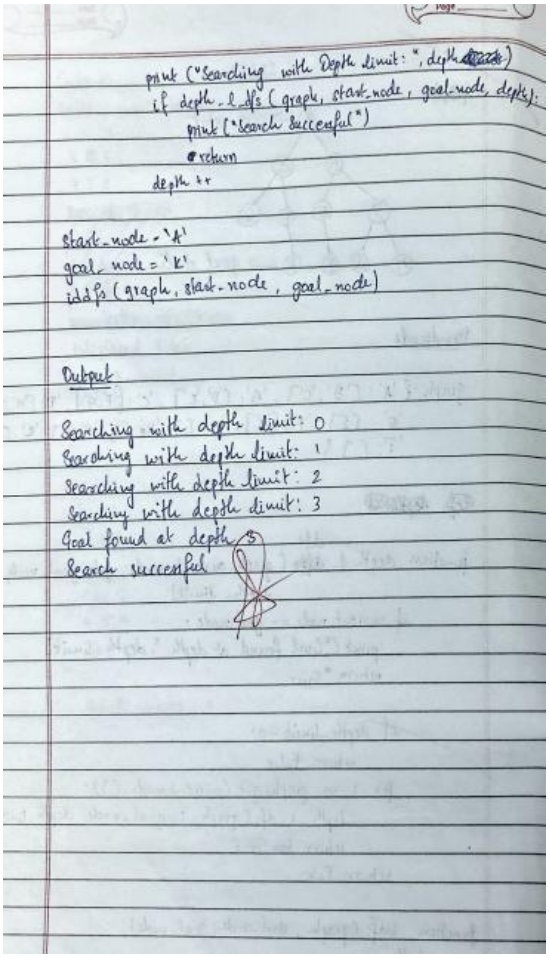
```
--- Depth 0 ---
State #1: [1, 2, 3, 4, 8, '_', 7, 6, 5]

--- Depth 1 ---
State #2: [1, 2, '_', 4, 8, 3, 7, 6, 5]

--- Depth 2 ---
State #3: [1, '_', 2, 4, 8, 3, 7, 6, 5]

--- Depth 3 ---
State #4: ['_', 1, 2, 4, 8, 3, 7, 6, 5]

--- Depth 4 ---
State #5: [4, 1, 2, '_', 8, 3, 7, 6, 5]

--- Depth 5 ---
State #6: [4, 1, 2, 8, '_', 3, 7, 6, 5]

--- Depth 6 ---
State #7: [4, '_', 2, 8, 1, 3, 7, 6, 5]

--- Depth 7 ---
State #8: ['_', 4, 2, 8, 1, 3, 7, 6, 5]

--- Depth 8 ---
State #9: [8, 4, 2, '_', 1, 3, 7, 6, 5]
```

```
--- Depth 9 ---
State #10: [8, 4, 2, 1, '_', 3, 7, 6, 5]

--- Depth 10 ---
State #11: [8, '_', 2, 1, 4, 3, 7, 6, 5]

--- Depth 11 ---
State #12: ['_', 8, 2, 1, 4, 3, 7, 6, 5]

--- Depth 12 ---
State #13: [1, 8, 2, '_', 4, 3, 7, 6, 5]

--- Depth 13 ---
State #14: [1, 8, 2, 7, 4, 3, '_', 6, 5]

--- Depth 14 ---
State #15: [1, 8, 2, 7, 4, 3, 6, '_', 5]

--- Depth 15 ---
State #16: [1, 8, 2, 7, 4, 3, 6, 5, '_']

--- Depth 16 ---
State #17: [1, 8, 2, 7, 4, '_', 6, 5, 3]
```

IDDFS

Algorithm





Code

```
import time

def find_possible_moves(state):
   index = state.index('_')

   if index == 0:
return [1, 3]     elif
index == 1:
return [0, 2, 4]     elif
index == 2:
return [1, 5]     elif
index == 3:
return [0, 4, 6]     elif
index == 4:
       return [1, 3, 5, 7]
elif index == 5:
```

```
return [2, 4, 8]     elif
index == 6:
return [3, 7]     elif
index == 7:
return [4, 6, 8]     elif
index == 8:
return [5, 7]
   return []

def depth_limited_dfs(state, goal_state, limit, path, visited):
if state == goal_state:
       return path

   if limit <= 0:
return None

   visited.add(tuple(state))

   for move_index in find_possible_moves(state):
      next_state = list(state)         blank_index = next_state.index('_')
next_state[blank_index], next_state[move_index] = next_state[move_index],
next_state[blank_index]

       if tuple(next_state) not in visited:
          result = depth_limited_dfs(next_state, goal_state, limit - 1, path + [next_state], visited)
if result is not None:
             return result
   return None

def iddfs(initial_state, goal_state, max_depth=30):
for depth in range(max_depth):
       print(f"Searching at depth limit = {depth}")         visited = set()         result =
depth_limited_dfs(initial_state, goal_state, depth, [initial_state], visited)         if
result is not None:             return result, depth
   return None, max_depth

# ----------------- TEST ----------------- initial_state
= [1, 2, 3,
              4, 8, '_',
              7, 6, 5]

goal_state    = [1, 2, 3,
              4, 5, 6,
              7, 8, '_']
```

```
# Measure execution time start_time = time.time() solution_path,
depth_reached = iddfs(initial_state, goal_state, max_depth=30) end_time =
time.time()

if solution_path is None:
    print("Goal state is not reachable within given depth limit.") else:
    print("\n\nSolution path found:")     for step, state
in enumerate(solution_path, start=0):
        print(f"Step {step}: {state}")

print("\nExecution time: {:.6f} seconds".format(end_time - start_time))
print("Depth reached:", depth_reached)
```

Output

```
Searching at depth limit = 0
Searching at depth limit = 1
Searching at depth limit = 2
Searching at depth limit = 3
Searching at depth limit = 4
Searching at depth limit = 5


Solution path found:
Step 0: [1, 2, 3, 4, 8, '_', 7, 6, 5]
Step 1: [1, 2, 3, 4, 8, 5, 7, 6, '_']
Step 2: [1, 2, 3, 4, 8, 5, 7, '_', 6]
Step 3: [1, 2, 3, 4, '_', 5, 7, 8, 6]
Step 4: [1, 2, 3, 4, 5, '_', 7, 8, 6]
Step 5: [1, 2, 3, 4, 5, 6, 7, 8, '_']

Execution time: 0.000194 seconds
Depth reached: 5

=== Code Execution Successful ===
```

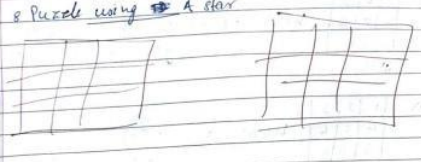
Program 3

Implement A* search algorithm

Algorithm

LAB - 3

8 Puzzle using A star



Tracing for Manhattan Distance & Misplaced Tiles

- Initial state =

1	2	3
4	0	6
7	5	8

Goal State =

1	2	3
4	5	6
7	8	0

① Misplaced Tiles Heuristic

Step1

1	2	3
4	0	6
7	5	8

State 1

closed list = {State 1} g(n) = 0
Open list = {State 1} f(n) = 2

h(n) = 1+1 = 2 (5 & 5)

Possible moves.

a)

1	2	3
4	6	0
7	5	8

State 2

g(n) = 1
h(n) = 1+1+1 = 3 (5, 6 & 5)
f(n) = 4

b)

1	0	3
4	2	6
7	5	8

State 3

h(n) = 1+1+1 = 3 (2, 5 & 8)
g(n) = 1 f(n) = 4

c)

1	2	3
4	5	6
7	0	8

State 4

h(n) = 1 (8)
g(n) = 1 f(n) = 2

d)

1	2	3
0	4	6
7	5	8

State 5

h(n) = 1+1+1 = 3 (4, 5 & 8)
g(n) = 1 f(n) = 4

Choosing state 5,

open list = {State 6, state 5, state 2, State 3, state 4}

closed list = {State 1, state 5}

Step2

1	2	3
0	5	6
7	0	8

State 5

g(n) = 1 h(n) = 1
f(n) = 2

Possible moves.

a)

1	2	3
4	0	6
7	5	8

State 4

X rejected. Already considered.
h(n) = 1+1 = 2 (5 & 8)
g(n) = 2 f(n) = 4

b)

1	2	3
4	5	0
7	8	6

State 6

h(n) = 0
g(n) = 2
f(n) = 2

closed state = {State 1, State 5, State 6}

State 6' = Goal state

∴ Output =

1	2	3
4	5	6
7	8	0

No. of moves = 2

② Manhattan Distance

State 1

1	2	3
4	0	6
7	5	8

State 1

h(n) = 1+1 = 2
g(n) = 0 f(n) = 2

Possible moves.

a)

1	2	3
0	4	6
7	5	8

State 2

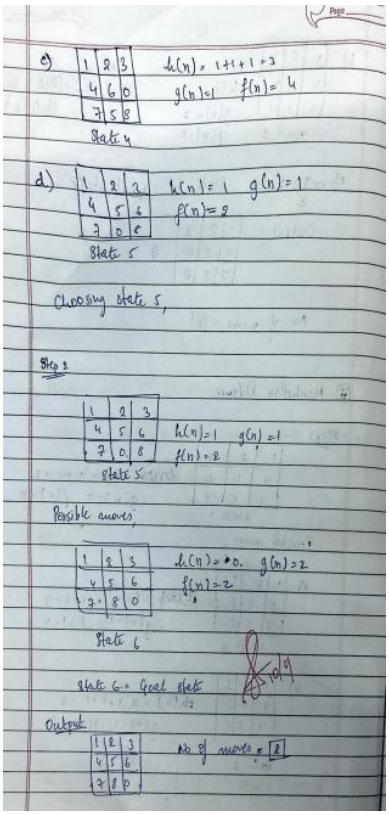
h(n) = 1+1+1 = 3
g(n) = 1 f(n) = 4

b)

1	0	3
4	2	6
7	5	8

State 3

h(n) = 1+1+1 = 3
g(n) = 1 f(n) = 4



Code

```
import heapq
import time

# Heuristic: Manhattan Distance def
heuristic(state, goal):
   distance = 0     for i in range(1, 9):  # tile
numbers 1 to 8         x1, y1 =
divmod(state.index(i), 3)         x2, y2 =
divmod(goal.index(i), 3)         distance +=
abs(x1 - x2) + abs(y1 - y2)     return
distance

# Get neighbors by sliding blank (0) up/down/left/right def
get_neighbors(state):
   neighbors = []     i = state.index(0)  #
position of blank     x, y = divmod(i, 3)
   moves = [(-1,0), (1,0), (0,-1), (0,1)]

   for dx, dy in moves:
```

```
        new_x, new_y = x + dx, y + dy         if
0 <= new_x < 3 and 0 <= new_y < 3:
j = new_x * 3 + new_y             new_state =
list(state)             new_state[i], new_state[j]
= new_state[j], new_state[i]
neighbors.append(tuple(new_state))
return neighbors

# A* Search for 8-puzzle def astar(start, goal):     open_set
= []     heapq.heappush(open_set, (heuristic(start, goal), 0,
start))

    came_from = {}
    g_score = {start: 0}

    while open_set:
        _, cost, current = heapq.heappop(open_set)

        if current == goal:             #
Reconstruct path             path = []
while current in came_from:
path.append(current)                 current
= came_from[current]
            path.append(start)
            return path[::-1]

        for neighbor in get_neighbors(current):             tentative_g =
g_score[current] + 1             if neighbor not in g_score or tentative_g
< g_score[neighbor]:
                came_from[neighbor] = current
g_score[neighbor] = tentative_g                 f_score =
tentative_g + heuristic(neighbor, goal)
                heapq.heappush(open_set, (f_score, tentative_g, neighbor))

    return None  # no solution

# ----------------- TEST ----------------- start
= (1, 2, 3,
         4, 8, 0,
         7, 6, 5)

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

```
# Measure execution time start_time
= time.time() path = astar(start,
goal) end_time = time.time()

if path:
   print("Steps to solve ({} moves):".format(len(path)-1))
for state in path:         for i in range(0, 9, 3):
print(state[i:i+3])         print() else:     print("No solution
found")

print("Execution time: {:.6f} seconds".format(end_time - start_time))
```

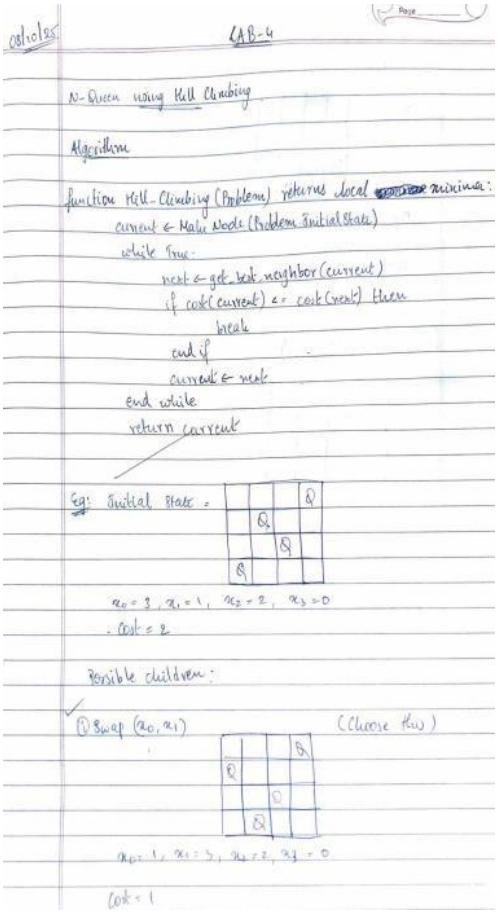
Output

```
Steps to solve (5 moves):
(1, 2, 3)
(4, 8, 0)
(7, 6, 5)

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

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

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

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

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

Execution time: 0.000111 seconds
```

Program 4

Implement Hill Climbing search algorithm to solve N-Queens problem

Algorithm



LAB-4

N-Queen using Hill Climbing

Algorithm

function Hill-Climbing (Problem) returns local minima:
current ← Make Node (Problem.InitialState)
while true:
next ← get.best.neighbor(current)
if cost(current) <= cost(next) then
break
end if
current ← next
end while
return current

Eg: Initial State =

$x_0 = 3, x_1 = 1, x_2 = 2, x_3 = 0$

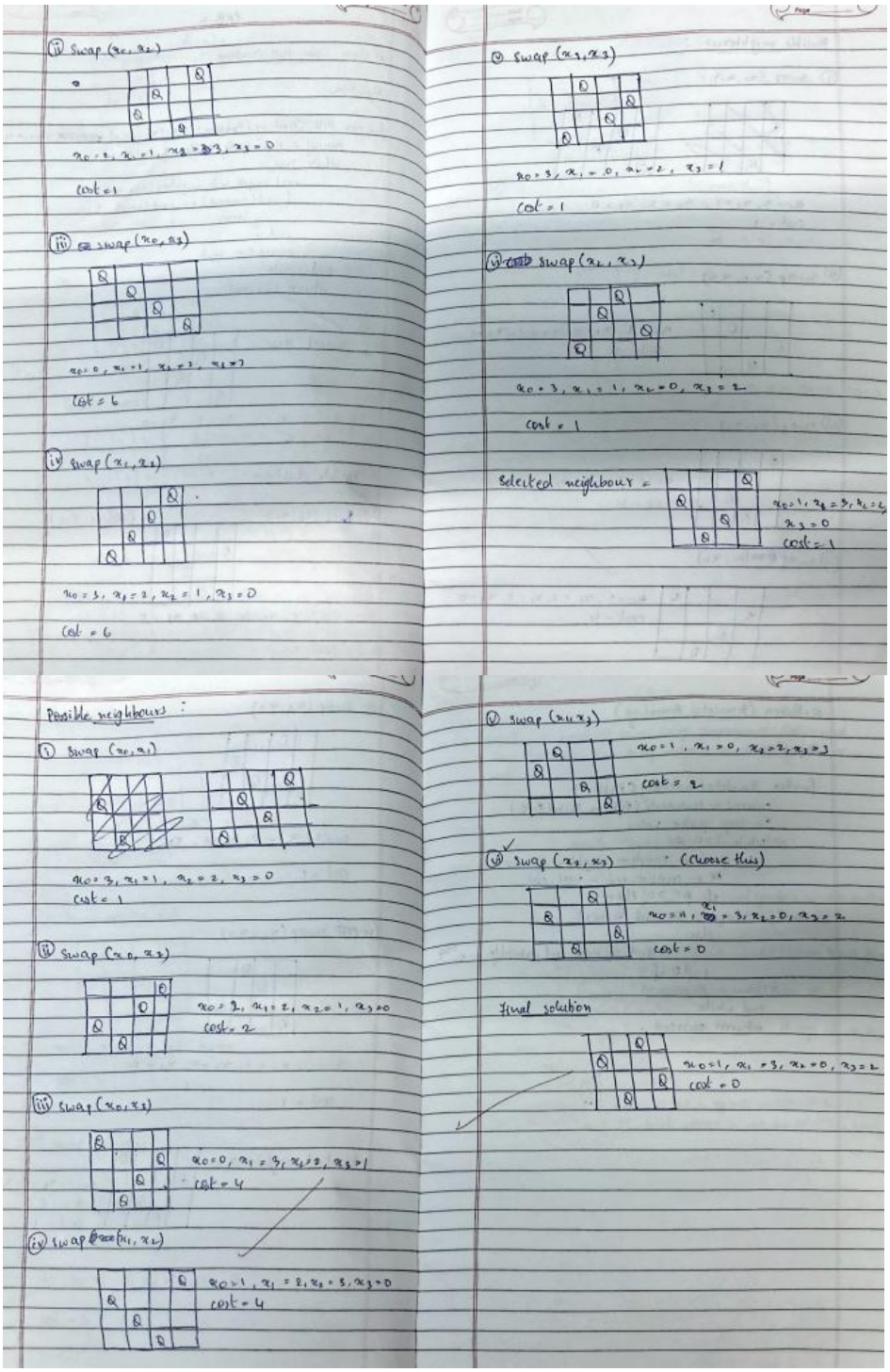
Cost = 2

Possible children:

① Swap (x_0, x_1) (Choose this)

$x_0 = 1, x_1 = 3, x_2 = 2, x_3 = 0$

Cost = 1



Code

```
import random
import math
```

```
def compute_cost(state):
    """Count diagonal conflicts for a permutation-state (one queen per row & column)."""
conflicts = 0     n = len(state)     for i in range(n):         for j in range(i + 1, n):             if
abs(state[i] - state[j]) == abs(i - j):
                conflicts += 1
    return conflicts

def random_permutation(n):
arr = list(range(n))
random.shuffle(arr)
    return arr

def neighbors_by_swaps(state):
    """All neighbors obtained by swapping two columns (keeps permutation property)."""
n = len(state)     for i in range(n - 1):         for j in range(i + 1, n):             nb =
state.copy()             nb[i], nb[j] = nb[j], nb[i]             yield nb

def hill_climb_with_restarts(n, max_restarts=None):
    """Hill climbing on permutations with random restart on plateau (no revisits)."""
visited = set()     total_states = math.factorial(n)
    restarts = 0

    while True:
        # pick a random unvisited start permutation
if len(visited) >= total_states:
            raise RuntimeError("All states visited — giving up (no solution found).")

        state = random_permutation(n)
while tuple(state) in visited:
            state = random_permutation(n)
        visited.add(tuple(state))

        # climb from this start
while True:
            cost = compute_cost(state)
if cost == 0:
                return state, restarts

            # find best neighbor (swap-based neighbors)
best_neighbor = None
            best_cost = float("inf")             for nb
in neighbors_by_swaps(state):
```

```
            c = compute_cost(nb)
if c < best_cost:
best_cost = c
                best_neighbor = nb

        # if strictly better, move; otherwise it's a plateau/local optimum -> restart
if best_cost < cost:
            state = best_neighbor
visited.add(tuple(state))           else:
            # plateau or local optimum -> restart
            restarts += 1               if max_restarts is not None and
restarts >= max_restarts:
                raise RuntimeError(f"Stopped after {restarts} restarts (no solution found).")
break  # go pick a new unvisited start

def format_board(state):
   n = len(state)
lines = []     for r in
range(n):
      lines.append(" ".join("Q" if state[c] == r else "-" for c in range(n)))
return "\n".join(lines)

if __name__ == "__main__":
   n = 4     solution, restarts =
hill_climb_with_restarts(n)     print("Found
solution:", solution)
   print(format_board(solution))
```

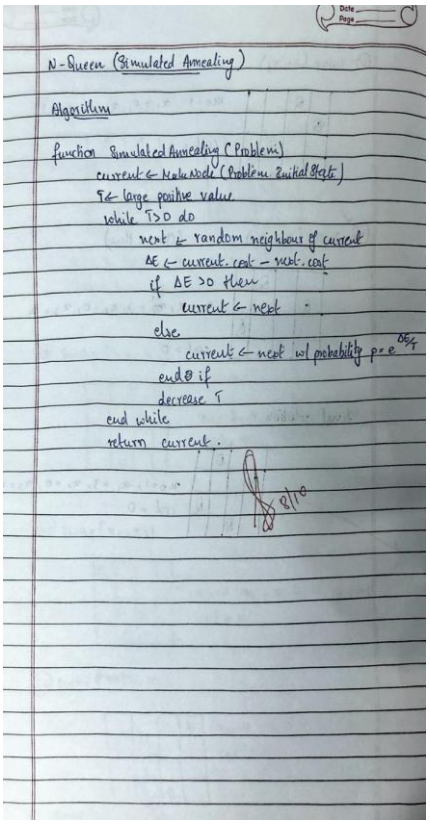
Output

```
Found solution: [2, 0, 3, 1]
- Q - -
- - - Q
Q - - -
- - Q -
```

Program 5

Simulated Annealing to Solve 8-Queens problem

Algorithm

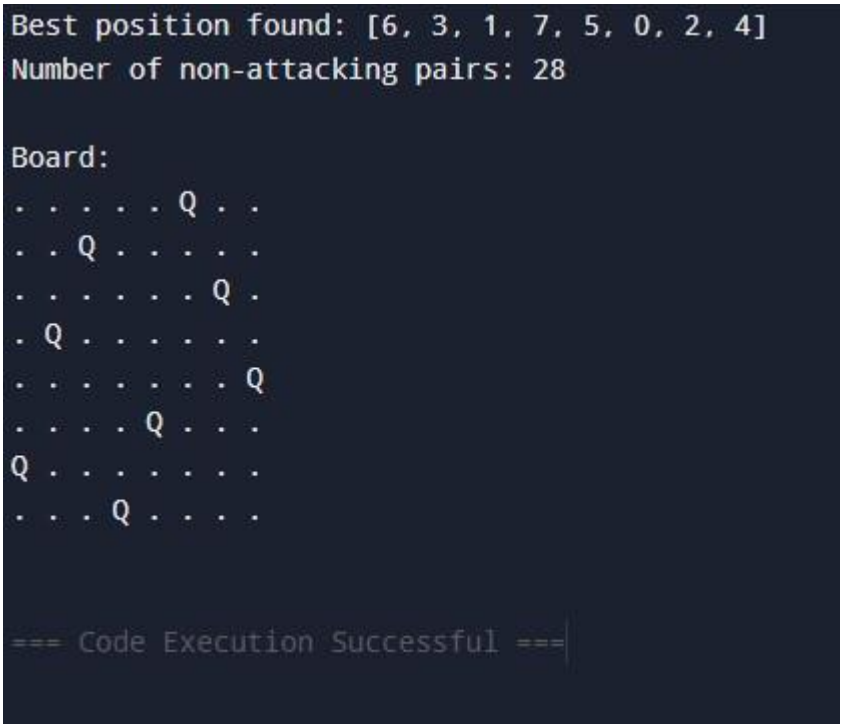


Code

```
import random
import math

def cost(state):

    attacks = 0     n = len(state)     for i in range(n):         for j in
range(i + 1, n):             if state[i] == state[j] or abs(state[i] -
state[j]) == abs(i - j):
                attacks += 1
    return attacks

def get_neighbor(state):

    neighbor = state[:]     i, j =
random.sample(range(len(state)), 2)     neighbor[i],
neighbor[j] = neighbor[j], neighbor[i]     return
neighbor

def simulated_annealing(n=8, max_iter=10000, temp=100.0, cooling=0.95):
```

```
    current = list(range(n))
random.shuffle(current)
    current_cost = cost(current)

    temperature = temp
    cooling_rate = cooling

    best = current[:]
    best_cost = current_cost

    for _ in range(max_iter):         if
temperature <= 0 or best_cost == 0:
break

        neighbor = get_neighbor(current)
neighbor_cost = cost(neighbor)
        delta = current_cost - neighbor_cost

        if delta > 0 or random.random() < math.exp(delta / temperature):
            current, current_cost = neighbor, neighbor_cost
if neighbor_cost < best_cost:
                best, best_cost = neighbor[:], neighbor_cost

        temperature *= cooling_rate

    return best, best_cost

def print_board(state):

    n = len(state)     for
row in range(n):
        line = " ".join("Q" if state[col] == row else "." for col in range(n))
print(line)
    print()


n = 8 solution, cost_val = simulated_annealing(n,
max_iter=20000) print("Best position found:", solution)
print(f"Number of non-attacking pairs: {n*(n-1)//2 - cost_val}") print("\nBoard:")
print_board(solution)
```

Output



Program 6

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

Algorithm

LAB-5

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

Pseudocode

function TT_entails (KB, α) returns true or false:
  Inputs: KB - the knowledge base of propos
    α - the query
  symbols ← a list of the propositional symbols in KB and α.
  return TT_check_all (KB, α, symbols, [ ], model)

function TT_check_all (KB, α, symbols, model) returns true or false:
  if EMPTY(symbols) then
    if PL_true? (KB, model) then return
      PL_true?(α, model)
    else return true // when KB is false, always return true
  else do
    P ← First (symbols)
    rest ← Rest (symbols)
    return TT_check_all (KB, α, rest, model ∪ {P=true})
      and TT_check_all (KB, α, rest, model ∪ {P=false})

5) Consider a knowledge base KB that contains the following propositional logic sentences:
Q→P
P→¬R→Q
R∨R

i) Construct a truth table that shows the truth values of each sentence in KB and indicate the models in which KB is true

Q	P	R	Q→P	P→¬R→Q	R∨R	KB
T	T	T	T	T	T	T
T	T	F	T	T	T	T
T	F	T	F	T	T	F
T	F	F	F	T	F	F
F	T	T	T	T	T	T ✓
F	T	F	T	F	F	F
F	F	T	T	T	T	T ✓
F	F	F	T	F	F	F

ii) Does KB entail R?
Yes Because whenever KB is true, R is also true

iii) Does KB entail R→P?

Q	P	R	R→P	KB
T	T	T	T	T
T	T	F	T	T
T	F	T	F	F
T	F	F	T	F
F	T	T	T	T ✓
F	T	F	T	T
F	F	T	F	F ✗
F	F	F	T	F

No. Because R→P is not true whenever KB is true

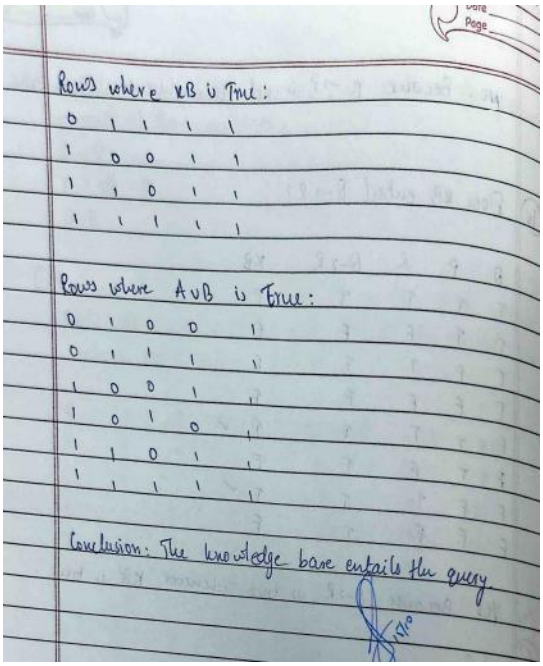
iv) Does KB entail Q→R?

Q	P	R	Q→R	KB
T	T	T	T	T
T	T	F	F	F
T	F	T	T	T
T	F	F	T	T
F	T	T	T	T ✓
F	T	F	T	F
F	F	T	T	T ✓
F	F	F	T	F

Yes Because Q→P is true whenever KB is true.

6) KB = A∨(B∨C)∧(B∨¬C)
α = A∨B
check if KB ⊨ α

A	B	C	A∨C	B∨¬C	A∧KB	A∨B
0	0	0	0	1	0	0
0	0	1	1	0	0	0
0	1	0	0	1	0	1
0	1	1	1	1	1	1
1	0	0	1	1	1	1
1	0	1	1	0	0	1
1	1	0	1	1	1	1
1	1	1	1	1	1	1

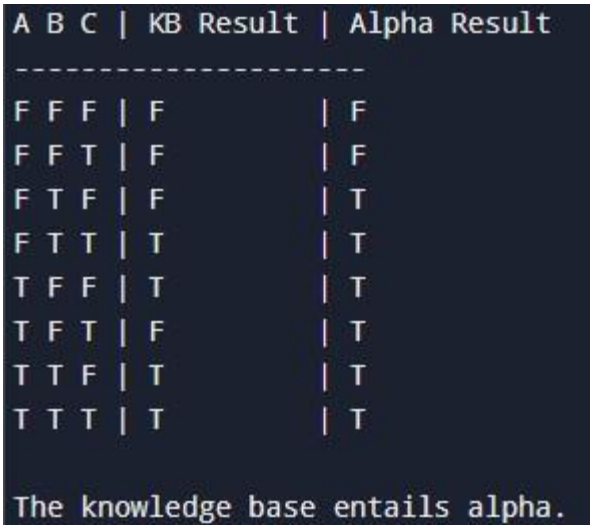


Code

```
import itertools def evaluate_formula(formula,
truth_assignment):
   eval_formula = formula     for symbol, value
in truth_assignment.items():
       eval_formula = eval_formula.replace(symbol, str(value))
return eval(eval_formula)

def generate_truth_table(variables):
   return list(itertools.product([False, True], repeat=len(variables)))

def is_entailed(KB_formula, alpha_formula, variables):
truth_combinations = generate_truth_table(variables)
print(f"{' '.join(variables)} | KB Result | Alpha Result")
print("-" * (len(variables) * 2 + 15))     for combination in
truth_combinations:
       truth_assignment = dict(zip(variables, combination))        KB_value =
evaluate_formula(KB_formula, truth_assignment)        alpha_value =
evaluate_formula(alpha_formula, truth_assignment)        result_str = " ".join(["T" if
value else "F" for value in combination])        print(f"{result_str} | {'T' if KB_value
else 'F'}        | {'T' if alpha_value else 'F'}")        if KB_value and not alpha_value:
           return False
   return True

KB = "(A or C) and (B or not C)"
```

```
alpha = "A or B"
variables = ['A', 'B', 'C']

if is_entailed(KB, alpha, variables):
   print("\nThe knowledge base entails alpha.") else:
print("\nThe knowledge base does not entail alpha.")
```

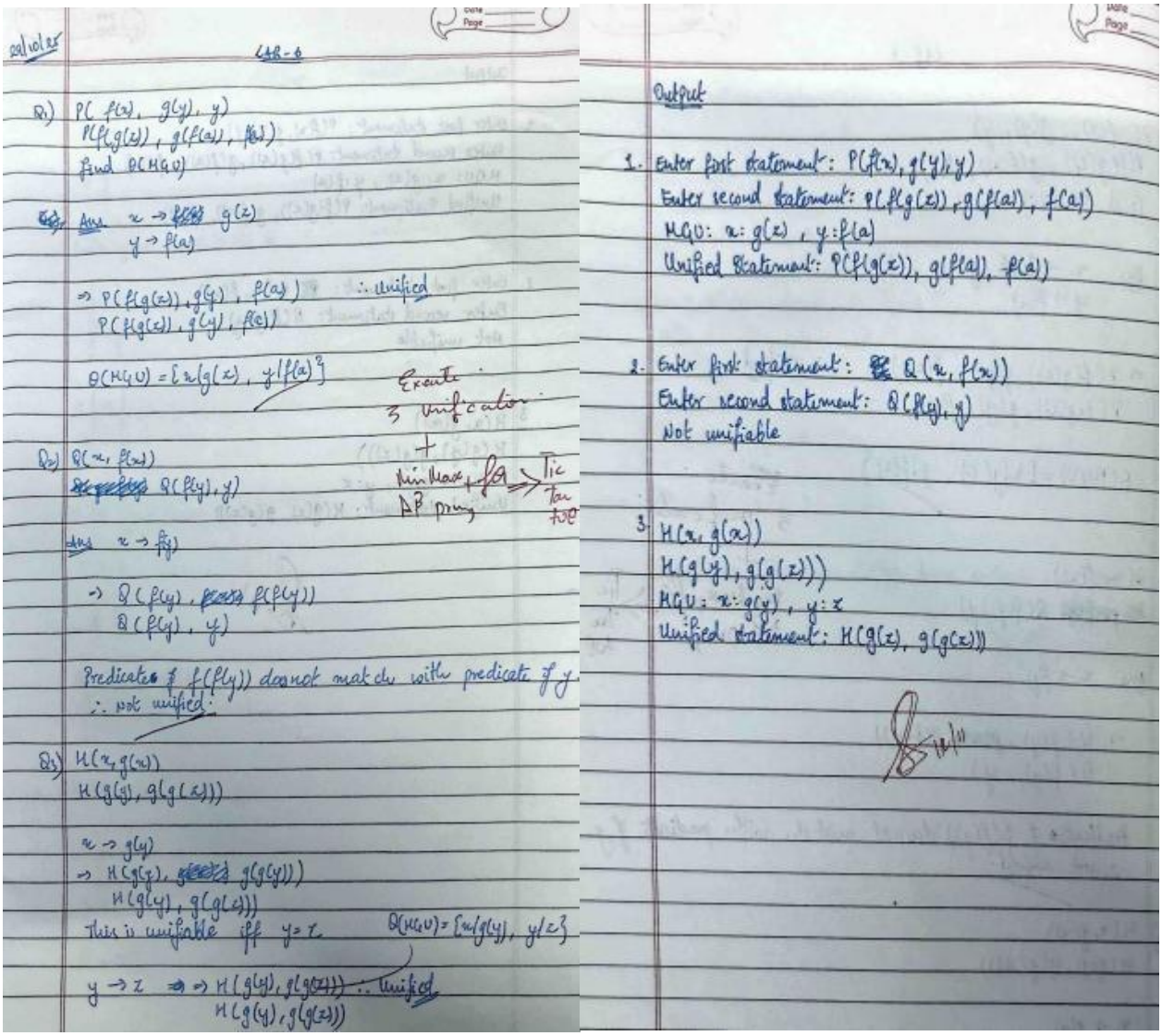
Output



Program 7

Implement unification in first order logic

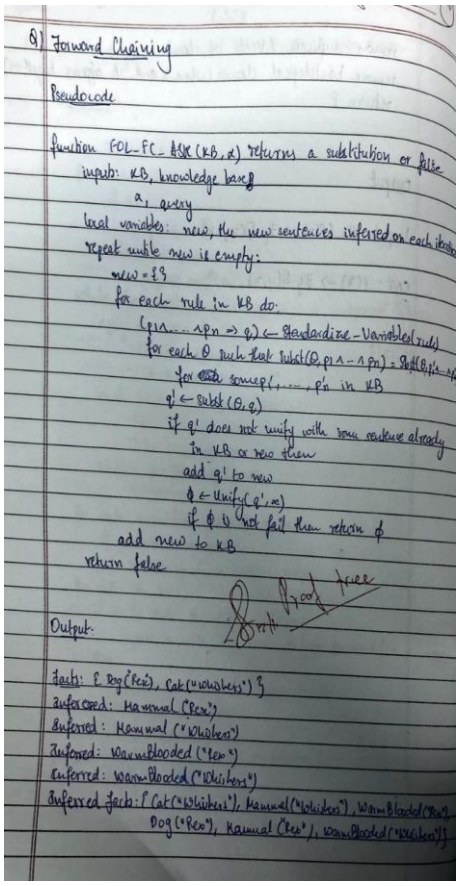
Algorithm



Program 8

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

Algorithm



Code

```
import re

def match_pattern(pattern, fact):
    """
    Checks if a fact matches a rule pattern using regex-style variable substitution.
    Variables are lowercase words like p, q, x, r etc.
    Returns a dict of substitutions or None if not matched.
    """
    # Extract predicate name and arguments
pattern_pred, pattern_args = re.match(r'(\w+)
', pattern).groups()
    fact_pred, fact_args = re.match(r'(\w+)
', fact).groups()

    if pattern_pred != fact_pred:
        return None  # predicate mismatch
```

```
    pattern_args = [a.strip() for a in pattern_args.split(",")]
fact_args = [a.strip() for a in fact_args.split(",")]

    if len(pattern_args) != len(fact_args):
        return None

    subst = {}      for p_arg, f_arg in
zip(pattern_args, fact_args):          if
re.fullmatch(r'[a-z]\w*', p_arg):  # variable
subst[p_arg] = f_arg          elif p_arg != f_arg:  #
constants mismatch
            return None
    return subst


def apply_substitution(expr, subst):
    """Replaces all variable names in expr using the given substitution dict."""
for var, val in subst.items():
        expr = re.sub(rf'\b{var}\b', val, expr)
return expr


# ---------- Knowledge Base ----------

rules = [
    (["American(p)", "Weapon(q)", "Sells(p,q,r)", "Hostile(r)"], "Criminal(p)"),
    (["Missile(x)"], "Weapon(x)"),
    (["Enemy(x, America)"], "Hostile(x)"),
    (["Missile(x)", "Owns(A, x)"], "Sells(Robert, x, A)")
]

facts = {
    "American(Robert)",
    "Enemy(A, America)",
    "Owns(A, T1)",
    "Missile(T1)"
}

goal = "Criminal(Robert)"

def forward_chain(rules, facts, goal):
    added = True
    while added:          added = False
for premises, conclusion in rules:
```

```
        possible_substs = []
for p in premises:
for f in facts:
                subst = match_pattern(p, f)
if subst:
                    possible_substs.append(subst)
                    break
else:

break
else:

            combined = {}
for s in possible_substs:
combined.update(s)

            new_fact = apply_substitution(conclusion, combined)

            if new_fact not in facts:
facts.add(new_fact)
print(f"Inferred: {new_fact}")
added = True                    if new_fact ==
goal:
                    return True
   return goal in facts


print("Goal achieved:", forward_chain(rules, facts, goal))
```

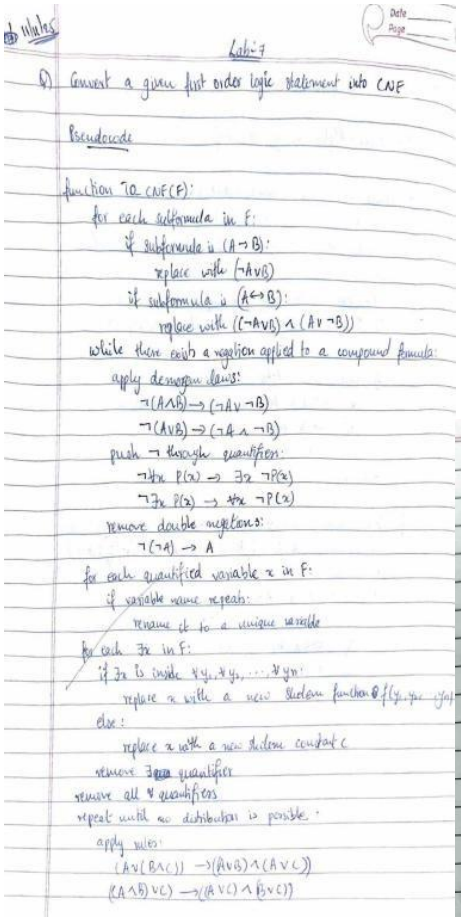
Output

```
Inferred: Weapon(T1)
Inferred: Hostile(A)
Inferred: Sells(Robert, T1, A)
Inferred: Criminal(Robert)
Goal achieved: True
```

Program 9

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

Algorithm

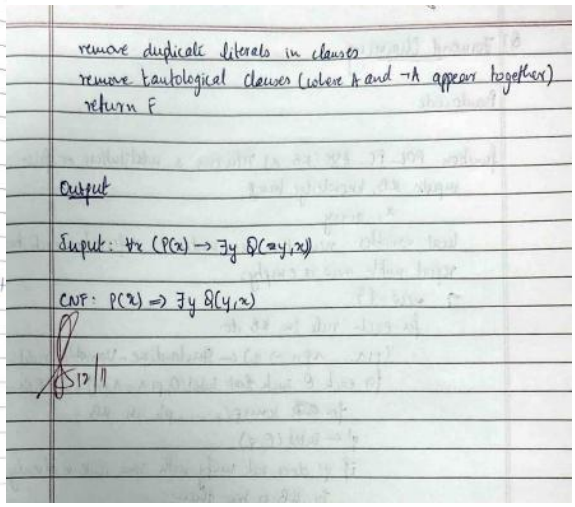


Lab-7

1) Convert a given first order logic statement into CNF

Pseudocode

function TO_CNF(F):
for each subformula in F:
if subformula is (A → B):
replace with (¬A ∨ B)
if subformula is (A ↔ B):
replace with ((¬A ∨ B) ∧ (A ∨ ¬B))
while there exists a negation applied to a compound formula:
apply demorgan laws:
¬(A ∧ B) → (¬A ∨ ¬B)
¬(A ∨ B) → (¬A ∧ ¬B)
push ¬ through quantifiers:
¬∀x P(x) → ∃x ¬P(x)
¬∃x P(x) → ∀x ¬P(x)
remove double negations:
¬(¬A) → A
for each quantified variable x in F:
if variable name repeats:
rename it to a unique variable
for each ∃x in F:
if ∃x is inside ∀y1, ∀y2, ..., ∀yn:
replace x with a new Skolem function f(y1, y2, ...)
else:
replace x with a new Skolem constant c
remove ∃ quantifier
remove all ∀ quantifiers
repeat until no distribution is possible:
apply rules:
(A ∨ (B ∧ C)) → ((A ∨ B) ∧ (A ∨ C))
((A ∧ B) ∨ C) → ((A ∨ C) ∧ (B ∨ C))



remove duplicate literals in clauses
remove tautological clauses (where A and ¬A appear together)
return F

Output

Input: ∀x (P(x) → ∃y Q(x,y))

CNF: P(x) ⇒ ∃y Q(y,x)

12/11

Code

```
from copy import deepcopy

def print_step(title, content):
   print(f"\n{'='*45}\n{title}\n{'='*45}")
if isinstance(content, list):         for i, c in
enumerate(content, 1):
          print(f"{i}. {c}")
else:
       print(content)
```

```
KB = [
   ["¬Food(x)", "Likes(John,x)"],
   ["Food(Apple)"],
   ["Food(Vegetable)"],
   ["¬Eats(x,y)", "Killed(x)", "Food(y)"],
   ["Eats(Anil,Peanuts)"],
   ["Alive(Anil)"],
   ["¬Alive(x)", "¬Killed(x)"],
   ["Killed(x)", "Alive(x)"]
]

QUERY = ["Likes(John,Peanuts)"]

def negate(literal):     if
literal.startswith("¬"):
       return literal[1:]
return "¬" + literal

def substitute(clause, subs):
   new_clause = []     for lit in
clause:         for var, val in
subs.items():             lit =
lit.replace(var, val)
new_clause.append(lit)
   return new_clause

def unify(lit1, lit2):
   """Small unifier for patterns like Food(x) and Food(Apple)."""
if "(" not in lit1 or "(" not in lit2:         return None     pred1,
args1 = lit1.split("(")     pred2, args2 = lit2.split("(")     args1 =
args1[:-1].split(",")     args2 = args2[:-1].split(",")     if pred1 !=
pred2 or len(args1) != len(args2):
       return None     subs = {}
for a, b in zip(args1, args2):
if a == b:             continue
if a.islower():             subs[a]
= b         elif b.islower():
subs[b] = a         else:
           return None
   return subs

def resolve(ci, cj):
   """Return list of (resolvent, substitution, pair)."""
resolvents = []     for li in ci:         for lj in cj:
if li == negate(lj):
```

```
            new_clause = [x for x in ci if x != li] + [x for x in cj if x != lj]
resolvents.append((list(set(new_clause)), {}, (li, lj)))            else:
            # same predicate, opposite sign                if li.startswith("¬") and not
lj.startswith("¬") and li[1:].split("(")[0] == lj.split("(")[0]:
                subs = unify(li[1:], lj)
if subs:
                    new_clause = substitute([x for x in ci if x != li] + [x for x in cj if x != lj], subs)
resolvents.append((list(set(new_clause)), subs, (li, lj)))                elif lj.startswith("¬") and not
li.startswith("¬") and lj[1:].split("(")[0] == li.split("(")[0]:
                subs = unify(lj[1:], li)
if subs:
                    new_clause = substitute([x for x in ci if x != li] + [x for x in cj if x != lj], subs)
resolvents.append((list(set(new_clause)), subs, (li, lj)))     return resolvents

def resolution(kb, query):     clauses =
deepcopy(kb)     negated_query = [negate(q)
for q in query]
clauses.append(negated_query)
   print_step("Initial Clauses", clauses)

   steps = []
new = []
while True:
      pairs = [(clauses[i], clauses[j]) for i in range(len(clauses))
            for j in range(i + 1, len(clauses))]
for (ci, cj) in pairs:             for r, subs, pair
in resolve(ci, cj):                if not r:
                steps.append({
                   "parents": (ci, cj),
                   "resolvent": r,
                   "subs": subs
                })
                print_tree(steps)                  print("\n☑ Empty
clause derived — query proven.")                    return True
if r not in clauses and r not in new:
                new.append(r)
steps.append({                      "parents":
(ci, cj),
                   "resolvent": r,
                   "subs": subs
                })
      if all(r in clauses for r in new):
         print_step("No New Clauses", "Query cannot be proven ❌")
print_tree(steps)           return False
```

```
        clauses.extend(new)

def print_tree(steps):     print("\n"
+ "="*45)     print("Resolution
Proof Trace")     print("="*45)
for i, s in enumerate(steps, 1):
        p1, p2 = s["parents"]         r = s["resolvent"]
subs = s["subs"]         subs_text = f"  Substitution:
{subs}" if subs else ""

        print(f"  Resolve {p1} and {p2}")
if subs_text:
            print(subs_text)
if r:                print(f"  ⇒
{r}")         else:
            print("  ⇒ {} (empty clause)")         print("-
"*45)

def main():
   print_step("Knowledge Base in CNF", KB)
print_step("Negated Query", [negate(q) for q in QUERY])
proven = resolution(KB, QUERY)     if proven:         print("\n☑
Query Proven by Resolution: John likes peanuts.")     else:
        print("\n❌ Query cannot be proven from KB.")

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

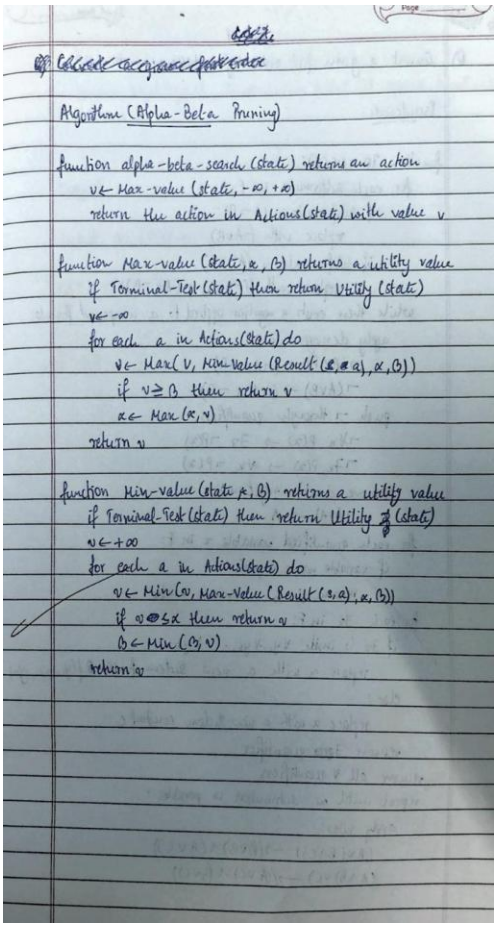
Output

```
Unifying: P(f(x),g(y),y)  and  P(f(g(z)),g(f(a)),f(a
    ))
=> Substitution: x : g(z), y : f(a)

Unifying: Q(x,f(x))  and  Q(f(y),y)
=> Not unifiable.

Unifying: H(x,g(x))  and  H(g(y),g(g(z)))
=> Substitution: x : g(y), y : z

=== Code Execution Successful ===
```

Program 10

Implement Alpha-Beta Pruning

Algorithm



Algorithm (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
if Terminal-Test (state) then return Utility (state)
v ← -∞
for each a in Actions(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 return 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

Code

```
def unify(a, b):
    """Very simple unification for small terms like ('line', [X,O,X])"""
if a == b:          return {}      if isinstance(a, str) and a.islower():  #
variable
        return {a: b}      if isinstance(b,
str) and b.islower():
        return {b: a}      if isinstance(a, tuple) and
isinstance(b, tuple):          if a[0] != b[0] or
len(a[1]) != len(b[1]):
            return None          subs
= {}          for x, y in zip(a[1],
```

```
b[1]):            s = unify(x, y)
if s is None:                return
None            subs.update(s)
return subs
   return None


# Winning triples (rows, cols, diagonals)
WIN_TRIPLES = [(0,1,2),(3,4,5),(6,7,8),(0,3,6),(1,4,7),(2,5,8),(0,4,8),(2,4,6)]

def winner(board):
   pattern = ('line', ['X','X','X'])     for i,j,k in
WIN_TRIPLES:         term = ('line', [board[i],
board[j], board[k]])         if unify(term, pattern):
          return 'X'         if unify(term,
('line',['O','O','O'])):
          return 'O'
   return None

def is_full(board): return all(c != '_' for c in board)

def evaluate(board):     w =
winner(board)     if w ==
'X': return 1     if w == 'O':
return -1     if
is_full(board): return 0
   return None

def alpha_beta(board, player, alpha=-float('inf'), beta=float('inf')):
   val = evaluate(board)
if val is not None:
return val, None

   moves = [i for i,c in enumerate(board) if c == '_']
   best_move = None
if player == 'X':
      max_eval = -float('inf')
for m in moves:
          new_board = board[:]            new_board[m] = 'X'
eval_, _ = alpha_beta(new_board, 'O', alpha, beta)
if eval_ > max_eval:
             max_eval, best_move = eval_, m
alpha = max(alpha, eval_)            if beta
<= alpha: break
```

```
        return max_eval, best_move
else:
        min_eval = float('inf')
for m in moves:
            new_board = board[:]            new_board[m] = 'O'
eval_, _ = alpha_beta(new_board, 'X', alpha, beta)
if eval_ < min_eval:                min_eval, best_move =
eval_, m            beta = min(beta, eval_)            if beta
<= alpha: break
        return min_eval, best_move

def print_board(b):
for i in range(0,9,3):
        print(' '.join(b[i:i+3]))
print()

# --- Example usage --- board =
['_']*9 score, move =
alpha_beta(board, 'X') print("Best
first move for X:", move)
board[move] = 'X'
print_board(board)
```

Output