VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

Afreen Anz(1BM23CS016)

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 **Afreen Anz (1BM23CS016),** 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.

Prof. Swati Sridharan Assistant Professor Department of CSE, BMSCE	**Dr. Kavitha Sooda** Professor &HOD Department of CSE, BMSCE

Index

Github Link:

https://github.com/1BM23CS047/AI-lab

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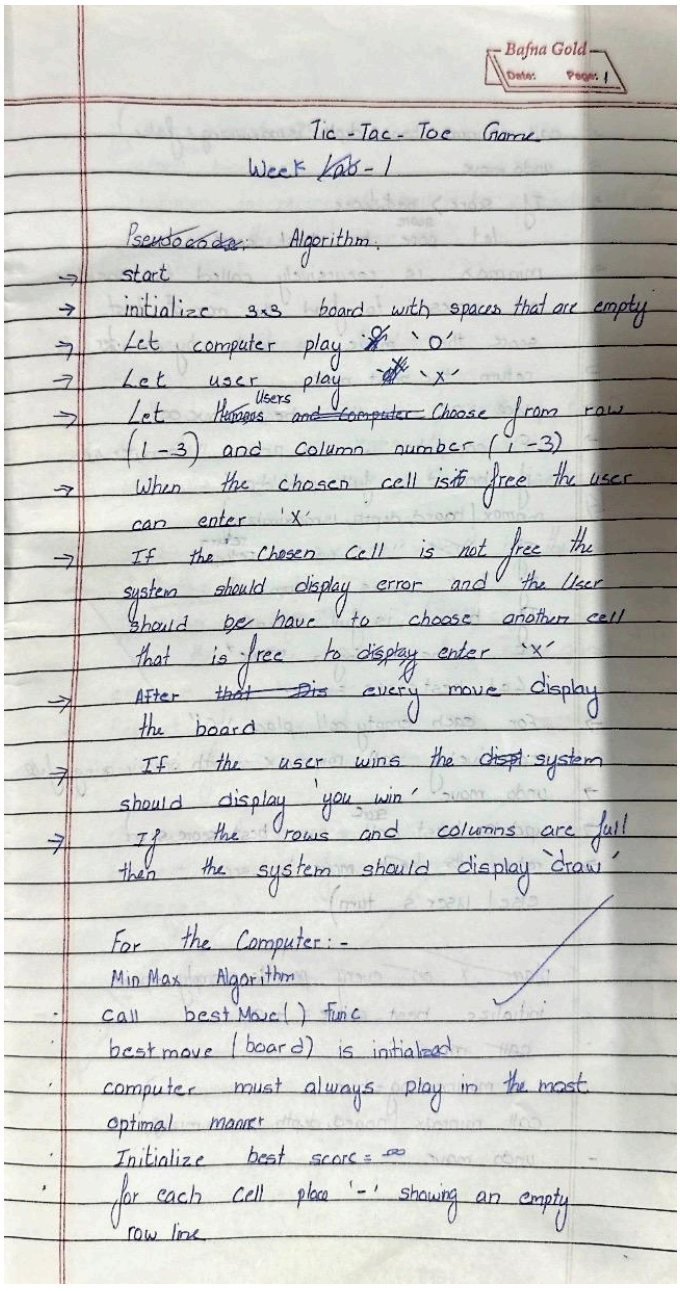
Program 1
Implement Tic –Tac –Toe Game
Implement vacuum cleaner agent

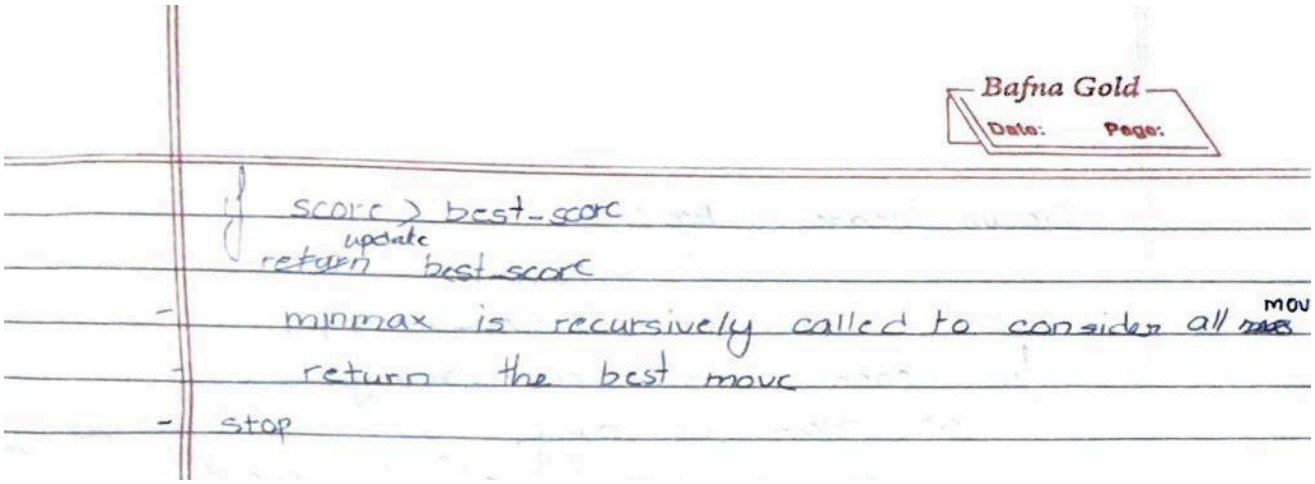
Tic-Tac-Toe

Algorithm



→ call minmax (board, depth, is maximizing = false)
→ undo move
→ If score > best score
let score be best_score
→ minmax is recursively called to consider all moves to find the move of best score, that move is made by computer
→ return the best move
→ place 'O' in the best move cell.
→ if computer wins → print "computer win"
if board is full print draw'
minmax (board, depth, is maximizing)
If "O" wins return +1
If "X" wins return -1
If board is full return 0
IF is maximizing = "True"
Let best score = -∞
→ For each empty cell place "O"
recursively call minmax with is maximizing = false
→ undo move
→ update best score = max (best_score, score)
→ return best move best_score
else (user's turn)

place X on every possible empty space
initialize best_score = +∞
call minmax
is maximizing = true
call minmax (board, depth, is maximizing)
- undo move



Code

```
import math

def print_board(board):
    for row in board:
        print(" | ".join(row))
        print("-" * 5)

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

def is_full(board):
    return all(cell != " " for row in board for cell in row)

def minimax(board, depth, is_maximizing, ai, human):
    if check_winner(board, ai):
        return 1
    if check_winner(board, human):
        return -1
    if is_full(board):
```

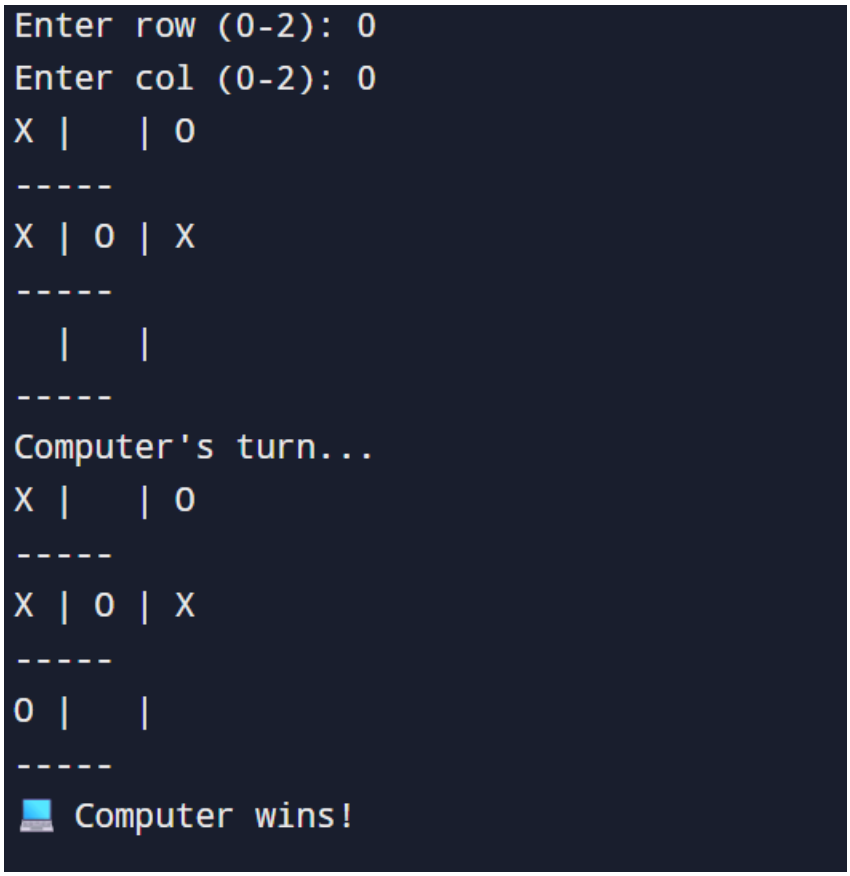
```
        return 0

    if is_maximizing:
        best = -math.inf
        for r in range(3):
            for c in range(3):
                if board[r][c] == " ":
                    board[r][c] = ai
                    score = minimax(board, depth + 1, False, ai, human)
                    board[r][c] = " "
                    best = max(best, score)
        return best
    else:
        best = math.inf
        for r in range(3):
            for c in range(3):
                if board[r][c] == " ":
                    board[r][c] = human
                    score = minimax(board, depth + 1, True, ai, human)
                    board[r][c] = " "
                    best = min(best, score)
        return best

def best_move(board, ai, human):
    best_score = -math.inf
    move = None
    for r in range(3):
        for c in range(3):
            if board[r][c] == " ":
                board[r][c] = ai
                score = minimax(board, 0, False, ai, human)
                board[r][c] = " "
                if score > best_score:
                    best_score = score
                    move = (r, c)
    return move

def tic_tac_toe():
    board = [[" " for _ in range(3)] for _ in range(3)]
    human, ai = "X", "O"

    print("Welcome to Tic-Tac-Toe!")
    print("You are X, Computer is O (Unbeatable AI)")
    print_board(board)

    while True:
        # Human move
```

```
        try:
            row = int(input("Enter row (0-2): "))
            col = int(input("Enter col (0-2): "))
        except ValueError:
            print("Invalid input. Try again.")
            continue

        if row not in [0,1,2] or col not in [0,1,2] or board[row][col] != " ":
            print("Invalid move! Try again.")
            continue

        board[row][col] = human
        print_board(board)

        if check_winner(board, human):
            print("🎉 You win!")
            break
        if is_full(board):
            print("It's a draw!")
            break

        # Computer move
        print("Computer's turn...")
        row, col = best_move(board, ai, human)
        board[row][col] = ai
        print_board(board)

        if check_winner(board, ai):
            print("💻 Computer wins!")
            break
        if is_full(board):
            print("It's a draw!")
            break

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

Output

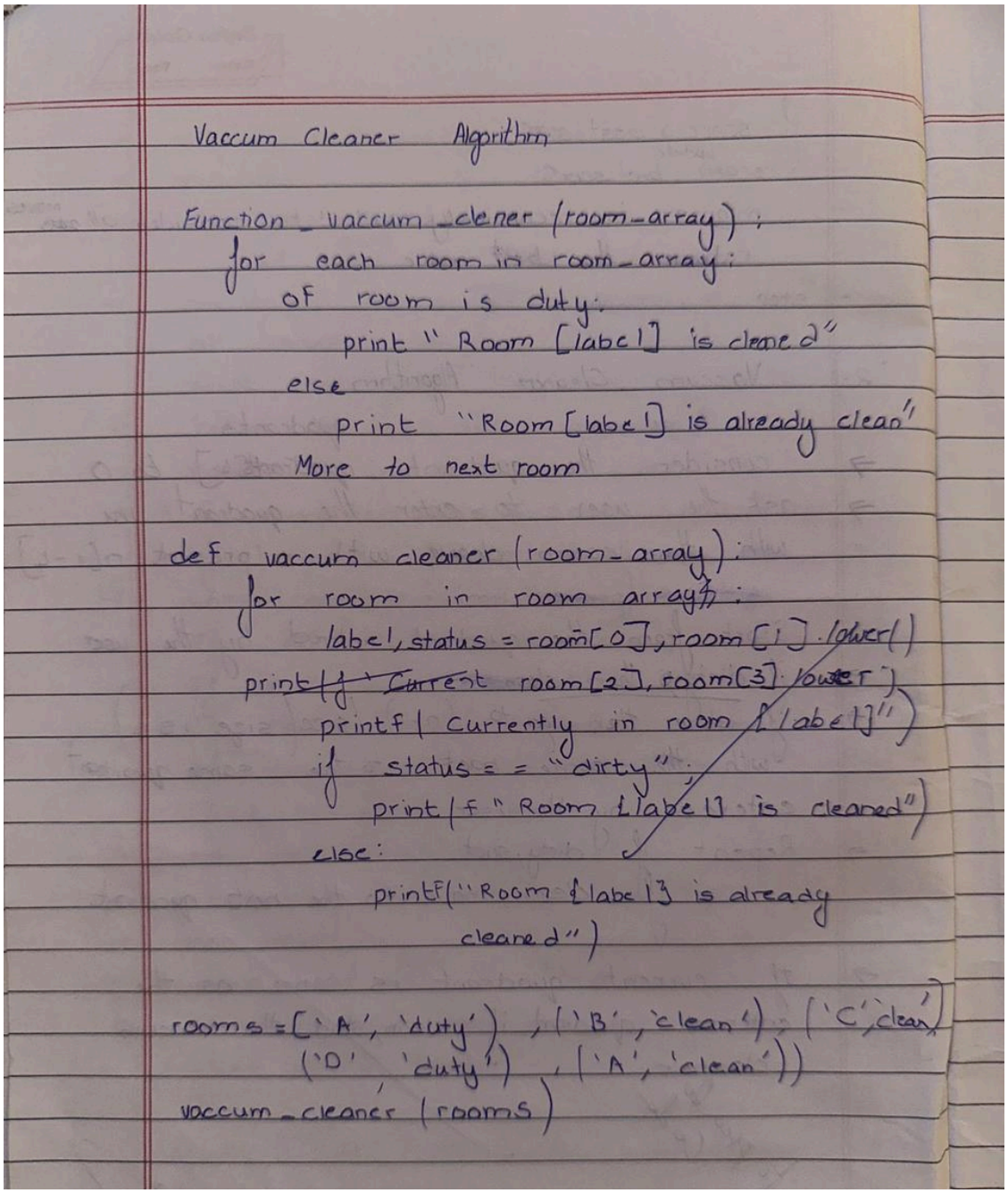
```
Welcome to Tic-Tac-Toe!
You are X, Computer is O (Unbeatable AI)
  |   |
-----
  |   |
-----
  |   |
-----
Enter row (0-2): 1
Enter col (0-2): 2
  |   |
-----
  |   | X
-----
  |   |
-----
Computer's turn...
  |   | O
-----
  |   | X
-----
  |   |
-----
```

```
Enter row (0-2): 1
Enter col (0-2): 0
  |   | O
-----
X |   | X
-----
  |   |
-----
Computer's turn...
  |   | O
-----
X | O | X
-----
  |   |
-----
```



Vacuum Cleaner

Algorithm



Code

```
def vacuum_cleaner(room_array):
    for room in room_array:
        label, status = room[0], room[1].lower()
        print(f"Currently in Room {label}")
        if status == "dirty":
            print(f"Room {label} is cleaned")
        else:
```

```
        print(f"Room {label} is already clean")
    print("Moving to next room...\n")

# Example input: list of rooms with their status
rooms = [('A', 'dirty'), ('B', 'clean'), ('A', 'clean'), ('B', 'dirty')]
vacuum_cleaner(rooms)
```

Output

```
Currently in Room A
Room A is cleaned
Moving to next room...

Currently in Room B
Room B is already clean
Moving to next room...

Currently in Room A
Room A is already clean
Moving to next room...

Currently in Room B
Room B is cleaned
Moving to next room...
```

Program 2

Implement 8 puzzle problems using Depth First Search (DFS)
Implement Iterative deepening search algorithm

8 Puzzle Problem

Algorithm

Date: Page:

Week ~~Lab~~ 2

Q) 8 puzzle problem using misplaced tiles and Manhattan distance and IDDFS

~~Initialize~~ 8 puzzle problem using misplaced tiles and Manhattan distance

Goal State
1 2 3
4 5 6
7 8 _

- Initialize by creating a priority queue (total cost so far)
- $F(n) = g(n) + h(n)$ - heuristic estimate
- Set $g(start) = 0$
- Set $f(start) = heuristic(start, goal)$
- Store parent[start] = null
- ~~Search loop~~
- insert start into openset
- Search loop while openset is not empty
- Remove the current with lowest f from openset

IF current = goal:

Return path by reconstructing from parent

Else expand current for each valid move of the blank tile:

- Generate neighbour with next move

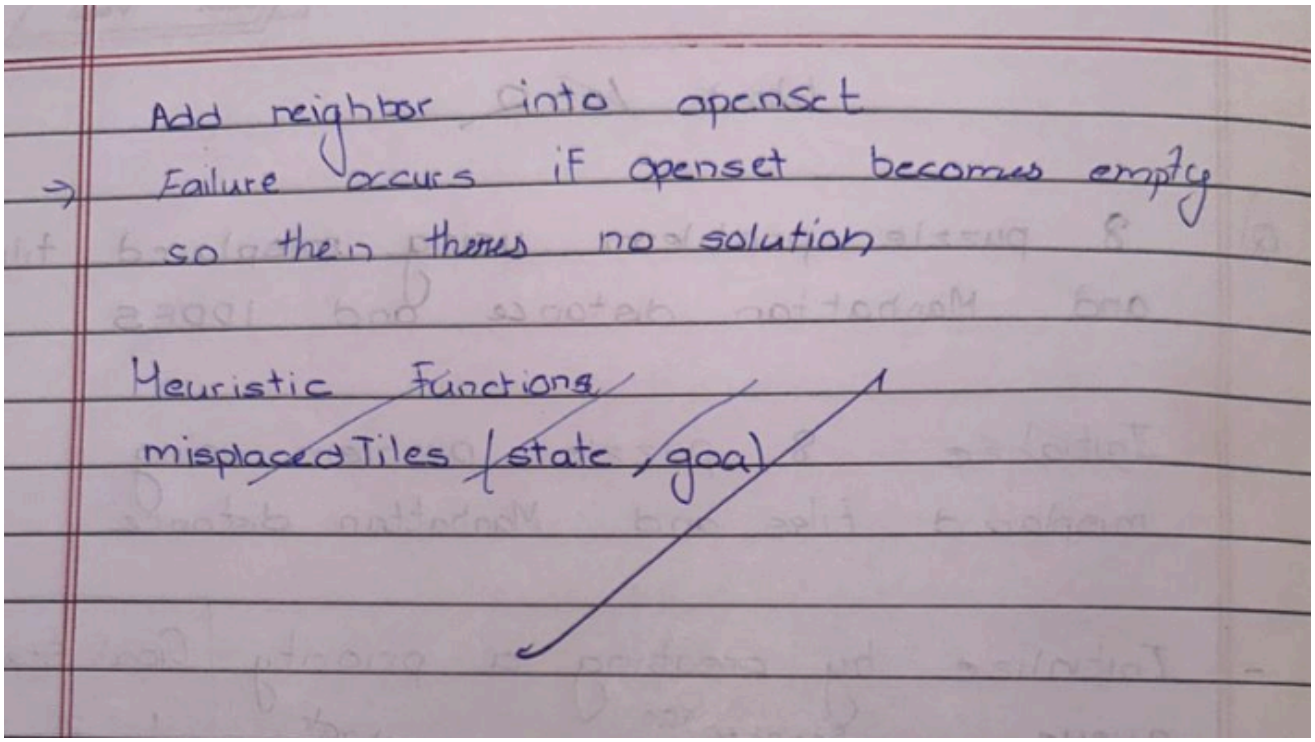
tentative_g = g(current) + 1

IF neighbour is not in gscore or tentative_g < g(neighbour):

Update g(neighbour) = tentative_g

Compute f(neighbor) = g(neighbor) + heuristic (neighbour, goal)

Set parent[neighbor] = current



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)
```

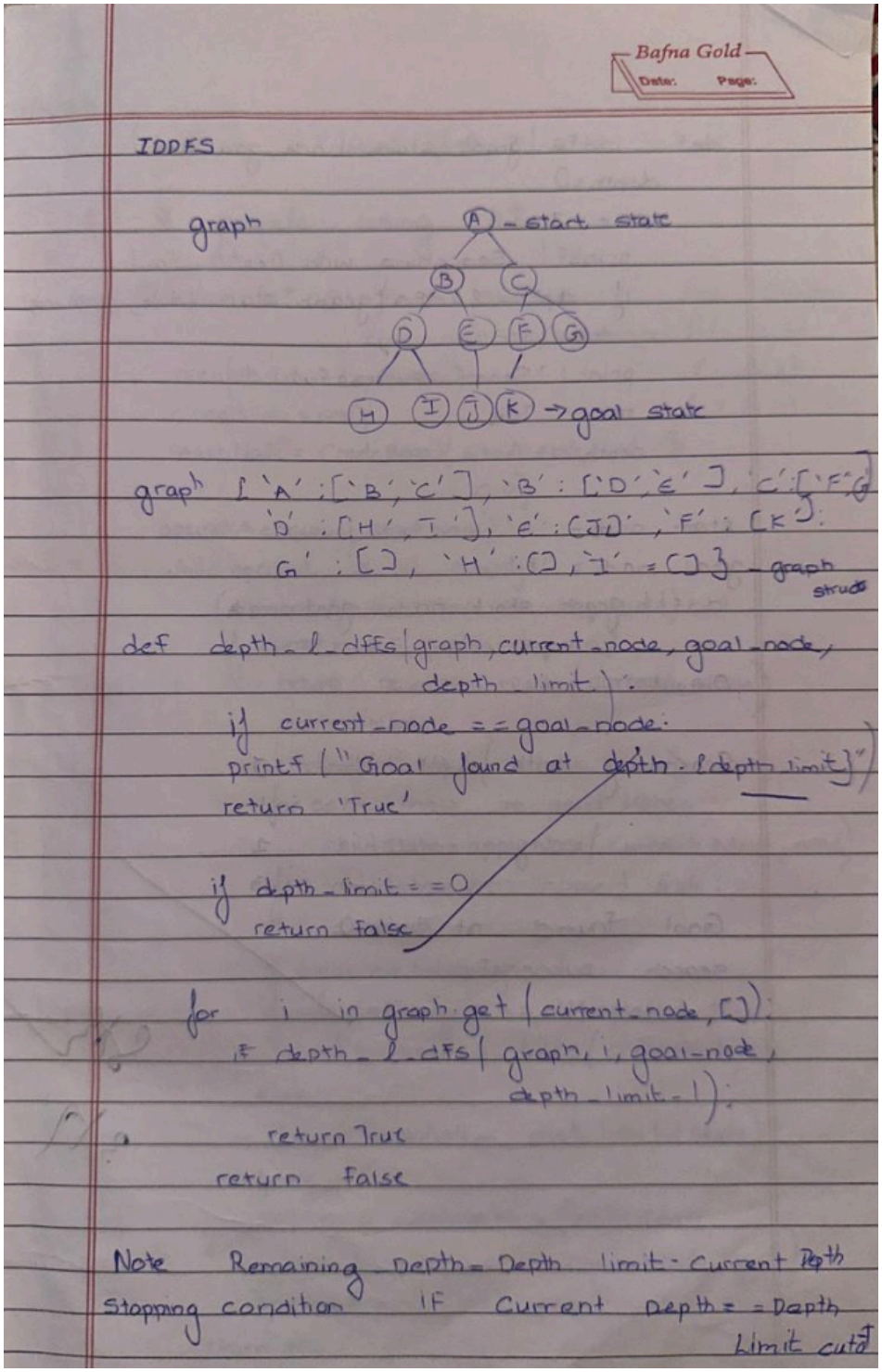
Output

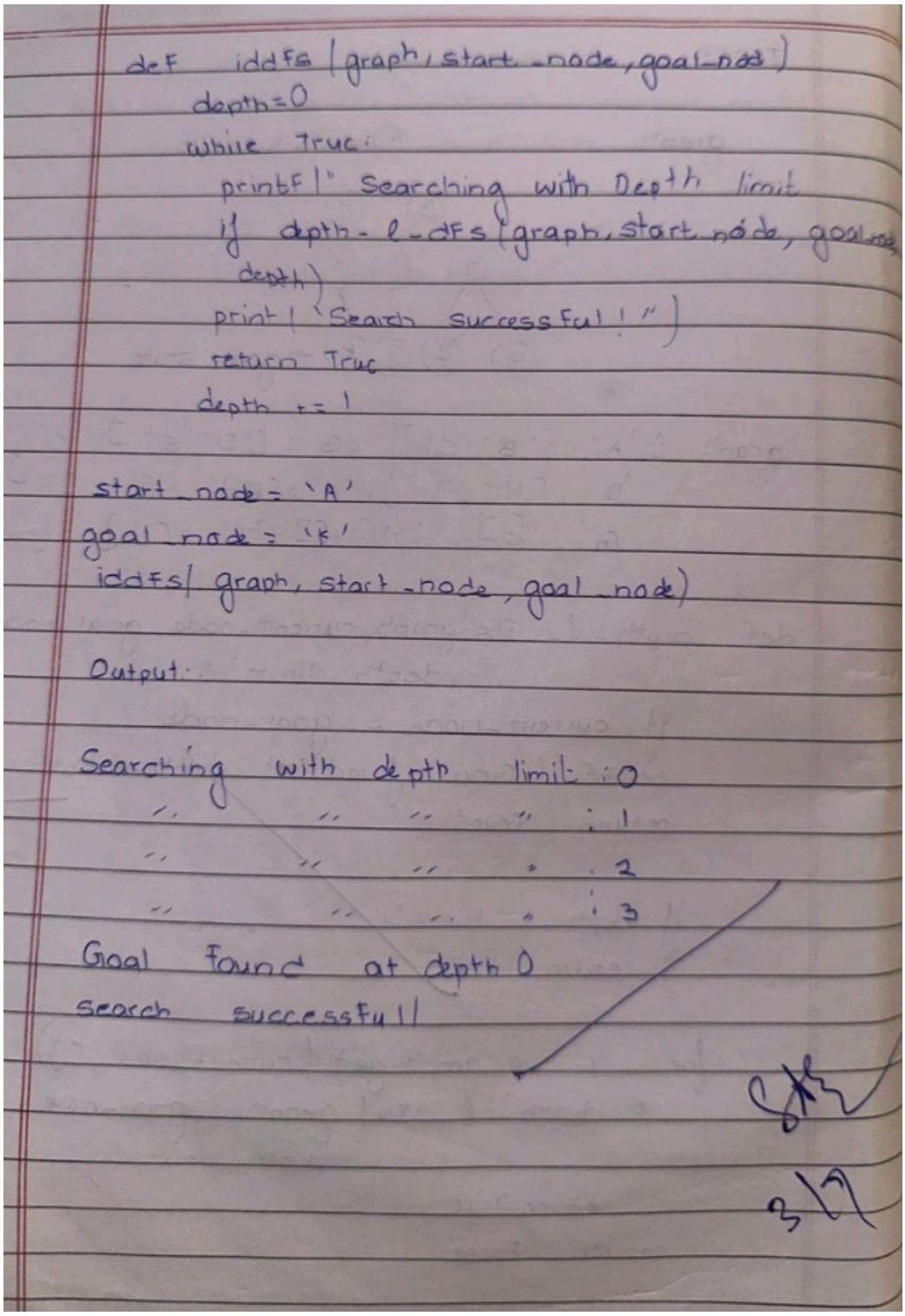
```
--- Depth 0 ---
State #1: [1, 2, 3, 4, 8, '_', 7, 6, 5]

--- 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)
```

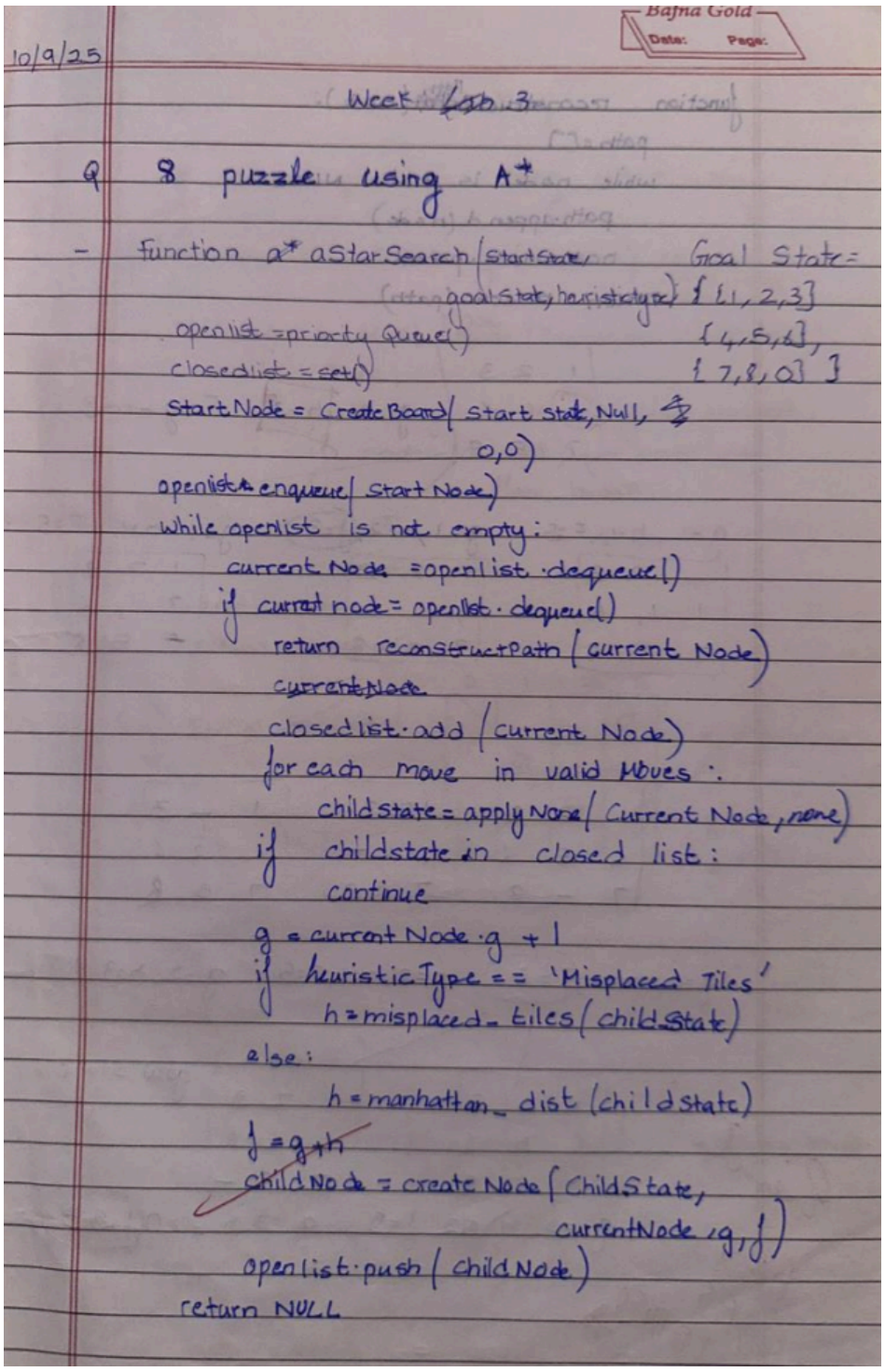
Output

```
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



10/9/25

Week 3

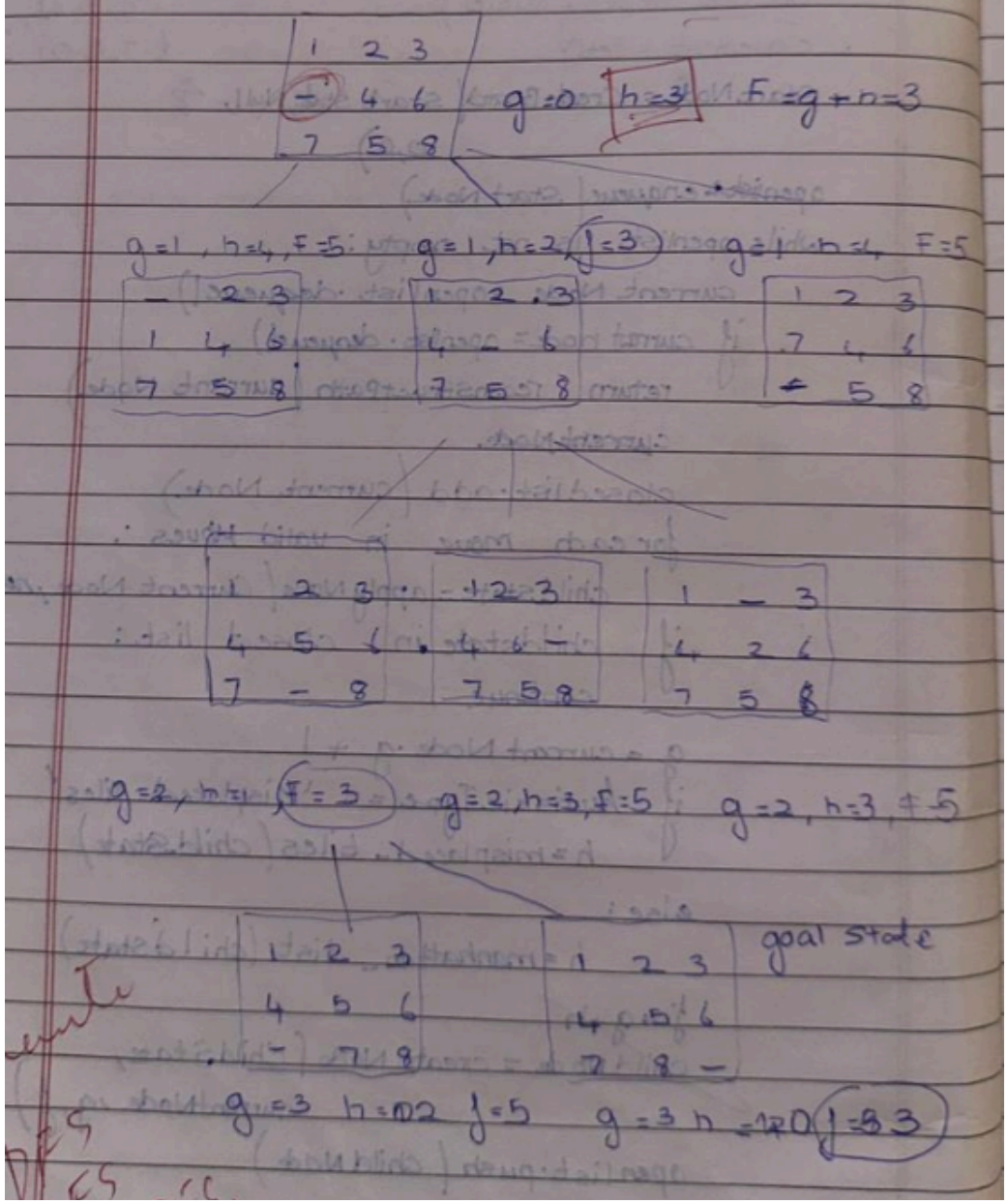
Q 8 puzzle using A*

- function a* aStarSearch (startState, goalState, heuristicType)

Goal State = { {1, 2, 3}, {4, 5, 6}, {7, 8, 0} }

openlist = priorityQueue()
closedlist = set()
StartNode = CreateBoard(start state, Null, 0,0)
openlist.enqueue(Start Node)
while openlist is not empty:
current Node = openlist.dequeue()
if current node = openlist.dequeue()
return reconstructPath (current Node)
closedlist.add (current Node)
for each move in valid Moves:
childstate = applyNone(Current Node, none)
if childstate in closed list:
continue
g = current Node.g + 1
if heuristic Type == 'Misplaced Tiles'
h = misplaced_tiles(child.State)
else:
h = manhattan_dist (childstate)
f = g+h
childNode = create Node (ChildState, currentNode, g, f)
openlist.push (child Node)
return NULL

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



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

8/10/25

Bafna Gold
Date: Page:

Week 4

Q N Queens problem Using Hill Climbing

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

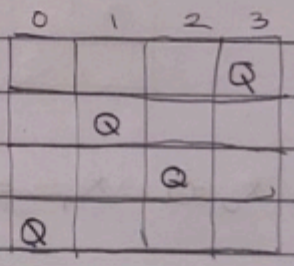
end if

current ← next

end while

return current

Eg) Initial State =

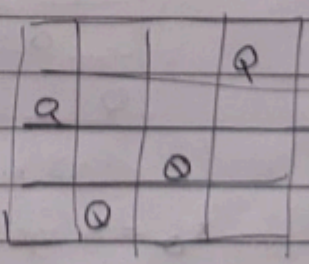


$x_0 = 3$
$x_1 = 1$
$x_2 = 2$
$x_3 = 0$

Cost = 2

Possible children

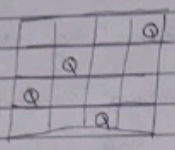
i) Swap (x_0, x_1)



Choose this

$x_0 = 1, x_1 = 3,$

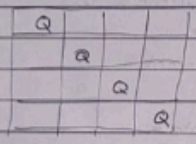
ii) Swap (x_0, x_2)



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

cost = 1

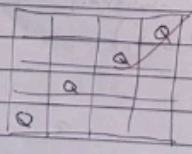
iii) Swap (x_0, x_3)



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

cost = 6

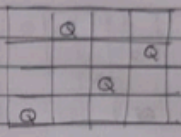
iv) Swap (x_1, x_2)



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

Cost = 6

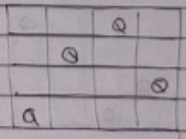
v Swap (x_1, x_3)



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

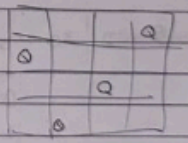
Cost = 1

vi Swap (x_2, x_3)



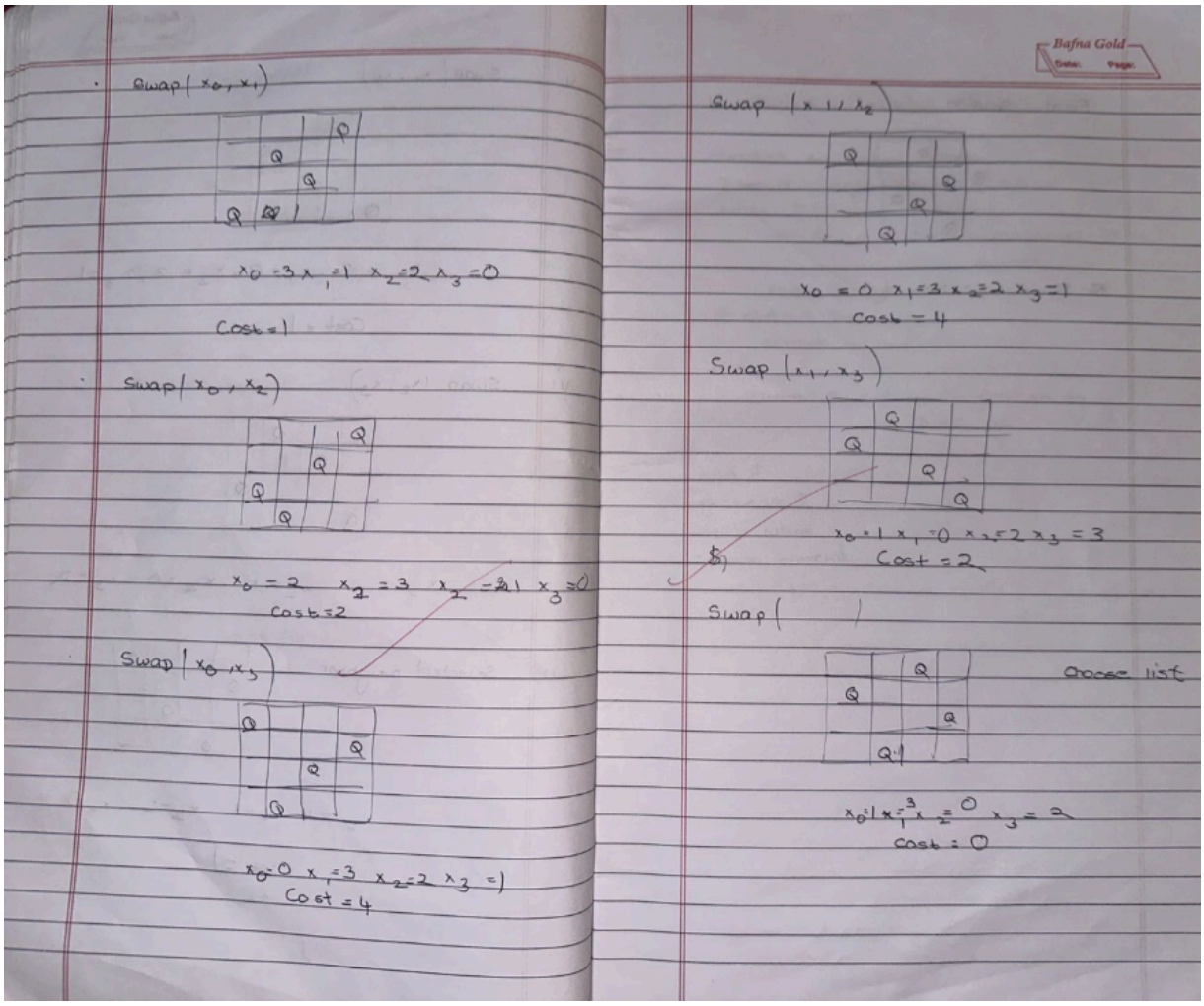
$x_0 = 3$ $x_1 = 1$ $x_2 = 0$ $x_3 =$

vii Selected neighbor =



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

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))
```

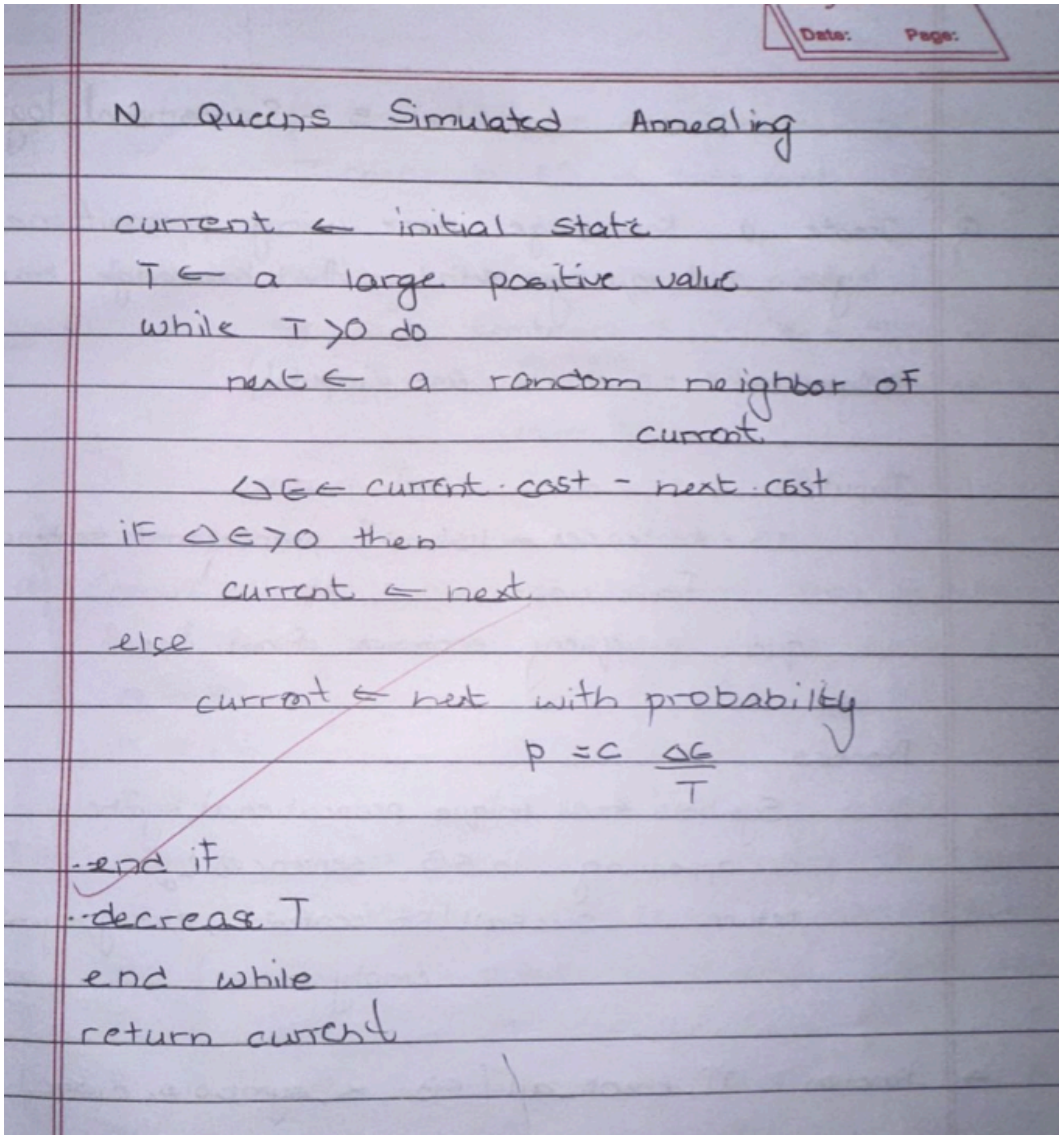
Output

```
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)
```

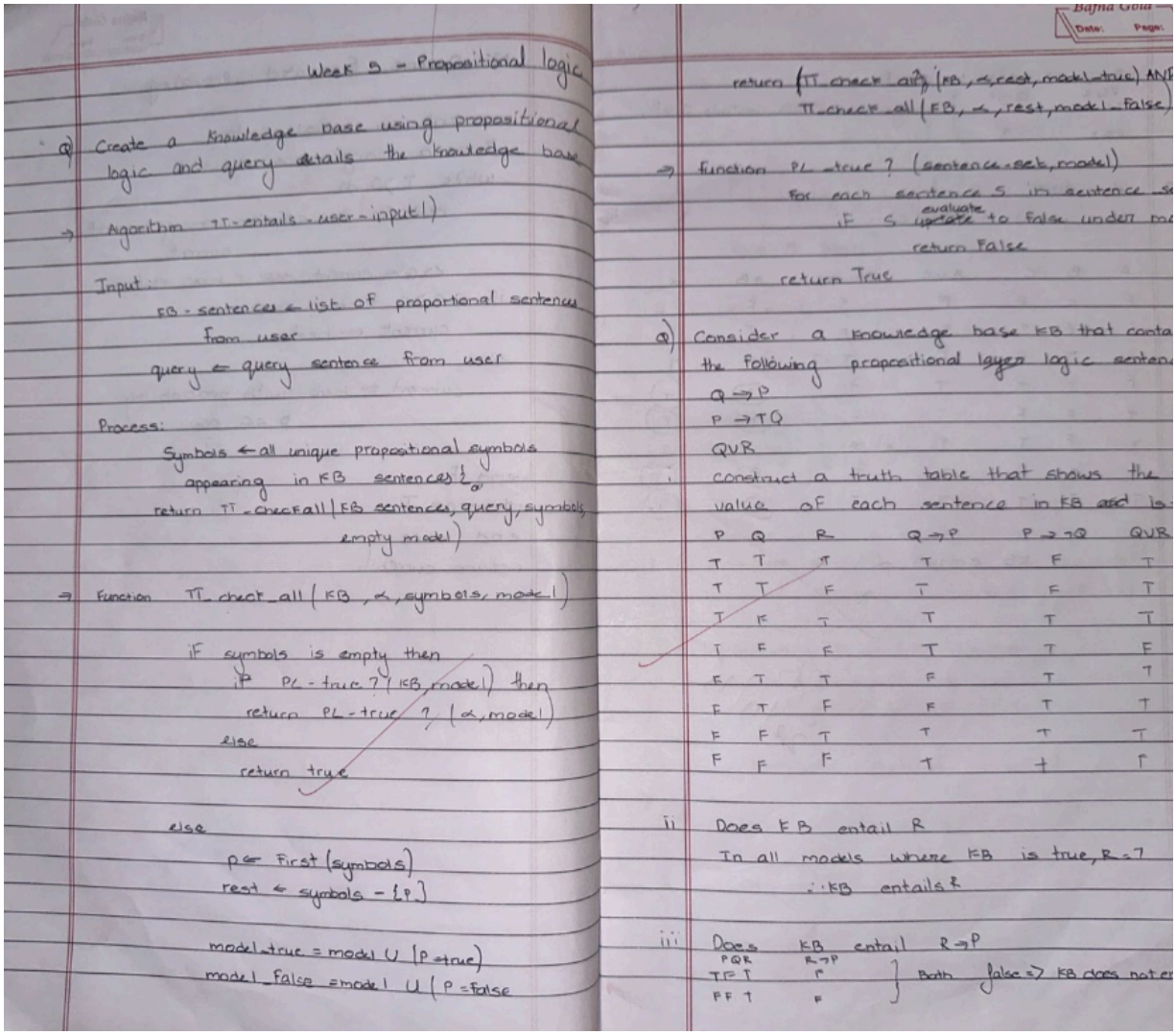
Output

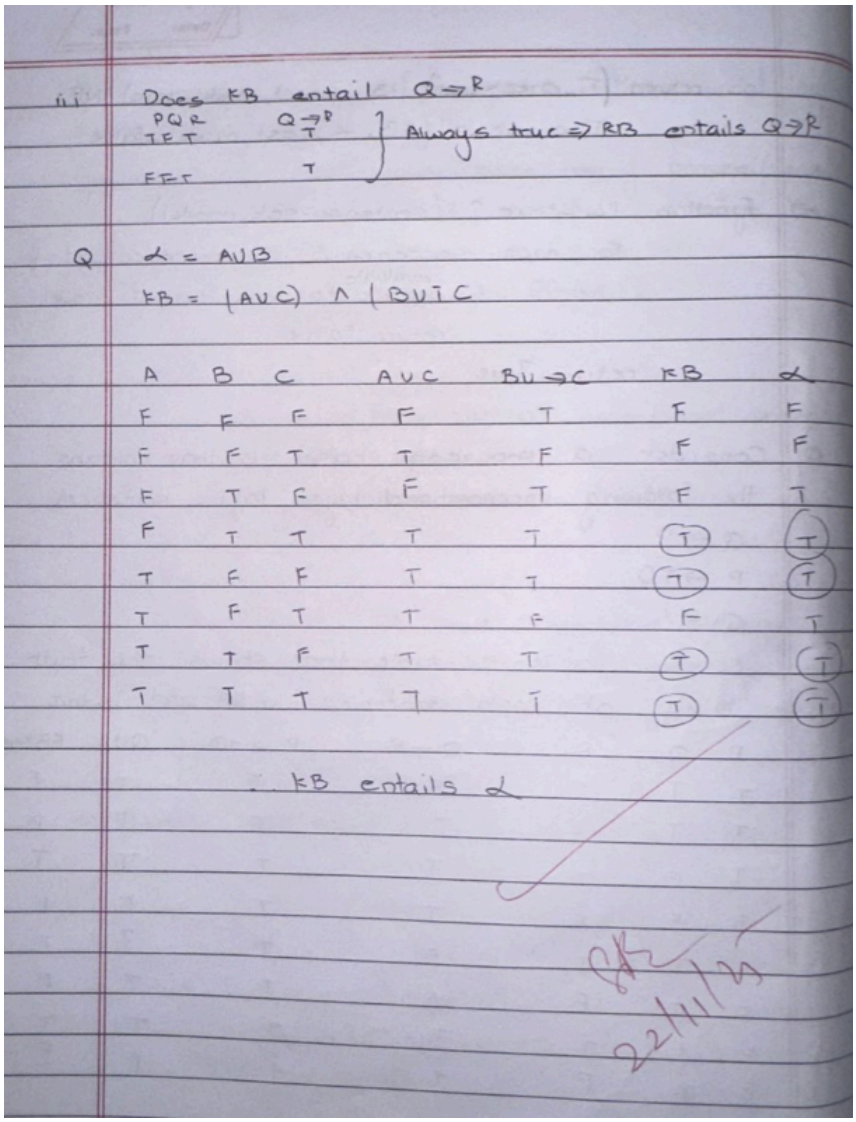
```
Best position found: [6, 3, 1, 7, 5, 0, 2, 4]
Number of non-attacking pairs: 28

Board:
. . . . . Q . .
. . Q . . . . .
. . . . . . Q .
. Q . . . . . .
. . . . . . . Q
. . . . Q . . .
Q . . . . . . .
. . . Q . . . .


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

Program 6

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

Algorithm





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.")
```

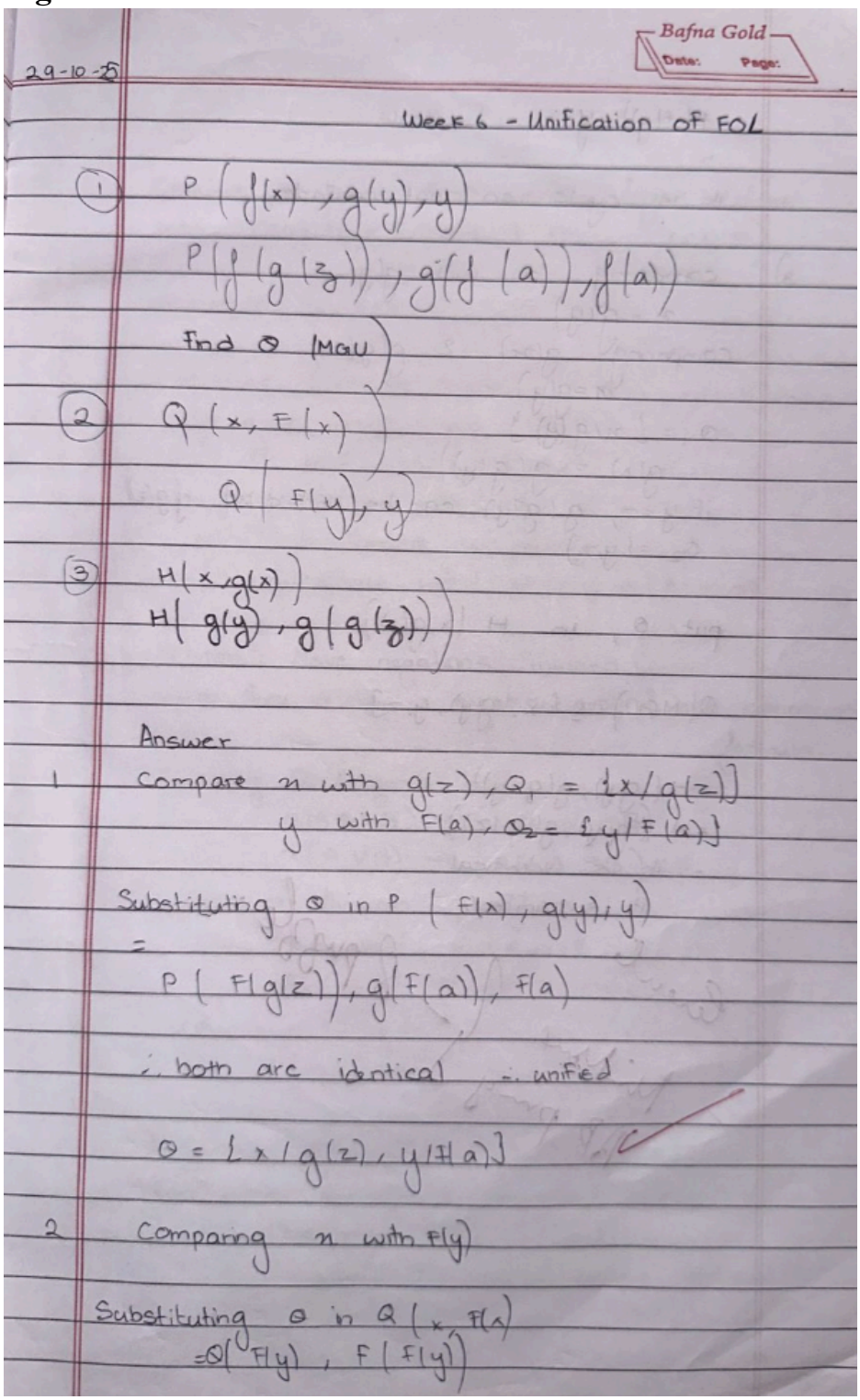
Output

```
A B C | KB Result | Alpha Result
---------------------
F F F | F         | F
F F T | F         | F
F T F | F         | T
F T T | T         | T
T F F | T         | T
T F T | F         | T
T T F | T         | T
T T T | T         | T

The knowledge base entails alpha.
```

Program 7

Implement unification in first order logic

Algorithm



29-10-25

Bafna Gold

Date: Page:

Week 6 - Unification of FOL

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. $H(x, g(x))$

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

Answer

1 Compare x with $g(z)$, $\Theta_1 = \{x/g(z)\}$

y with $F(a)$, $\Theta_2 = \{y/F(a)\}$

Substituting Θ in $P(F(x), g(y), y)$

=

$P(F(g(z)), g(F(a)), F(a))$

∴ both are identical ∴ unified

$\Theta = \{x/g(z), y/F(a)\}$

2 Comparing x with $F(y)$

Substituting Θ in $Q(x, F(x))$

$= \Theta(F(y), F(F(y)))$

$F(F(y)) = y$

it is cyclic so not unifable

3) comparing x with $g(y)$

$x = g(y)$

comparing $g(x)$ & $g(g(z))$

$x = g(y)$

$\theta_1 = \{x/g(y)\}$

$g(x) = g(g(y))$

if $y = z$, $g(g(y)$ can be unified but $g(g(z)$

$\theta_2 = \{y, z\}$

put θ_1 in $H(x, g(x))$

$\theta(MGU) = \{x, g(y), y, z\}$

$= H(g(y), g(g(y))$

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

∴ it is identical

∴ it is unifable

Resolution

Minimax

AB pruning

8 puzzle

Code

```
import re

def is_variable(x):
    return x[0].islower() and x.isalpha()

def parse(term):
    term = term.strip()
    if '(' not in term:
        return term
    name, args = term.split('(', 1)
    args = args[:-1]  # remove closing parenthesis
    return name.strip(), [parse(a.strip()) for a in args.split(',')]

def occurs_check(var, expr):
    if var == expr:
        return True
    if isinstance(expr, tuple):
        _, args = expr
        return any(occurs_check(var, a) for a in args)
    return False

def substitute(subs, expr):
    if isinstance(expr, str):
        if expr in subs:
            return substitute(subs, subs[expr])
        return expr
    else:
        func, args = expr
        return (func, [substitute(subs, a) for a in args])

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

    x = substitute(subs, x)
    y = substitute(subs, y)

    if x == y:
```

```
        return subs

    if isinstance(x, str) and is_variable(x):
        if occurs_check(x, y):
            return None
        subs[x] = y
        return subs

    if isinstance(y, str) and is_variable(y):
        if occurs_check(y, x):
            return None
        subs[y] = x
        return subs

    if isinstance(x, tuple) and isinstance(y, tuple):
        if x[0] != y[0] or len(x[1]) != len(y[1]):
            return None
        for a, b in zip(x[1], y[1]):
            subs = unify(a, b, subs)
            if subs is None:
                return None
        return subs

    return None


def term_to_str(t):
    if isinstance(t, str):
        return t
    func, args = t
    return f"{func}({', '.join(term_to_str(a) for a in args)})"

def pretty_print(subs):
    return ', '.join(f"{v} : {term_to_str(t)}" for v, t in subs.items())


pairs = [
    ("P(f(x),g(y),y)", "P(f(g(z)),g(f(a)),f(a))"),
    ("Q(x,f(x))", "Q(f(y),y)"),
    ("H(x,g(x))", "H(g(y),g(g(z)))")
```

```
]

for s1, s2 in pairs:
    print(f"\nUnifying: {s1}  and  {s2}")
    result = unify(parse(s1), parse(s2))
    if result:
        print("=> Substitution:", pretty_print(result))
    else:
        print("=> Not unifiable.")
```

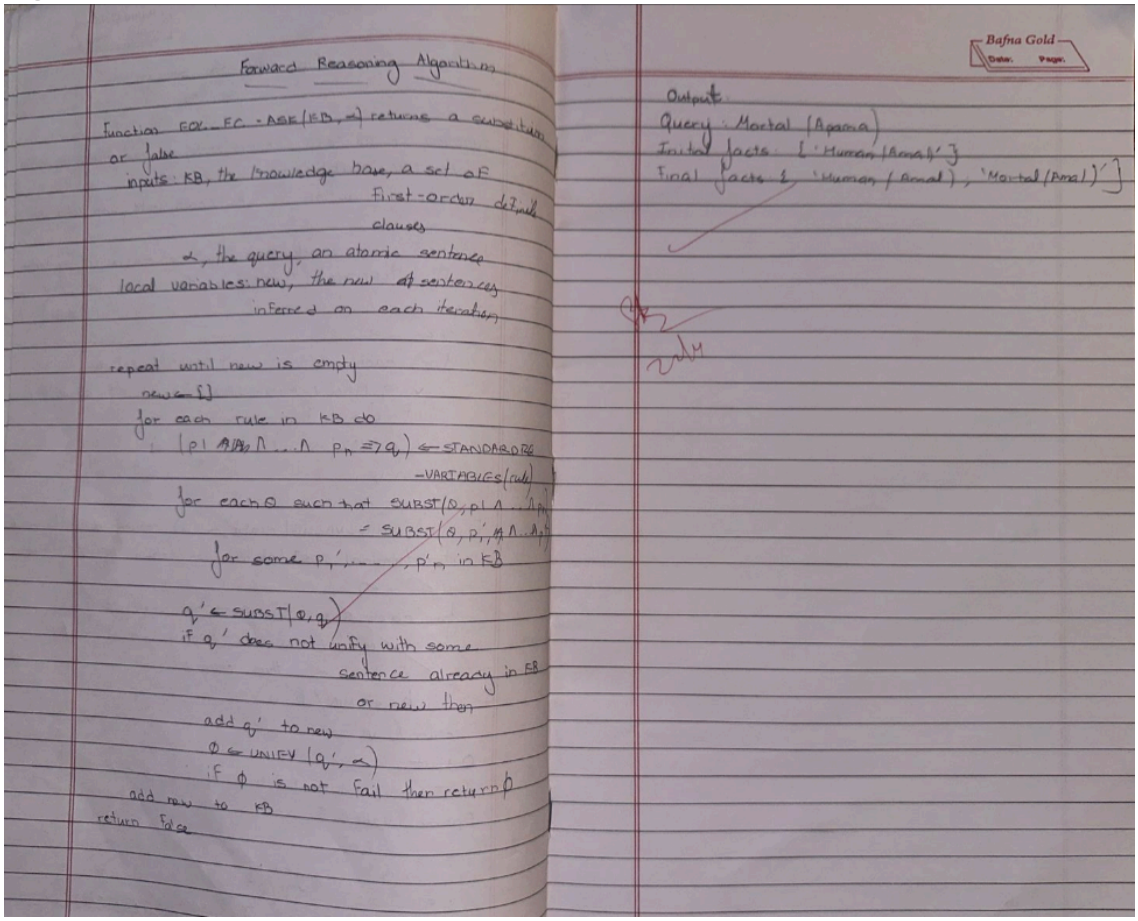
Output:

```
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
```

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))
```

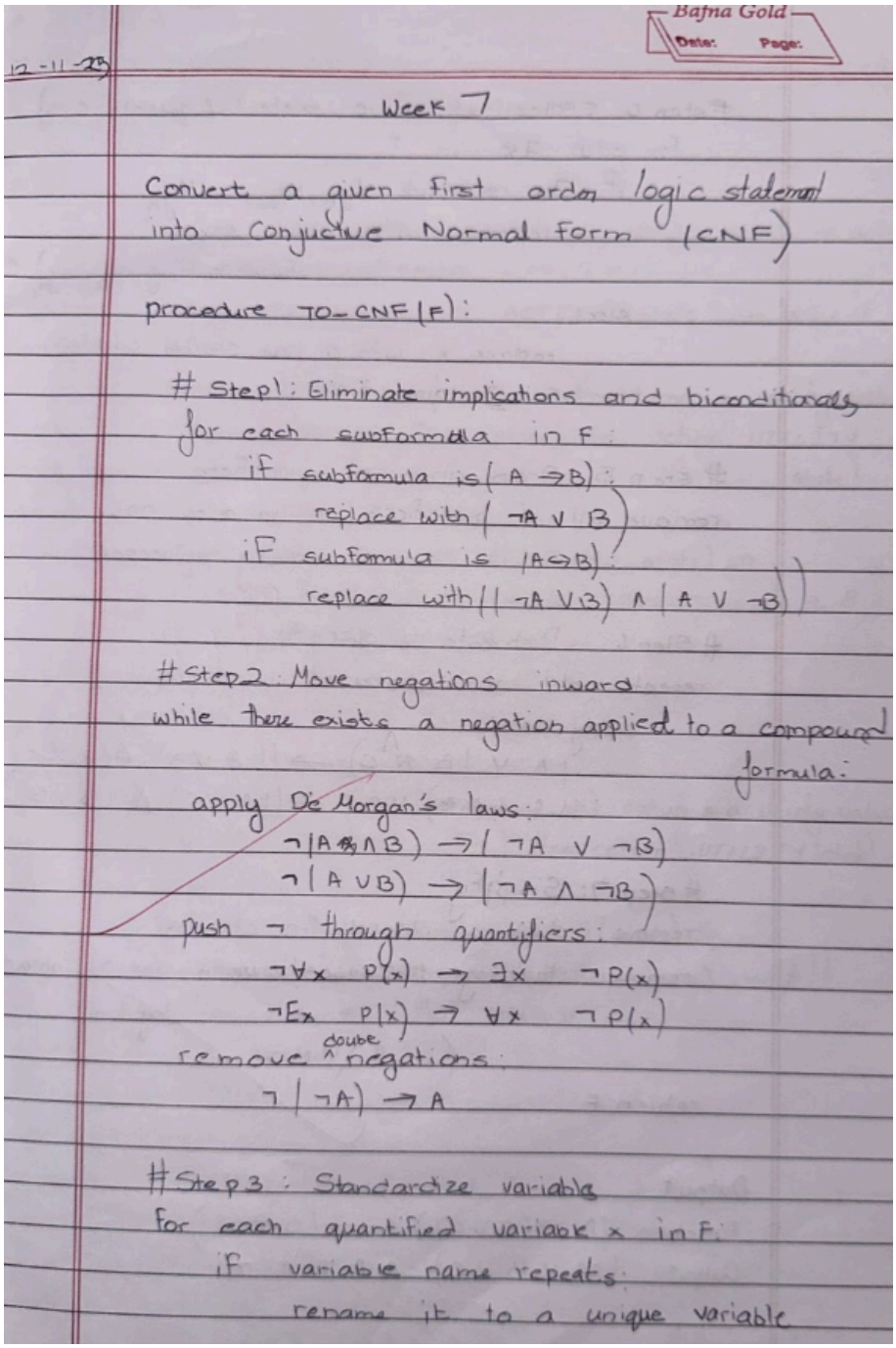
Output

```
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



Bafna Gold

Date: Page:

12-11-25

Week 7

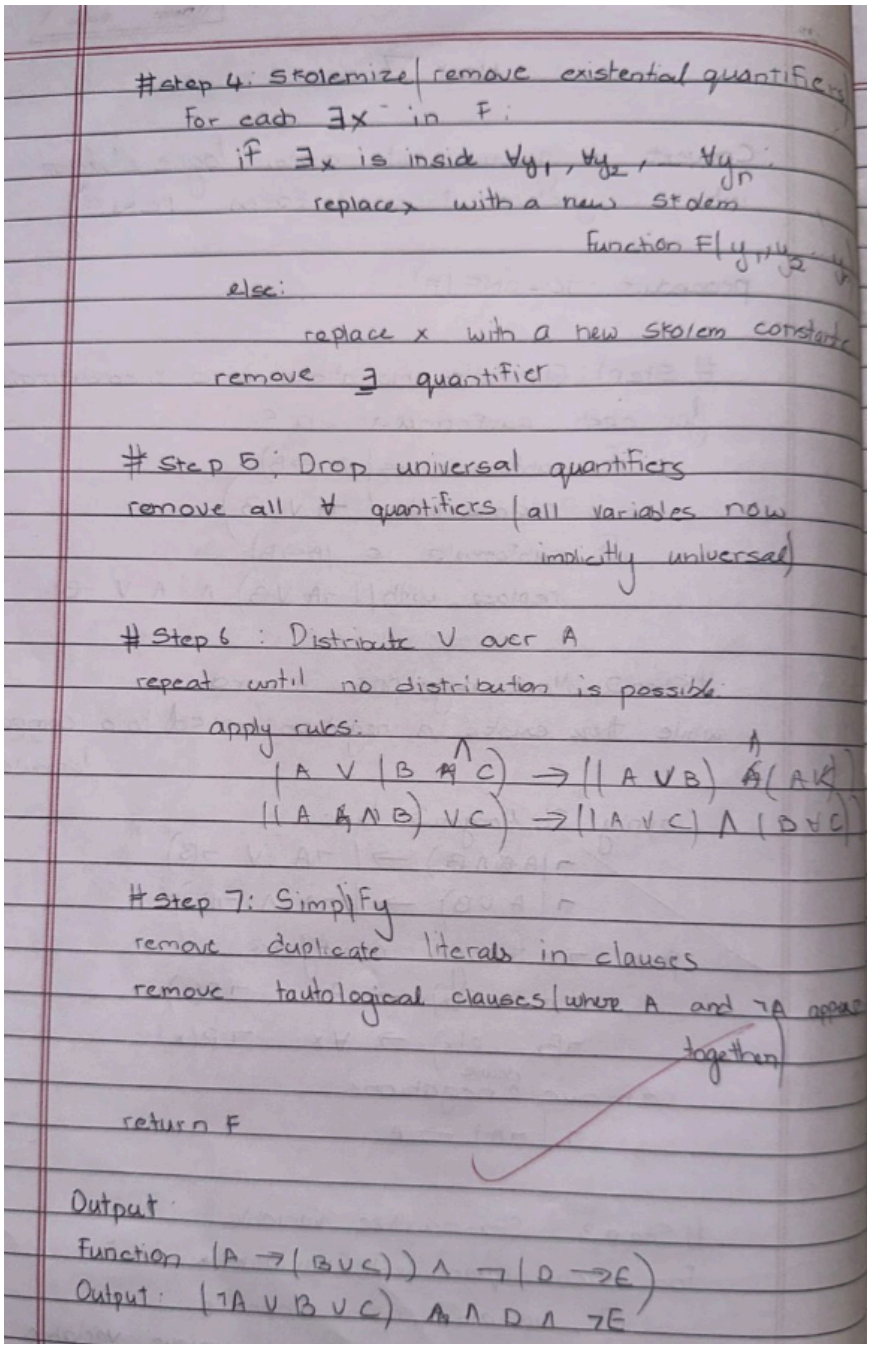
Convert a given first order logic statement into Conjuctive Normal Form (CNF)

procedure TO-CNF(F):

# Step1: Eliminate implications and biconditionals
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))

# Step2: Move negations inward
while there exists a negation applied to a compound formula:
apply De Morgan's 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

# Step3: Standardize variables
for each quantified variable x in F:
if variable name repeats:
rename it to a unique variable



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

2-11-25

Date: Page:

Alpha beta Search Algorithm

Function ALPHA-BETA-SEARCH(state) returns an action
  $v \leftarrow$ MAX-VALUE(state, $-\infty$, $+\infty$)
  return the action in ACTIONS(state) with value v

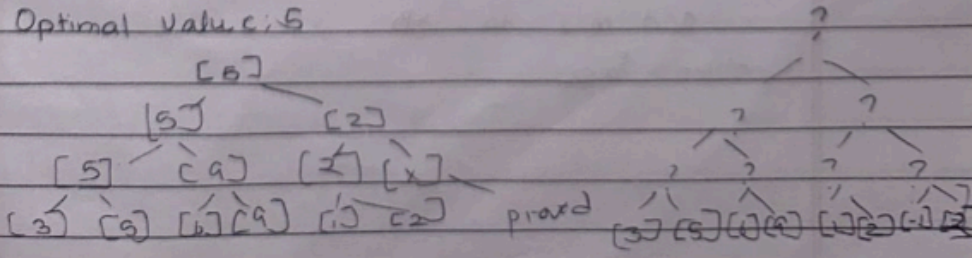
Function MAX-VALUE(state, α, β) returns a utility value
  if TERMINAL_TEST(state) then return UTILITY(state)
  $v \leftarrow -\infty$
  for each a in ACTIONS(state) do
    $v \leftarrow$ MAX(v, MIN-VALUE(RESULT(s,a), α, β))
    if $v \geq \beta$ then return v
    $\alpha \leftarrow$ MAX(α, v)
  return v

Function MIN-VALUE(state, α, β) returns a utility value
  if terminal_TEST(state) then return UTILITY(state)
  $v \leftarrow +\infty$
  for each a in ACTIONS(state) do
    $v \leftarrow$ MIN(v, MAX-VALUE(RESULT(s,a), α, β))
    if $v \leq \alpha$ then return v
    $\beta \leftarrow$ MIN(β, v)
  return v

Output

Leaf Node Values: [3, 5, 6, 9, 1, 2, 0, -1]

Optimal value: 5

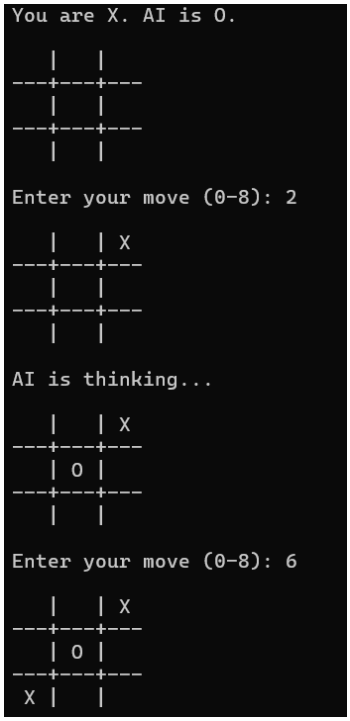


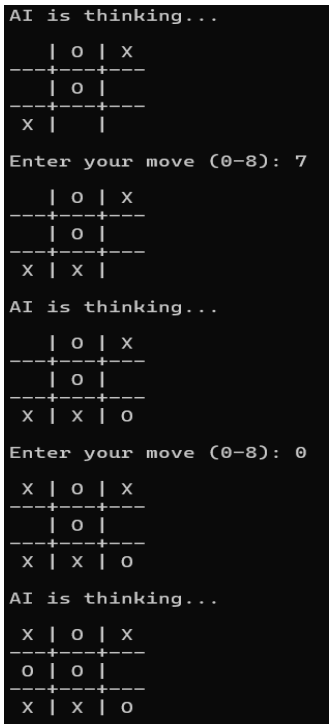
Code

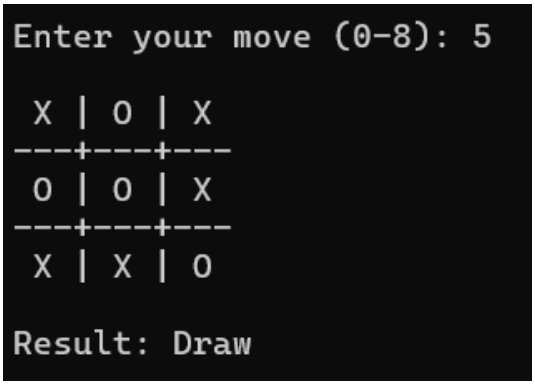
```
def unify(a, b):
    """Very simple unification for small terms like ('line', [X,O,X])"""
    if a == b:
        return {}
    if isinstance(a, str) and a.islower():  # variable
        return {a: b}
    if isinstance(b, str) and b.islower():
        return {b: a}
    if isinstance(a, tuple) and 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


You are X. AI is O.
Enter your move (0-8): 2
AI is thinking...
Enter your move (0-8): 6


AI is thinking...
Enter your move (0-8): 7
AI is thinking...
Enter your move (0-8): 0
AI is thinking...


Enter your move (0-8): 5
Result: Draw