VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB RECORD

Artificial Intelligence (23CS5PCAIN)

Submitted by

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in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
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CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence (23CS5PCAIN)" carried out by **Vignesh Bhat(1BM22CS327),** who is a 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 of the above mentioned subject and the work prescribed for the said degree.

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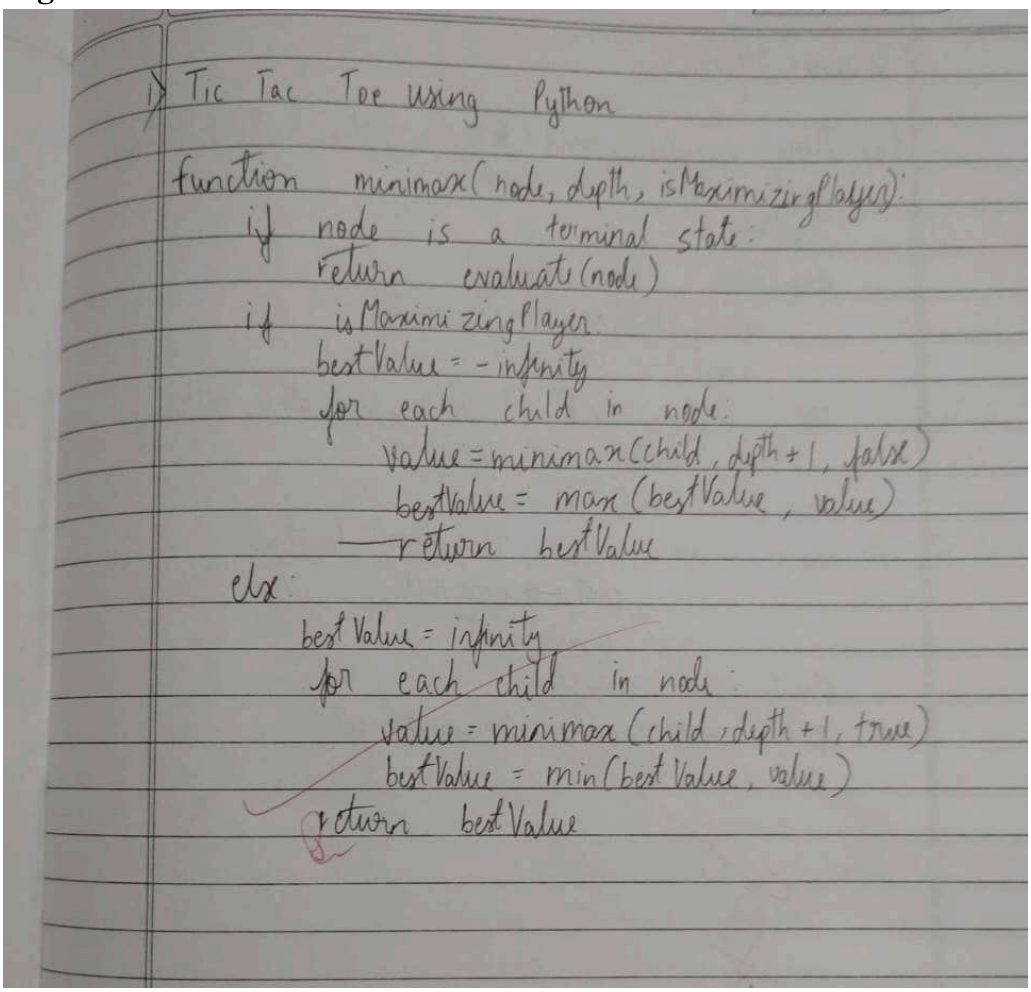
Program 1

Implement Tic –Tac –Toe Game

Algorithm :



1) Tic Tac Toe using Python

```
function minimax(node, depth, isMaximizingPlayer):
    if node is a terminal state:
        Return evaluate(node)
    if isMaximizingPlayer:
        bestValue = -infinity
        for each child in node:
            value = minimax(child, depth+1, false)
            bestValue = max(bestValue, value)
        return bestValue
    else:
        bestValue = infinity
        for each child in node:
            value = minimax(child, depth+1, true)
            bestValue = min(bestValue, value)
        return bestValue
```

Code :

```
board={1:' ',2:' ',3:' ',
      4:' ',5:' ',6:' ',
      7:' ',8:' ',9:' '
}



def printBoard(board):
   print(board[1]+'|'+board[2]+'|'+board[3]
   ) print('-+-+-')
   print(board[4] + '|' + board[5] + '|' +
   board[6]) print('-+-+-')
   print(board[7] + '|' + board[8] + '|' +
   board[9]) print('\n')

def spaceFree(pos):
   if(board[pos]==' '):
       return True
   else:
       return False

def checkWin():
   if(board[1]==board[2] and board[1]==board[3] and board[1]!=' '):
       return True
   elif(board[4]==board[5] and board[4]==board[6] and board[4]!=' '):
       return True
   elif(board[7]==board[8] and board[7]==board[9] and board[7]!=' '):
       return True
   elif (board[1] == board[5] and board[1] == board[9] and board[1] != ' '):
       return True
   elif (board[3] == board[5] and board[3] == board[7] and board[3] != ' '):
       return True
   elif (board[1] == board[4] and board[1] == board[7] and board[1] != ' '):
       return True
   elif (board[2] == board[5] and board[2] == board[8] and board[2] != ' '):
       return True
   elif (board[3] == board[6] and board[3] == board[9] and board[3] != ' '):
       return True
   else:
       return False
```

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

def checkDraw():
    for key in board.keys():
        if (board[key]==' '):
            return False
    return True


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

        if (checkDraw()):
            print('Draw!')
        elif (checkWin()):
            if (letter == 'X'):
                print('Bot wins!')
            else:
                print('You win!')
        return

    else:
        print('Position taken, please pick a different position.')
        position = int(input('Enter new position: '))
        insertLetter(letter, position)
        return
```

```
player = 'O'
bot ='X'

def playerMove():
   position=int(input('Enter position for O:'))
   insertLetter(player, position)
   return

def compMove():
   bestScore=-100
   0 bestMove=0
   for key in board.keys():
       if (board[key]==' '):
           board[key]=bot
           score = minimax(board, False)
           board[key] = ' '
           if (score > bestScore):
               bestScore = score
               bestMove = key

   insertLetter(bot, bestMove)
   return


def minimax(board, isMaximizing):
   if (checkMoveForWin(bot)):
       return 1
   elif (checkMoveForWin(player)):
       return -1
   elif (checkDraw()):
       return 0

   if isMaximizing:
       bestScore = -1000

       for key in board.keys():
           if board[key] == ' ':
               board[key] = bot
               score = minimax(board,
               False) board[key] = ' '
               if (score > bestScore):
                   bestScore = score
       return bestScore
   else:
       bestScore = 1000

       for key in board.keys():
```

```
            if board[key] == ' ':
                board[key] = player
score = minimax(board, True) board[key] = ' '
                if (score < bestScore):
                    bestScore = score
return bestScore

while not checkWin():
   playerMove()
   compMove()
```

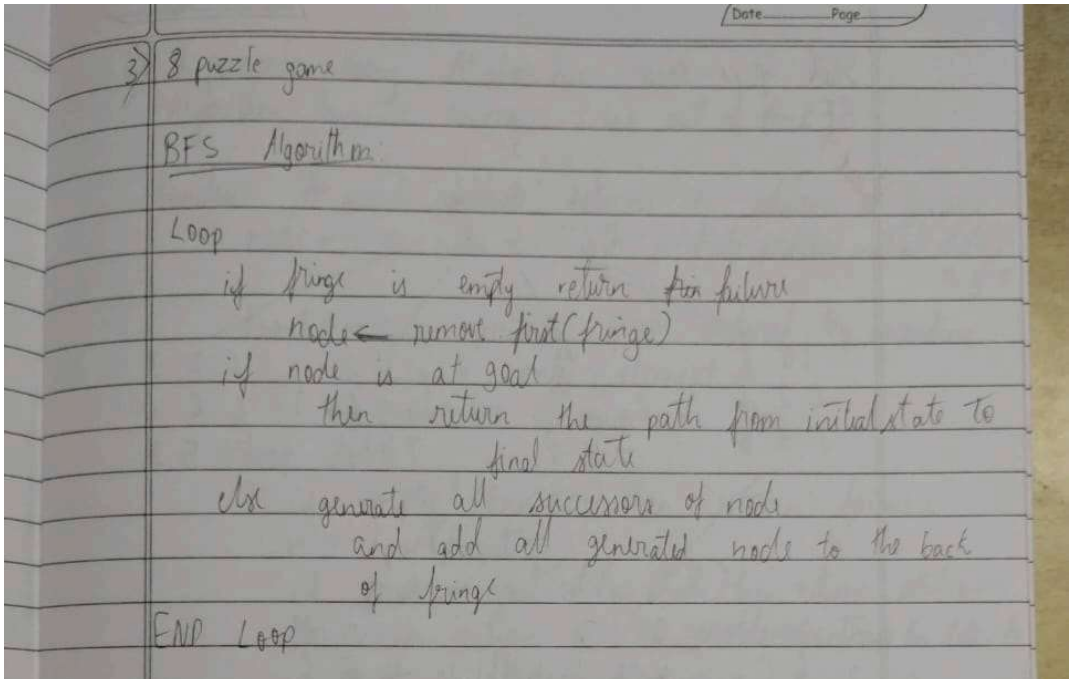
Output :

```
Enter position for O:3
 | |O
-+-+-
 | |
-+-+-
 | |


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


Enter position for O:2
 |O|O
-+-+-
 |X|
-+-+-
 | |


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


Enter position for O:6
X|O|O
-+-+-
 |X|O
-+-+-
 | |


X|O|O
-+-+-
 |X|O
-+-+-
 | |X
```

Program 2

Solve 8 puzzle problems
1.BFS

Algorithm :



Code :

```
from collections import deque

class PuzzleState:
    def _init_(self, board, zero_position, path=[]):
        self.board = board
self.zero_position = zero_position self.path =
        path

def is_goal(self):
return self.board == [1, 2, 3, 4, 5, 6, 7, 8, 0]

    def get_possible_moves(self):
        moves = []
row, col = self.zero_position
directions = [(0, 1), (1, 0), (0, -1), (-1, 0)]     # Right, Down, Left, Up

for dr, dc in directions:
new_row, new_col = row + dr, col + dc
```

```
            if 0 <= new_row < 3 and 0 <= new_col <
                3: new_board = self.board[:]
                # Swap zero with the adjacent tile
                new_board[row * 3 + col], new_board[new_row * 3 + new_col] =
new_board[new_row * 3 + new_col], new_board[row * 3 + col]
                moves.append(PuzzleState(new_board, (new_row, new_col), self.path +
[new_board]))

        return moves

def bfs(initial_state):
    queue = deque([initial_state])
    visited = set()

    while queue:
        current_state = queue.popleft()

        # Show the current board
        print("Current Board State:")
        print_board(current_state.board)
        print()

        if current_state.is_goal():
            return current_state.path

        visited.add(tuple(current_state.board))

        for next_state in current_state.get_possible_moves():
            if tuple(next_state.board) not in visited:
                queue.append(next_state)

    return None

def print_board(board):
    for i in range(3):
        print(board[i * 3:i * 3 + 3])

def main():
    print("Enter the initial state of the 8-puzzle (use 0 for the blank tile, e.g.,
'1 2 3 4 5 6 7 8 0'): ")
    user_input = input()
    initial_board = list(map(int, user_input.split()))

    if len(initial_board) != 9 or set(initial_board) != set(range(9)):
```

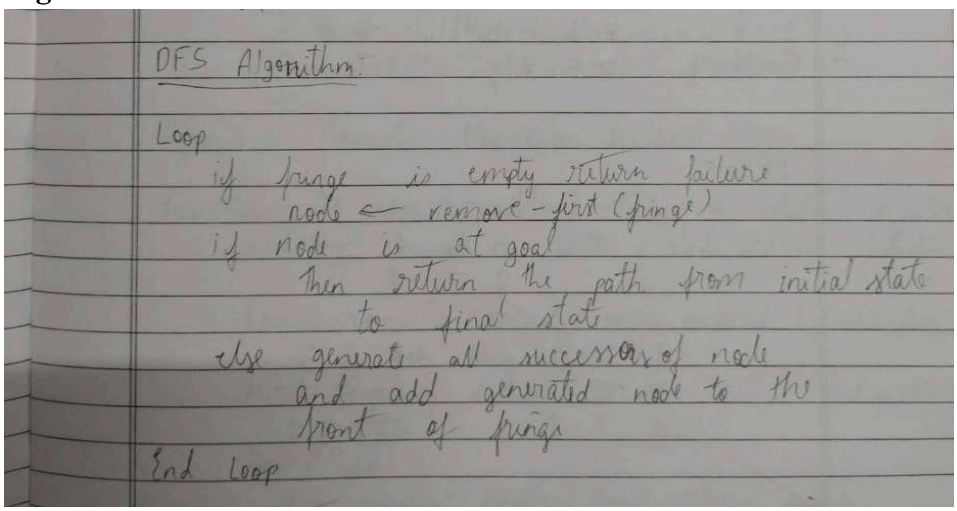
```
        print("Invalid input! Please enter 9 numbers from 0 to 8.")
      return
zero_position = initial_board.index(0)
initial_state = PuzzleState(initial_board, (zero_position // 3, zero_position %
3))
solution_path = bfs(initial_state) if
    solution_path is None:
        print("No solution found.")
    else:
print("Solution found in", len(solution_path), "steps.") for step
        in solution_path:
print_board(step) print()

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

Output :

```
Enter the initial state of the 8-puzzle (use 0 for the blank tile, e.g., '1 2 3 4 5 6 7 8 0'):
1 2 3 4 0 6 7 5 8
Current Board State:
[1, 2, 3]
[4, 0, 6]
[7, 5, 8]

Current Board State:
[1, 2, 3]
[4, 6, 0]
[7, 5, 8]

Current Board State:
[1, 2, 3]
[4, 5, 6]
[7, 0, 8]

Current Board State:
[1, 2, 3]
[0, 4, 6]
[7, 5, 8]

Current Board State:
[1, 0, 3]
[4, 2, 6]
[7, 5, 8]

Current Board State:
[1, 2, 3]
[4, 6, 8]
[7, 5, 0]

Current Board State:
[1, 2, 0]
[4, 6, 3]
[7, 5, 8]

Current Board State:
[1, 2, 3]
[4, 5, 6]
[7, 8, 0]

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

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

2.DFS

Algorithm :



Code:

```
from collections import deque

def
    get_user_input(prompt)
    : board = []
    print(prompt)
for i in range(3):
        row = list(map(int, input(f"Enter row {i+1} (space-separated numbers, use 0
for empty space): ").split()))
        board.append(row)
    return board

def is_solvable(board):
flattened_board = [tile for row in board for tile in row if tile != 0] inversions =
    0
for i in range(len(flattened_board)):
for j in range(i + 1, len(flattened_board)):
            if flattened_board[i] > flattened_board[j]:
                inversions += 1
return inversions % 2 == 0

class PuzzleState:
    def _init_(self, board, moves=0, previous=None):
        self.board = board
self.empty_tile = self.find_empty_tile()
        self.moves = moves
self.previous = previous

    def find_empty_tile(self):
        for i in range(3):
for j in range(3):
```

```
                    return (i, j)

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

    def get_possible_moves(self):
        row, col = self.empty_tile
        possible_moves = []
        directions = [(1, 0), (-1, 0), (0, 1), (0, -1)]  # down, up, right, left

        for dr, dc in directions:
            new_row, new_col = row + dr, col + dc
            if 0 <= new_row < 3 and 0 <= new_col <
                3: # Make the move
                new_board = [row[:] for row in self.board]  # Deep
                copy new_board[row][col], new_board[new_row][new_col]
                =
new_board[new_row][new_col], new_board[row][col]
                possible_moves.append(PuzzleState(new_board, self.moves + 1, self))

        return possible_moves

def dfs(initial_state,
    goal_state): stack =
    [initial_state]
    visited = set()

    while stack:
        current_state = stack.pop()

        if current_state.is_goal(goal_state):
            return current_state

        # Convert board to a tuple for the visited set
        state_tuple = tuple(tuple(row) for row in current_state.board)

        if state_tuple not in visited:
            visited.add(state_tuple)
            for next_state in current_state.get_possible_moves():
                stack.append(next_state)

    return None  # No solution found

def print_solution(solution):
    path = []
    while solution:
        path.append(solution.board)
        solution = solution.previous
    for state in reversed(path):
```

```
        for row in state:
            print(row)
print()

if _name    == "_main_":
# Get user input for initial and goal states
initial_board = get_user_input("Enter the initial state of the puzzle:") goal_board
    = get_user_input("Enter the goal state of the puzzle:")

if is_solvable(initial_board):
initial_state = PuzzleState(initial_board)
        solution = dfs(initial_state, goal_board)

if solution:
print("Solution found in", solution.moves, "moves:") print_solution(solution)
else:
print("No solution found.")
else:
print("This puzzle is unsolvable.")
```

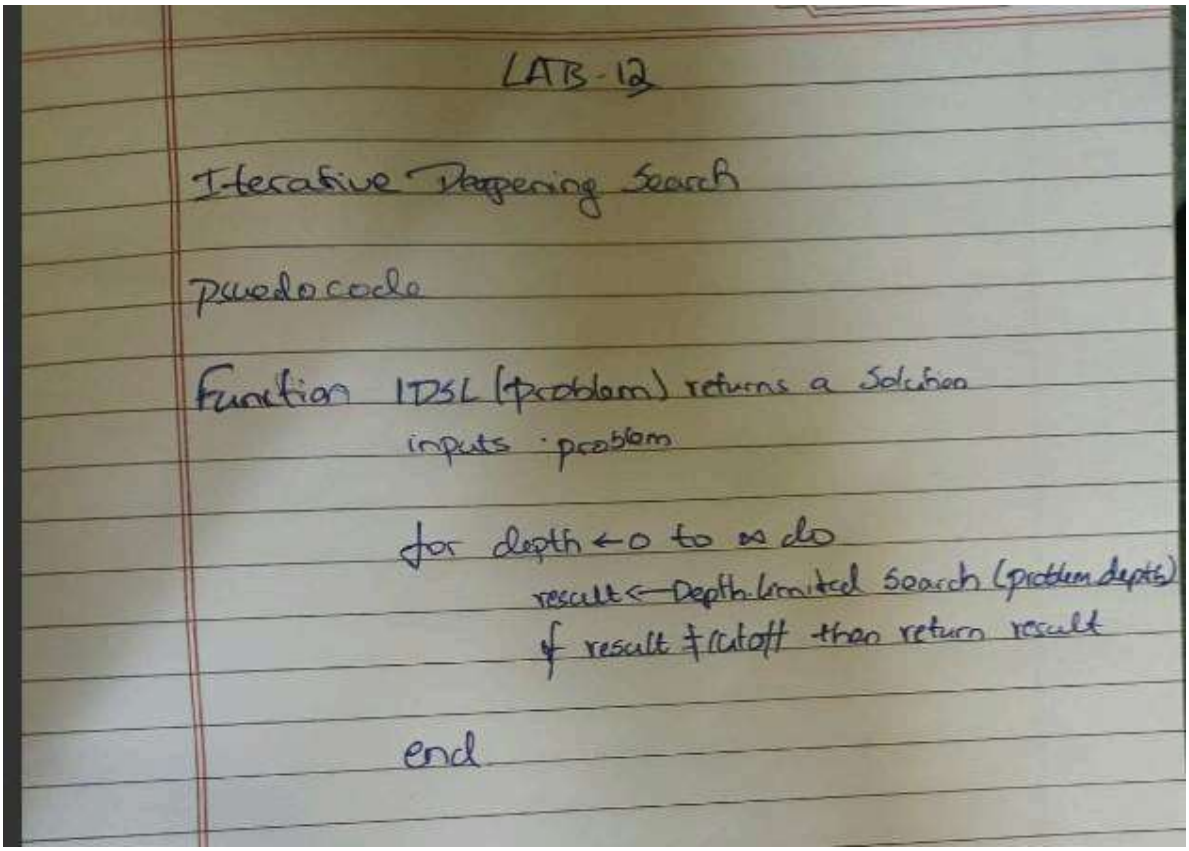
Output

```
Enter the initial state of the puzzle:
Enter row 1 (space-separated numbers, use 0 for empty space): 1 2 3
Enter row 2 (space-separated numbers, use 0 for empty space): 0 5 6
Enter row 3 (space-separated numbers, use 0 for empty space): 4 7 8
Enter the goal state of the puzzle:
Enter row 1 (space-separated numbers, use 0 for empty space): 1 2 3
Enter row 2 (space-separated numbers, use 0 for empty space): 4 5 6
Enter row 3 (space-separated numbers, use 0 for empty space): 7 8 0
Solution found in 431 moves:
```

Program 3

Implement Iterative deepening search algorithm.

Algorithm :



Code :

```
from copy import deepcopy

DIRECTIONS = [(-1, 0), (1, 0), (0, -1), (0, 1)]

class PuzzleState:
    def _init_(self, board, parent=None, move=""):
        self.board = board
self.parent = parent self.move =
        move

    def get_blank_position(self):
        for i in range(3):
for j in range(3):
if self.board[i][j] == 0:
```

```
                    return i, j

    def generate_successors(self):
        successors = []
        x, y = self.get_blank_position()

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

            if 0 <= new_x < 3 and 0 <= new_y < 3:
                new_board = deepcopy(self.board)
                new_board[x][y], new_board[new_x][new_y] = new_board[new_x][new_y],
new_board[x][y]
                successors.append(PuzzleState(new_board, parent=self))

        return successors

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

    def _str_(self):
        return "\n".join([" ".join(map(str, row)) for row in self.board])

def depth_limited_search(current_state, goal_state, depth):
    if depth == 0 and current_state.is_goal(goal_state):
        return current_state

    if depth > 0:
        for successor in current_state.generate_successors():
            found = depth_limited_search(successor, goal_state, depth - 1)
            if found:
                return found
    return None

def iterative_deepening_search(start_state, goal_state, max_depth):
    for depth in range(max_depth + 1):
        print(f"\nSearching at depth level: {depth}")
        result = depth_limited_search(start_state, goal_state, depth)
        if result:
            return result
    return None

def get_user_input():
    print("Enter the start state (use 0 for the blank):")
    start_state = []
    for _ in range(3):
        row = list(map(int, input().split()))
```

```
        start_state.append(row)

    print("Enter the goal state (use 0 for the blank):")
    goal_state = []
    for _ in range(3):
        row = list(map(int, input().split()))
        goal_state.append(row)

    max_depth = int(input("Enter the maximum depth for search: "))

    return start_state, goal_state, max_depth

def main():
    start_board, goal_board, max_depth = get_user_input()
    start_state = PuzzleState(start_board)
    goal_state = goal_board
    result = iterative_deepening_search(start_state, goal_state,
    max_depth) if result:
        print("\nGoal reached!")
        path = []
        while result:
            path.append(result)
            result = result.parent
        path.reverse()
        for state in path:
            print(state, "\n")
    else:
        print("Goal state not found within the specified depth.")

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

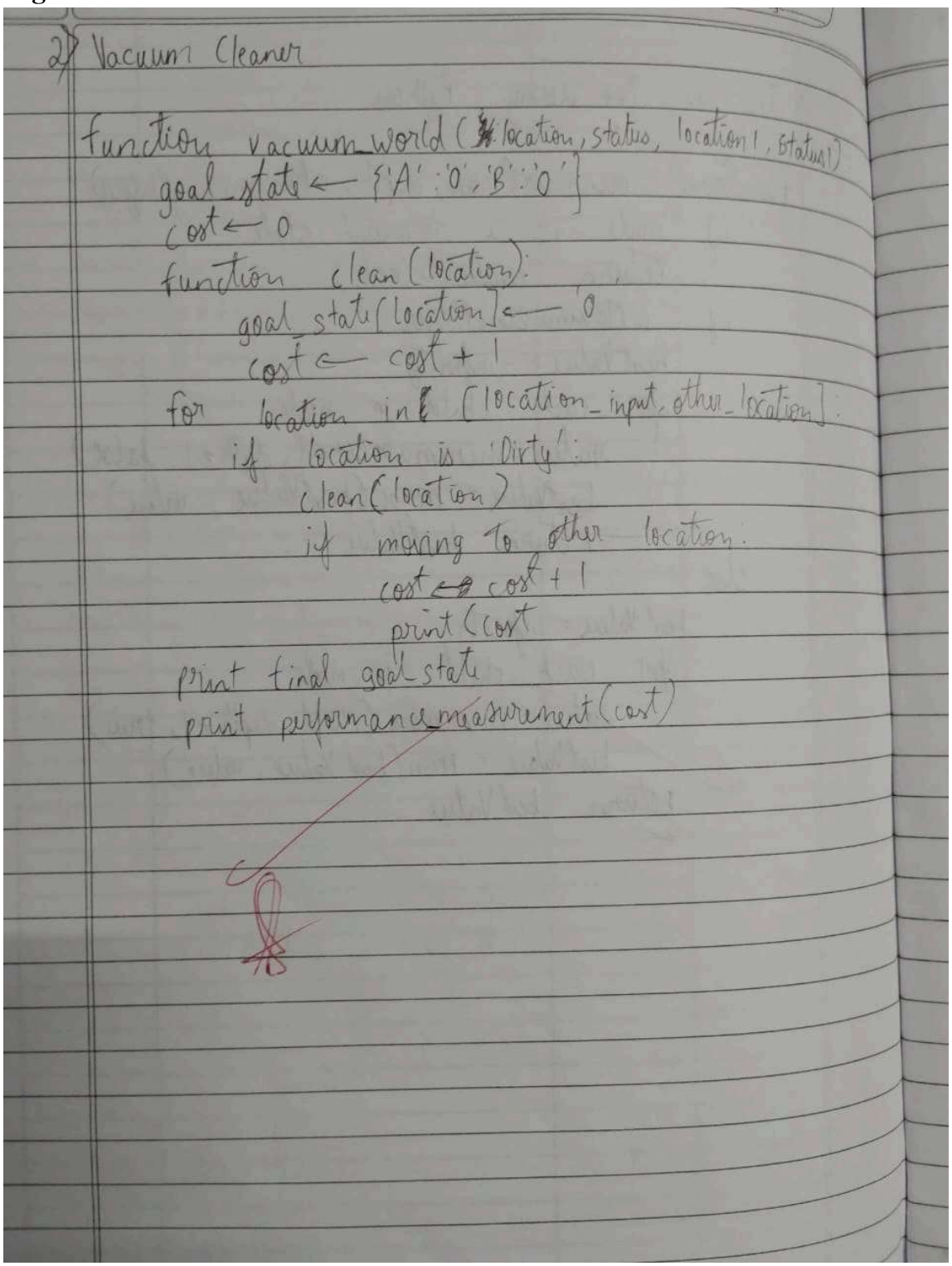
Output :

```
Enter the start state (use 0 for the blank):
2 8 3
1 6 4
7 0 5
Enter the goal state (use 0 for the blank):
1 2 3
8 0 4
7 6 5
Enter the maximum depth for search: 6

Searching at depth level: 0

Searching at depth level: 1

Searching at depth level: 2

Searching at depth level: 3

Searching at depth level: 4

Searching at depth level: 5

Goal reached!
2 8 3
1 6 4
7 0 5

2 8 3
1 0 4
7 6 5

2 0 3
1 8 4
7 6 5

0 2 3
1 8 4
7 6 5

1 2 3
0 8 4
7 6 5

1 2 3
8 0 4
7 6 5

--------------
```

Program 4

Implement a vacuum cleaner agent.

Algorithm :



Code :

```
def vacuum_world():

    goal_state = {'A': '0', 'B': '0'}
    cost = 0


    location_input = input("Enter Location of Vacuum (A or B): ").strip().upper()
    status_input = input(f"Enter status of A (0 for Clean, 1 for Dirty): ").strip()
    status_input_complement = input("Enter status of B (0 for Clean, 1 for Dirty):
").strip()
    print("Initial Location Condition: " + str(goal_state))
    if location_input == 'A':
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            goal_state['A'] = '0'
            cost += 1
            print("Cost for cleaning A: " + str(cost))
            print("Location A has been Cleaned.")

            if status_input_complement == '1':
                print("Location B is Dirty.")
                print("Moving right to Location
                B.") cost += 1
                print("Cost for moving RIGHT: " + str(cost))

                goal_state['B'] = '0'
                cost += 1
                print("Cost for suck: " + str(cost))
                print("Location B has been
                Cleaned.")
            else:
                print("Location B is already clean.")
        else:
            print("Location A is already clean.")
            if status_input_complement == '1':
                print("Location B is Dirty.")
                print("Moving RIGHT to Location
                B.") cost += 1
                print("Cost for moving RIGHT: " + str(cost))

                goal_state['B'] = '0'
                cost += 1
                print("Cost for suck: " + str(cost))
```

```
            print("Location B has been
        Cleaned.") else:
            print("Location B is already clean.")

elif location_input == 'B':
    print("Vacuum is placed in Location B")
    if status_input == '1':
        print("Location B is Dirty.")
        goal_state['B'] = '0'  # Clean
        B cost += 1            # Cost
        for sucking
        print("Cost for cleaning B: " + str(cost))
        print("Location B has been Cleaned.")

        if status_input_complement == '1':
            print("Location A is Dirty.")
            print("Moving LEFT to Location
            A.") cost += 1    # Cost for
            moving left
            print("Cost for moving LEFT: " + str(cost))

            goal_state['A'] = '0'
            cost += 1
            print("Cost for suck: " + str(cost))
            print("Location A has been
            Cleaned.")
        else:
            print("Location A is already clean.")
    else:
        print("Location B is already clean.")
        if status_input_complement == '1':
            print("Location A is Dirty.")
            print("Moving LEFT to Location A.")
            cost += 1
            print("Cost for moving LEFT: " + str(cost))

            goal_state['A'] = '0'
            cost += 1
            print("Cost for suck: " + str(cost))
            print("Location A has been
            Cleaned.")
        else:
            print("Location A is already clean.")


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

```
# Output
vacuum_world()
```

Output :

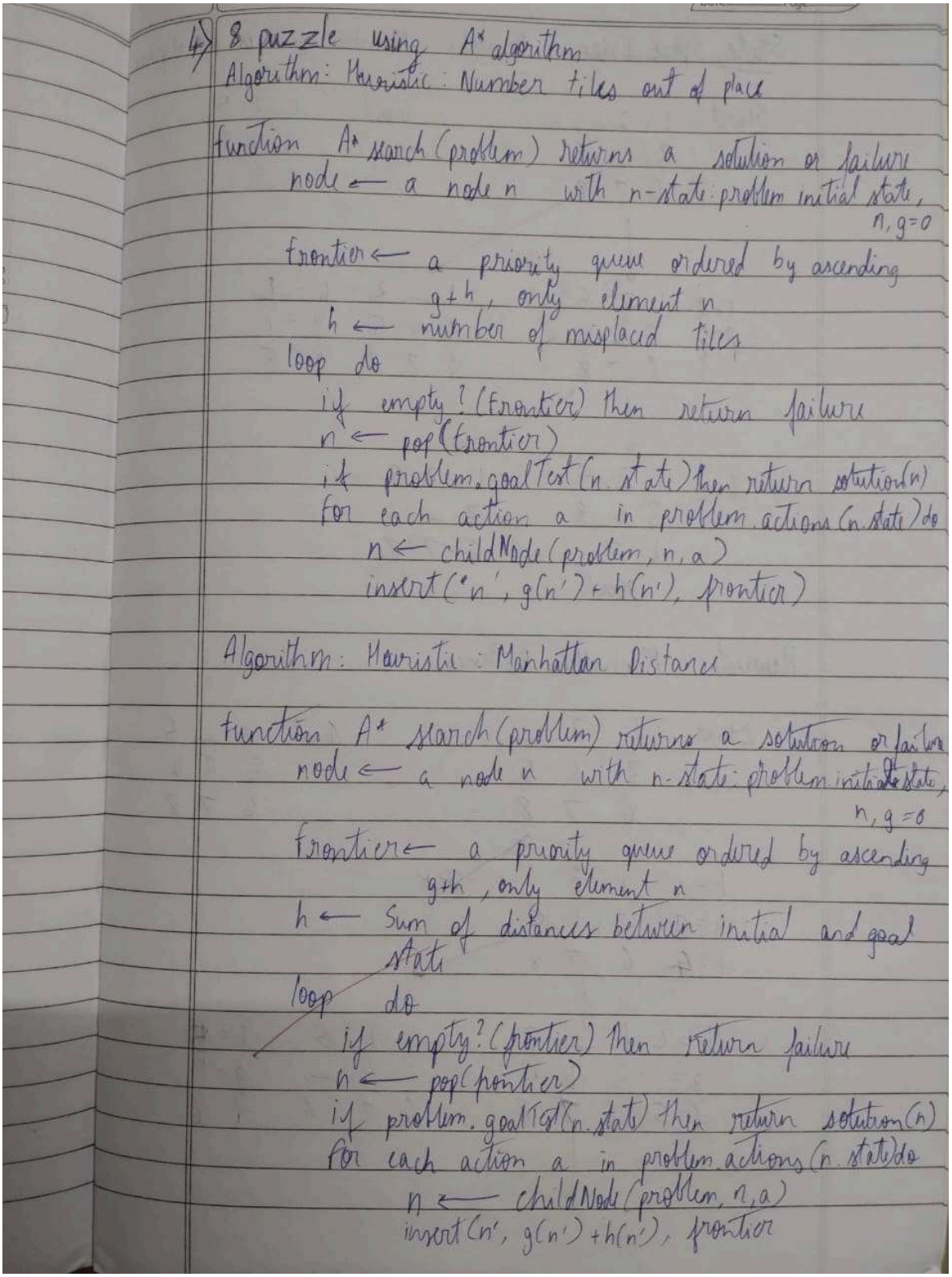
```
Enter Location of Vacuum (A or B): a
Enter status of A (0 for Clean, 1 for Dirty): 1
Enter status of B (0 for Clean, 1 for Dirty): 1
Initial Location Condition: {'A': '0', 'B': '0'}
Vacuum is placed in Location A
Location A is Dirty.
Cost for cleaning A: 1
Location A has been Cleaned.
Location B is Dirty.
Moving right to Location B.
Cost for moving RIGHT: 2
Cost for suck: 3
Location B has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 3
```

Program 5

Implement A* search algorithm.

1.Using Misplaced tiles

Algorithm :



4) 8 puzzle using A* algorithm
Algorithm: Heuristic: Number tiles out of place

function A* search (problem) returns a solution or failure
node ← a node n with n-state: problem initial state, n, g=0
frontier ← a priority queue ordered by ascending g+h, only element n
h ← number of misplaced tiles
loop do
if empty? (Frontier) then return failure
n ← pop(frontier)
if problem.goalTest(n.state) then return solution(n)
for each action a in problem.actions(n.state) do
n ← childNode(problem, n, a)
insert('n', g(n') + h(n'), frontier)

Algorithm: Heuristic: Manhattan distance

function A* search (problem) returns a solution or failure
node ← a node n with n-state: problem initial state, n, g=0
frontier ← a priority queue ordered by ascending g+h, only element n
h ← Sum of distances between initial and goal state
loop do
if empty? (frontier) then return failure
n ← pop(frontier)
if problem.goalTest(n.state) then return solution(n)
for each action a in problem.actions(n.state) do
n ← childNode(problem, n, a)
insert(n', g(n') + h(n'), frontier

Code :

```
import heapq

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

def misplaced_tiles_heuristic(state, goal_state):
    misplaced_tiles = 0
    for i in range(3):
        for j in range(3):
            if state[i][j] != goal_state[i][j] and state[i][j] != 0:
                misplaced_tiles += 1
    return misplaced_tiles

class PuzzleNode:
    def __init__(self, state, parent=None, g=0, h=0):
        self.state = state
        self.parent = parent
        self.g = g  # Cost from start to current node
        self.h = h  # Heuristic cost to goal (misplaced
        tiles) self.f = g + h      # Total cost

    def __lt__(self, other):
        return self.f < other.f

def get_empty_tile(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
                return i, j

def generate_neighbors(node):
    neighbors = []
    x, y = get_empty_tile(node.state)

    moves = [(0, -1), (0, 1), (-1, 0), (1, 0)]
    for dx, dy in moves:
        new_x, new_y = x + dx, y + dy
        if 0 <= new_x < 3 and 0 <= new_y < 3:
            new_state = [row[:] for row in node.state]
            new_state[x][y], new_state[new_x][new_y] =
new_state[new_x][new_y], new_state[x][y]
            h = misplaced_tiles_heuristic(new_state, GOAL_STATE)
            neighbors.append(PuzzleNode(new_state, node, node.g + 1, h))
```

```
    return neighbors
def is_goal_reached(state, goal_state):
    return state == goal_state

def reconstruct_path(node):
    path = []
    while node:
        path.append(node.state)
        node = node.parent
    return path[::-1]

def a_star_search(start_state):
    open_set = [PuzzleNode(start_state, h=misplaced_tiles_heuristic(start_state,
GOAL_STATE))]
    closed_set = set()

    while open_set:
        current_node = heapq.heappop(open_set)

        if is_goal_reached(current_node.state, GOAL_STATE):
            return reconstruct_path(current_node)

        closed_set.add(tuple(map(tuple, current_node.state)))

        for neighbor in generate_neighbors(current_node):
            if tuple(map(tuple, neighbor.state)) not in closed_set:
                heapq.heappush(open_set, neighbor)

    return None

def get_user_input():
    while True:
        print("Enter your 8-puzzle configuration (0 represents the empty tile):")
        state = []
        for i in range(3):
            row = input(f"Enter row {i+1}: ").split()
            if len(row) != 3:
                print("Invalid input. Please enter 3 numbers per row.")
                continue
            try:
                row = [int(x) for x in row]
            except ValueError:
                print("Invalid input. Please enter only numbers.")
                continue
```

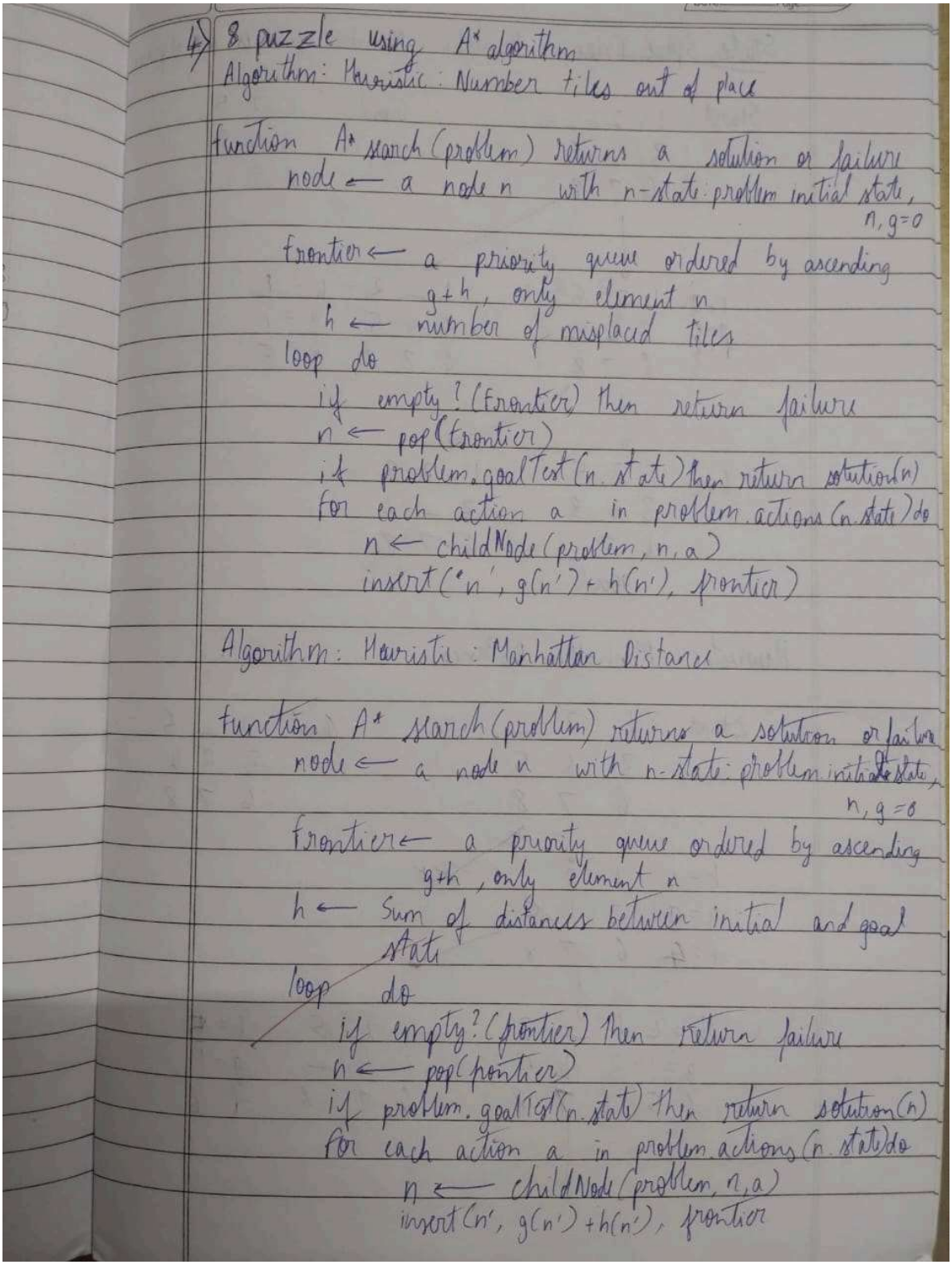
```
            if not all(0 <= x <= 8 for x in row):
                print("Numbers must be between 0 and
                8.") continue
        state.append(row)

        if len(set(sum(state, []))) != 9:
                print("Each number from 0 to 8 must appear exactly once.")
                continue

        return state

def main():
        start_state = get_user_input()
        solution =
a_star_search(start_state)
    if solution:
        print("Solution found in", len(solution) - 1, "steps:")
        for step in solution:
        for row in step:
        print(row)
        print() else:

          print("No solution found.")
        print("Vanith D Ramesh
(1BM22CS319)")
if    name  == "  main  ":
        main()
```

Output

```
Enter your 8-puzzle configuration (0 represents the empty tile):
Enter row 1: 1 2 3
Enter row 2: 0 5 6
Enter row 3: 4 7 8
Solution found in 3 steps:
[1, 2, 3]
[0, 5, 6]
[4, 7, 8]

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

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

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

Using Manhattan distance

Algorithm:



4) 8 puzzle using A* algorithm

Algorithm: Heuristic: Number tiles out of place

function A* search (problem) returns a solution or failure
node ← a node n with n.state: problem.initial state, n.g = 0
frontier ← a priority queue ordered by ascending g+h, only element n
h ← number of misplaced tiles
loop do
if empty?(frontier) then return failure
n ← pop(frontier)
if problem.goalTest(n.state) then return solution(n)
for each action a in problem.actions(n.state) do
n ← childNode(problem, n, a)
insert('n', g(n') + h(n'), frontier)

Algorithm: Heuristic: Manhattan Distance

function A* search (problem) returns a solution or failure
node ← a node n with n.state: problem.initial state, n.g = 0
frontier ← a priority queue ordered by ascending g+h, only element n
h ← Sum of distances between initial and goal state
loop do
if empty?(frontier) then return failure
n ← pop(frontier)
if problem.goalTest(n.state) then return solution(n)
for each action a in problem.actions(n.state) do
n ← childNode(problem, n, a)
insert(n', g(n') + h(n'), frontier

Code:

```
import heapq

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

MOVES = [(0, -1), (0, 1), (-1, 0), (1, 0)]

class PuzzleNode:
    def __init__(self, board, parent=None, g=0,
        h=0): self.board = board
        self.parent = parent
        self.g = g
        self.h = h
        self.f = g + h

    def __lt__(self, other):
        return self.f < other.f

def manhattan_distance(board):
    distance = 0
    for i in range(3):
        for j in range(3):
            value = board[i][j]
            if value != 0:
                goal_x, goal_y = (value - 1) // 3, (value - 1) % 3
                distance += abs(i - goal_x) + abs(j - goal_y)
    return distance

def get_empty_tile(board):
    for i in range(3):
        for j in range(3):
            if board[i][j] == 0:
                return i, j

def generate_neighbors(node):
    neighbors = []
    x, y = get_empty_tile(node.board)

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

```
        if 0 <= new_x < 3 and 0 <= new_y < 3:
            new_board = [row[:] for row in
            node.board]
            new_board[x][y], new_board[new_x][new_y] =
new_board[new_x][new_y], new_board[x][y]
            h = manhattan_distance(new_board)
            neighbors.append(PuzzleNode(new_board, node, node.g + 1, h))

    return neighbors

def is_goal_reached(board):
    return board == GOAL_BOARD

def reconstruct_path(node):
    path = []
    while node:
        path.append(node.board)
        node = node.parent
    return path[::-1]

def a_star_search(start_board):
    open_set = [PuzzleNode(start_board)]
    closed_set = set()

    while open_set:
        current_node = heapq.heappop(open_set)

        if is_goal_reached(current_node.board):
            return reconstruct_path(current_node)

        closed_set.add(tuple(map(tuple, current_node.board)))

        for neighbor in generate_neighbors(current_node):
            if tuple(map(tuple, neighbor.board)) not in closed_set:
                heapq.heappush(open_set, neighbor)

    return None

def get_user_input():
    while True:
        print("Enter your 8-puzzle configuration (0 represents the empty tile):")
        state = []
        for i in range(3):
            row = input(f"Enter row {i+1}: ").split()
            if len(row) != 3:
                print("Invalid input. Please enter 3 numbers per row.")
                continue
```

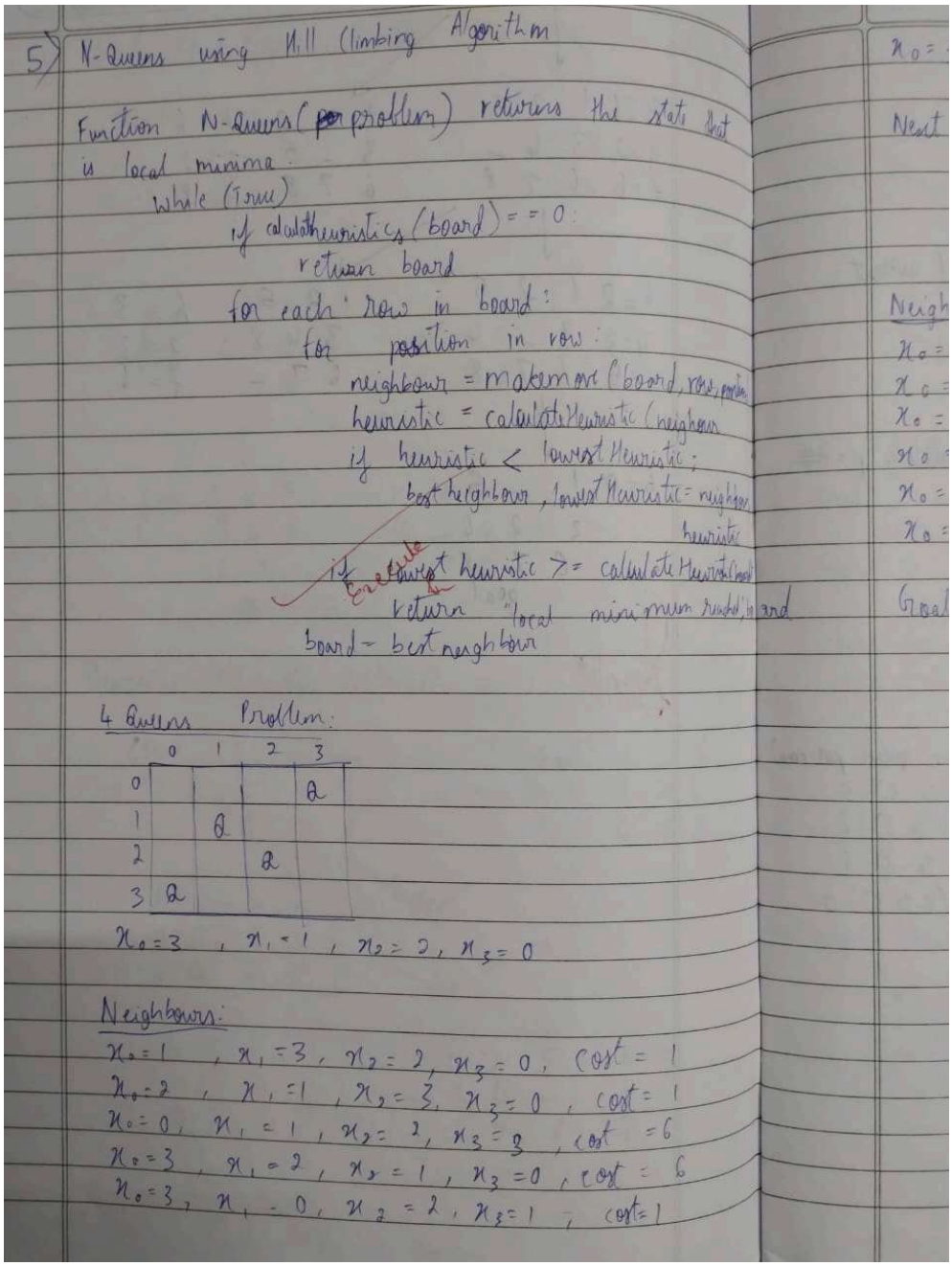
```
            try:
                row = [int(x) for x in row]
            except ValueError:
                print("Invalid input. Please enter only numbers.")
                continue
            if not all(0 <= x <= 8 for x in row):
                print("Numbers must be between 0 and 8.")
                continue
            state.append(row)

        if len(set(sum(state, []))) != 9:
            print("Each number from 0 to 8 must appear exactly
            once.") continue

        return state

def main():
    start_state = get_user_input()
    solution = a_star_search(start_state)

    if solution:
        print("Solution found in", len(solution) - 1, "steps:")
        for step in solution:
            for row in step:
                print(row)

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

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

Output:

```
Enter your 8-puzzle configuration (0 represents the empty tile):
Enter row 1: 1 2 3
Enter row 2: 0 5 6
Enter row 3: 4 7 8
Solution found in 3 steps:
[1, 2, 3]
[0, 5, 6]
[4, 7, 8]

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

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

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

2.Implement Hill Climbing Algorithm.

Algorithm :



5) N-Queens using Hill Climbing Algorithm

Function N-Queens(problem) returns the state that is local minima:
  while (True)
    if calculateHeuristics(board) == 0:
      return board
    for each row in board:
      for position in row:
        neighbour = makemove(board, row, position)
        heuristic = calculateHeuristic(neighbour)
        if heuristic < lowest Heuristic:
          best neighbour, lowest Heuristic = neighbour, heuristic
    if lowest heuristic >= calculate Heuristic(board):
      return "local minimum reached" and board
    board = best neighbour

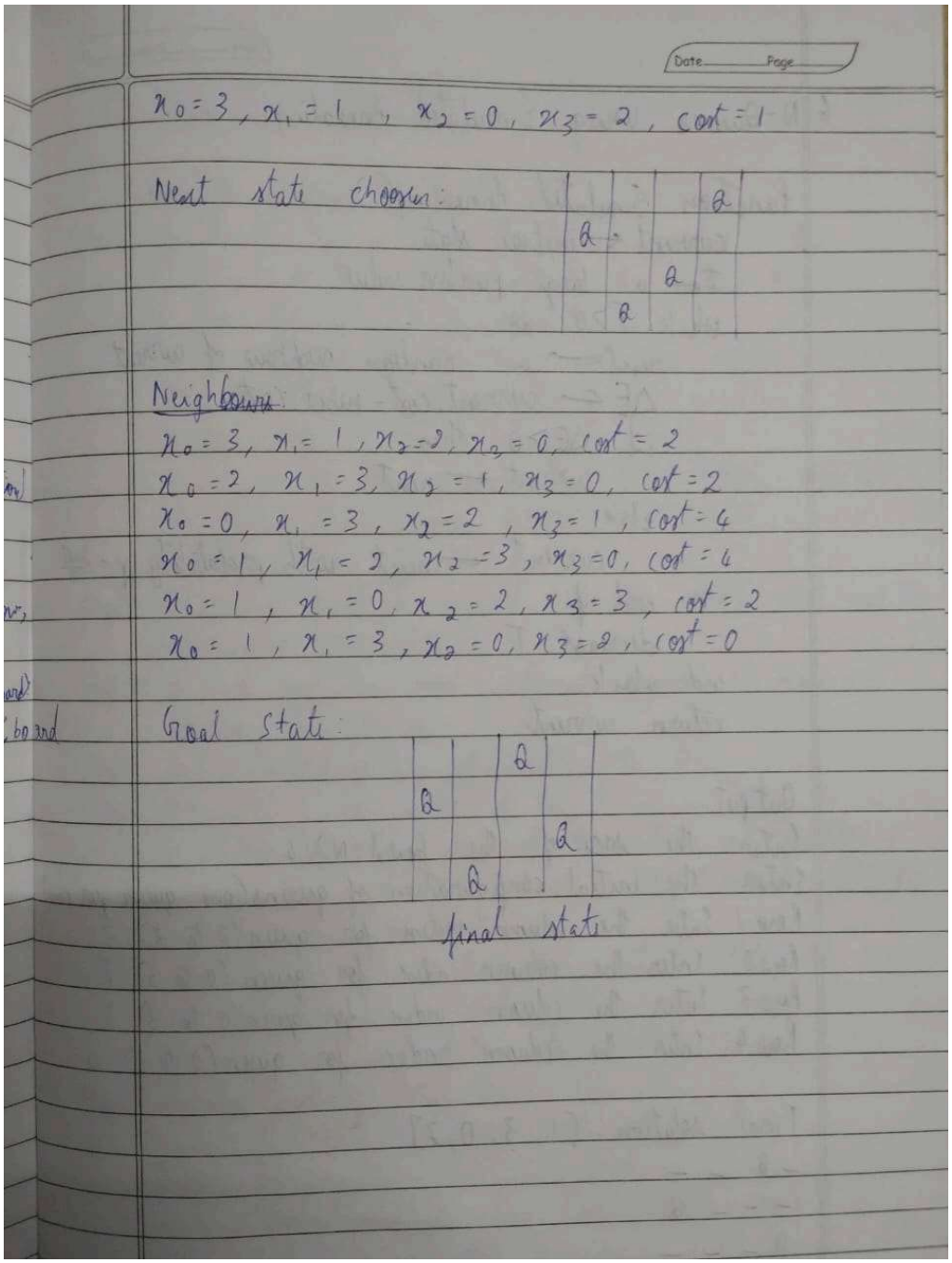
4 Queens Problem:

	0	1	2	3
0				Q
1		Q		
2			Q	
3	Q			

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

Neighbours:

$x_0 = 1$, $x_1 = 3$, $x_2 = 2$, $x_3 = 0$, cost = 1
$x_0 = 2$, $x_1 = 1$, $x_2 = 3$, $x_3 = 0$, cost = 1
$x_0 = 0$, $x_1 = 1$, $x_2 = 2$, $x_3 = 3$, cost = 6
$x_0 = 3$, $x_1 = 2$, $x_2 = 1$, $x_3 = 0$, cost = 6
$x_0 = 3$, $x_1 = 0$, $x_2 = 2$, $x_3 = 1$, cost = 1



Code :

```
import random

def hill_climbing_n_queens(n):
    board = generate_random_board(n)
```

```
    while True:
        current_cost = calculate_conflicts(board)
        if current_cost == 0:
            return board
        next_board, next_cost = get_best_neighbor(board)
        if next_cost >= current_cost:
            board = generate_random_board(n)
        else:

            board =

next_board def

generate_random_board(n):

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

range(n)] def calculate_conflicts(board):

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

def get_best_neighbor(board):
    n = len(board)
    best_board = board[:]
    best_cost = calculate_conflicts(board)
    for col in range(n):
        original_row = board[col]
        for row in range(n):
            if row != original_row:
                board[col] = row
                cost = calculate_conflicts(board)

                if cost < best_cost:
                    best_cost = cost
                    best_board =

        board[:] board[col] =

        original_row
```

```
    return best_board, best_cost

n=int(input("No of queens: "))
solution = hill_climbing_n_queens(n)
print("Solution for", n, "queens:")
print(solution)
```

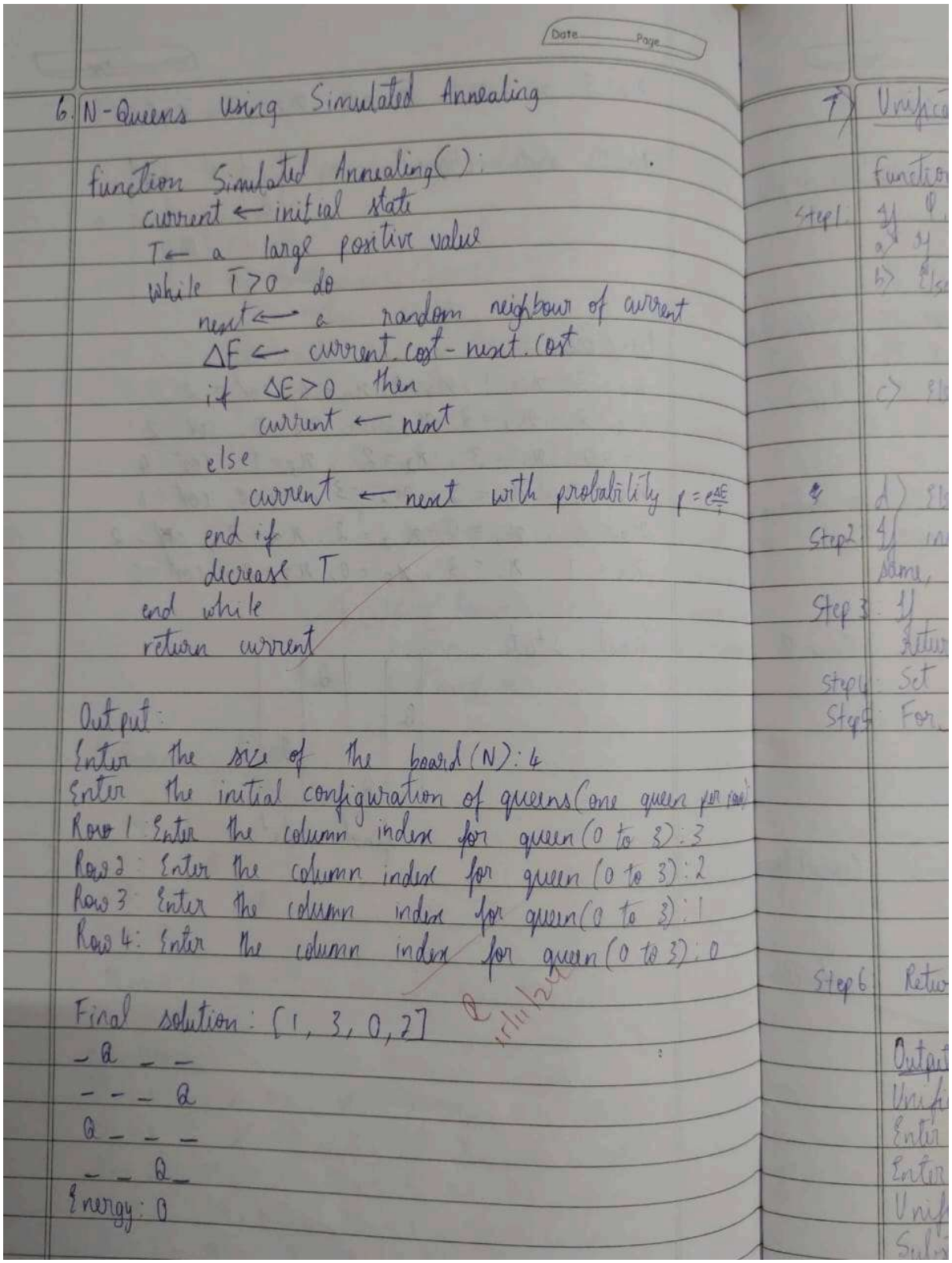
Output :

```
No of queens: 4
Solution for 4 queens:
[2, 0, 3, 1]
```

Program 6

Write a program to implement Simulated Annealing Algorithm

Algorithm :



6. N-Queens using Simulated Annealing

```
function SimulatedAnnealing():
    current ← initial state
    T ← a large positive value
    while T > 0 do
        next ← a random neighbour of current
        ΔE ← current.cost - next.cost
        if ΔE > 0 then
            current ← next
        else
            current ← next with probability p = e^(ΔE/T)
        end if
        decrease T
    end while
    return current
```

Output:

```
Enter the size of the board (N): 4
Enter the initial configuration of queens (one queen per row)
Row 1: Enter the column index for queen (0 to 3): 3
Row 2: Enter the column index for queen (0 to 3): 2
Row 3: Enter the column index for queen (0 to 3): 1
Row 4: Enter the column index for queen (0 to 3): 0

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

Code :

```
import random
import math

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

def generate_neighbors(state):
    neighbors = []
    n = len(state)
    for i in range(n):
        for j in range(i + 1, n):
            neighbor = state[:]
            neighbor[i], neighbor[j] = neighbor[j],
            neighbor[i] neighbors.append(neighbor)
    return neighbors

def acceptance_probability(old_cost, new_cost, temperature):
    if new_cost < old_cost:
        return 1.0
    return math.exp((old_cost - new_cost) / temperature)

def simulated_annealing(n, initial_state, initial_temp, cooling_rate,
max_iterations):
    state = initial_state
    current_cost = count_conflicts(state)
    temperature = initial_temp

    for iteration in range(max_iterations):
        neighbors = generate_neighbors(state)
        random_neighbor = random.choice(neighbors)
        new_cost = count_conflicts(random_neighbor)

        if acceptance_probability(current_cost, new_cost, temperature)
> random.random():
```

```
            state = random_neighbor
            current_cost = new_cost
        temperature *=
        cooling_rate if
        current_cost == 0:
            return state
    return None

def get_user_input(n):
    while True:
        try:
            user_input = input(f"Enter the column positions for the
queens (space-separated integers between 0 and {n-1}): ")
            initial_state = list(map(int, user_input.split()))
            for row in range(n):
              board = ['Q' if col == initial_state[row] else '.' for col
in range(n)]
              print(' '.join(board))
            if len(initial_state) != n or any(x < 0 or x >= n for x in
initial_state):
                print(f"Invalid input. Please enter exactly {n} integers between
0 and {n-1}.")
                continue
            return initial_state
        except ValueError:
            print(f"Invalid input. Please enter a list of {n} integers.")

n = 8
initial_state = get_user_input(n)

initial_temp = 1000
cooling_rate = 0.99
max_iterations = 10000


solution = simulated_annealing(n, initial_state, initial_temp, cooling_rate,
max_iterations)

if solution:
    print("Solution found!")

    for row in range(n):
        board = ['Q' if col == solution[row] else '.' for col in range(n)]
        print('
'.join(board)) else:
```

```
    print("No solution found within the given iterations.")
```

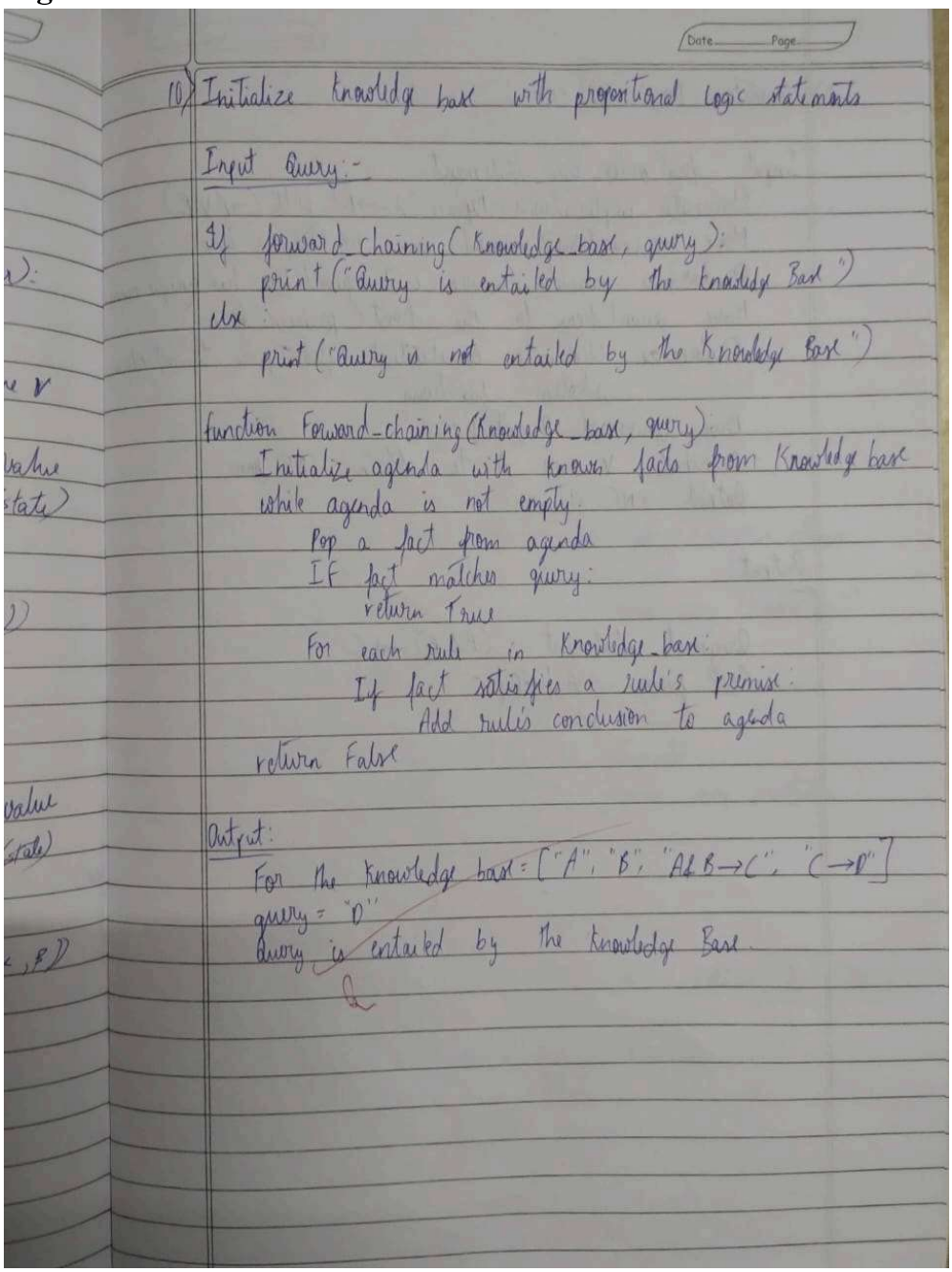
Output:

```
Enter the column positions for the queens (space-separated integers between 0 and 7): 0 1 2 3 4 5 6 7
Q . . . . . . .
. Q . . . . . .
. . Q . . . . .
. . . Q . . . .
. . . . Q . . .
. . . . . Q . .
. . . . . . Q .
. . . . . . . Q
Solution found!
. . . . . Q . .
. . Q . . . . .
Q . . . . . . .
. . . . . . . Q
. . . . Q . . .
. Q . . . . . .
. . . Q . . . .
. . . . . . Q .
```

Program 7

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

Algorithm :



Code :

```
from itertools import product
```

```
# Define a function to evaluate a propositional expression
def evaluate(expr, model):
    """
    Evaluates the given expression based on the values in the model.
    """
    for var, val in model.items():
        expr = expr.replace(var, str(val))
    return eval(expr)

# Define the truth-table enumeration algorithm
def truth_table_entails(KB, query, symbols):
    """
    Checks if KB entails query using truth-table enumeration.
    KB: list of propositional expressions (strings)
    query: propositional expression (string)
    symbols: list of symbols (propositions) in the KB and
    query """
    # Generate all possible truth assignments
    assignments = list(product([False, True], repeat=len(symbols)))

    entailing_models = []

    # Iterate over each assignment to check
    entailment for assignment in assignments:
        model = dict(zip(symbols, assignment))

        # Check if KB is true in this model
        KB_is_true = all(evaluate(expr, model) for expr in KB)

        # If KB is true, check if query is also
        true if KB_is_true:
            query_is_true = evaluate(query, model)
            if query_is_true:
                entailing_models.append(model)  # Store the
            model else:
                return False, []
               # Found a model where KB is true but query is false

    return True, entailing_models  # KB entails query if no counterexample
was found

# Get input from the user
symbols = input("Enter the propositions (symbols) separated by spaces: ").split()
KB = []
n = int(input("Enter the number of statements in the knowledge base: "))
```

```
for i in range(n):
expr = input(f"Enter statement {i + 1} in the knowledge base: ") KB.append(expr)

query = input("Enter the query: ")

# Check entailment
result, models = truth_table_entails(KB, query, symbols)
if truth_table_entails(KB, query, symbols):
print("KB entails the query.")
print("Models where KB entails query:") for
    model in models:
print(model)
else:
print("KB does not entail the query.")
```

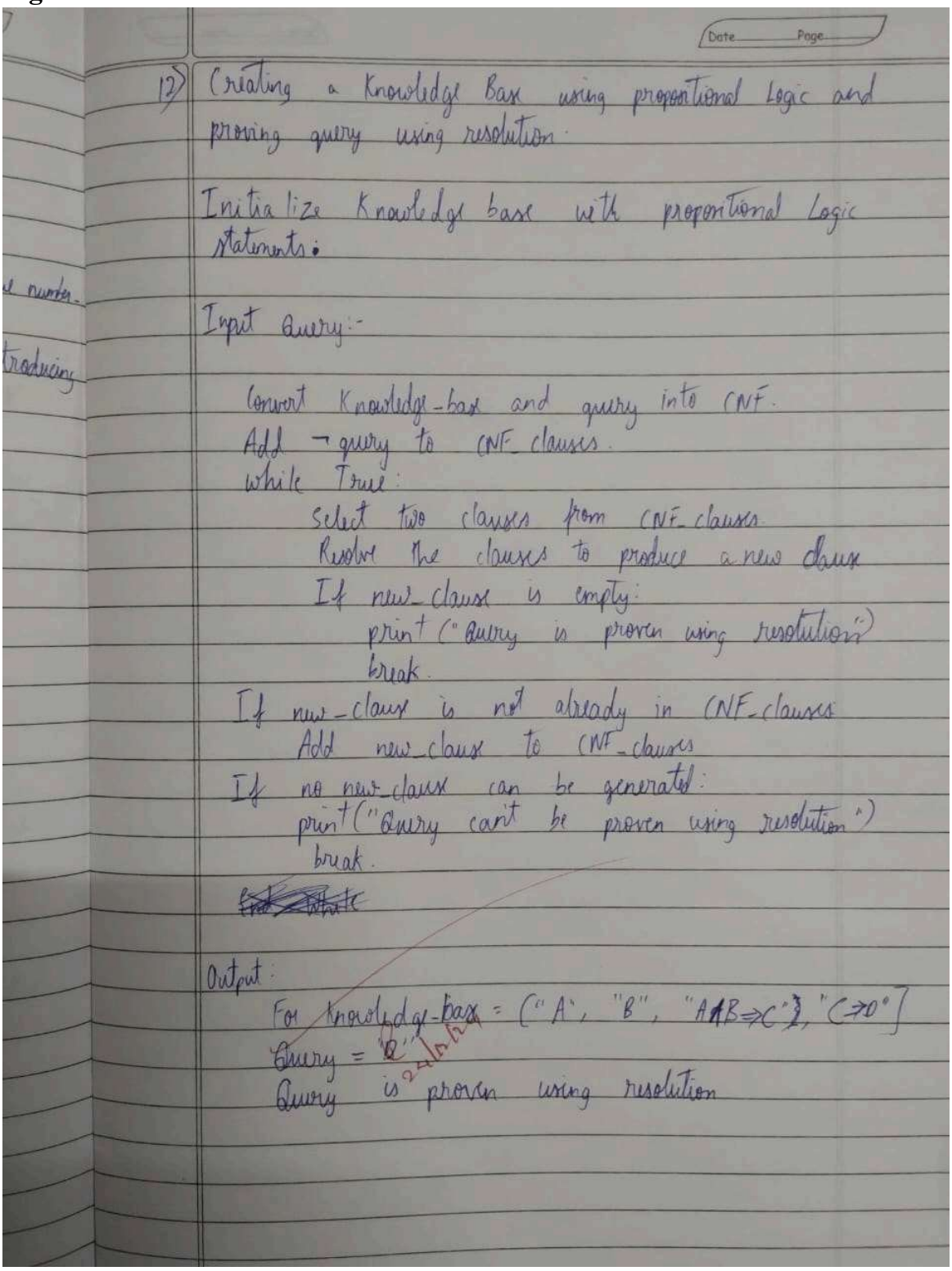
Output :

```
Enter the propositions (symbols) separated by spaces: A B C
Enter the number of statements in the knowledge base: 2
Enter statement 1 in the knowledge base: A or C
Enter statement 2 in the knowledge base: B or not C
Enter the query: A or B
KB entails the query.
Models where KB entails query:
{'A': False, 'B': True, 'C': True}
{'A': True, 'B': False, 'C': False}
{'A': True, 'B': True, 'C': False}
{'A': True, 'B': True, 'C': True}
```

Program 8

Create a knowledge base using propositional logic and prove the given query using resolution.

Algorithm :



12) Creating a Knowledge Base using propositional Logic and proving query using resolution.

Initialize Knowledge base with propositional Logic statements:

Input Query:-

Convert Knowledge-base and query into CNF.
Add ¬ query to CNF_clauses.
while True:
    Select two clauses from CNF_clauses
    Resolve the clauses to produce a new clause
    If new_clause is empty:
        print("Query is proven using resolution")
        break.
If new_clause is not already in CNF_clauses
    Add new_clause to CNF_clauses
If no new_clause can be generated:
    print("Query can't be proven using resolution")
    break.

Output:
For Knowledge-base = ["A", "B", "A∧B⇒C"], "C⇒D"]
Query = "D"
Query is proven using resolution

Code :

```
kb = [
    {"¬B", "¬C", "A"},  # ¬B ∨ ¬C ∨ A
    {"B"},              # B
    {"¬D", "¬E", "C"},  # ¬D ∨ ¬E ∨ C
    {"E", "F"},         # E ∨ F
    {"D"},              # D
    {"¬F"},             # ¬F
]

# Negate the query: If the query is "A", we negate it to "¬A"
def negate_query(query):
    if "¬" in query:
        return query.replace("¬", "")  # If it's negated, remove the negation
    else:
        return f"¬{query}"  # Otherwise, add negation in front

# Function to perform resolution on two clauses
def resolve(clause1, clause2):
    resolved_clauses = []
    for literal1 in clause1:
        # Try to find complementary literals for literal1 in clause1
        for literal2 in clause2:
            # If literals are complementary (e.g., "A" and "¬A"), resolve them
            if literal1 == f"¬{literal2}" or f"¬{literal1}" == literal2:
                new_clause = (clause1 | clause2) - {literal1, literal2}
                resolved_clauses.append(new_clause)
    return resolved_clauses

# Perform resolution-based proof
def resolution(kb, query):
    # Step 1: Negate the query and add it to the knowledge base
    negated_query = negate_query(query)
    kb.append({negated_query})

    # Step 2: Initialize the set of clauses
    new_clauses = set(frozenset(clause) for clause in kb)

    while True:
        resolved_this_round = set()
        clauses_list = list(new_clauses)

        # Try to resolve every pair of clauses
        for i in range(len(clauses_list)):
            for j in range(i + 1, len(clauses_list)):
                clause1 = clauses_list[i]
                clause2 = clauses_list[j]

                # Apply resolution to the two clauses
                resolved = resolve(clause1, clause2)
                if frozenset() in resolved:
                    return True  # Found an empty clause (contradiction), query
is provable
                resolved_this_round.update(resolved)

        # If no new clauses were added, stop
        if resolved_this_round.issubset(new_clauses):
            return False  # No new clauses, query is not provable

        # Add new resolved clauses to the set
```

```
        new_clauses.update(resolved_this_round)

# Query to prove: "A"
print("Using Resolution to prove a query")
query = input("Enter the query: ")
result = resolution(kb, query)
print(f"Is the query '{query}' provable? {'Yes' if result else 'No'}")
```

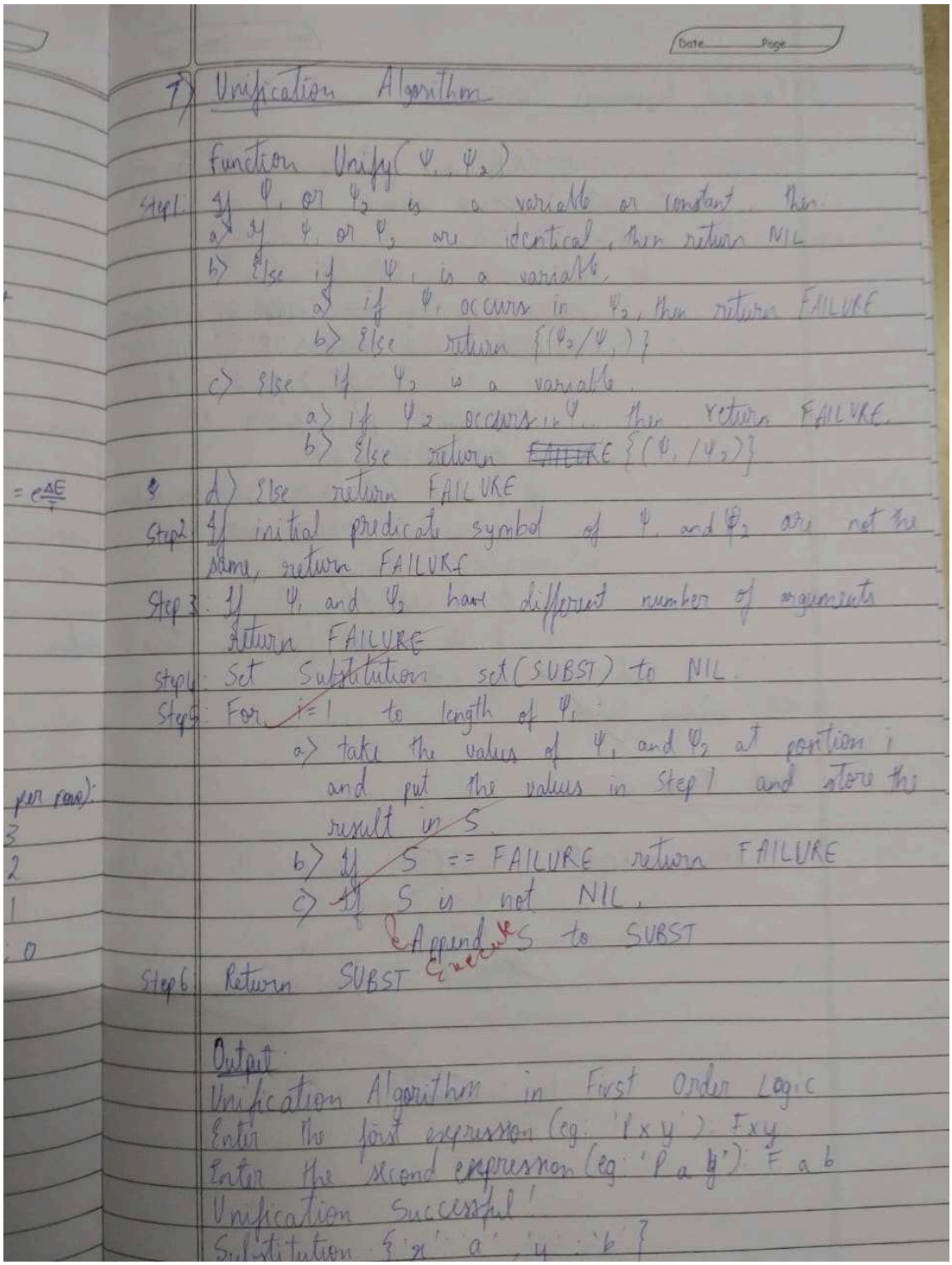
Output :

```
Enter the query: A
Using Resolution to prove a query
Is the query 'A' provable? Yes
```

Program 9

Implement unification in first order logic.

Algorithm :



Code :

```
def unify(s1, s2, theta={}):
    if theta is None:
        return None

    if s1 == s2:
        return theta

    if isinstance(s1, str) and
        s1.islower(): return unify_var(s1,
        s2, theta)

    if isinstance(s2, str) and s2.islower():
        return unify_var(s2, s1, theta)

    if isinstance(s1, tuple) and isinstance(s2, tuple) and len(s1) ==
        len(s2): return unify(s1[1:], s2[1:], unify(s1[0], s2[0], theta))

    return None

def unify_var(var, x, theta):
    if var in theta:
        return unify(theta[var], x,
    theta) elif x in theta:
        return unify(var, theta[x], theta)
    elif occurs_check(var, x, theta):
        return None
    else:
        theta[var] = x
        return theta

def occurs_check(var, x, theta):
```

```
    if var == x:
        return True
    elif isinstance(x, str) and x.islower() and x in theta:
        return occurs_check(var, theta[x], theta)
    elif isinstance(x, tuple):
        for arg in x:
            if occurs_check(var, arg, theta):
                return True
        return False

s1 = ('p', 'x', ('f', 'x'), ('y'))
s2 = ('p', 'a', 'y', ('f', 'x'))

substitution = unify(s1, s2)

if substitution:
    print("Unification successful:")
    print(f"Substitution:
else{substitution}")
    print("Unification
failed.")
```

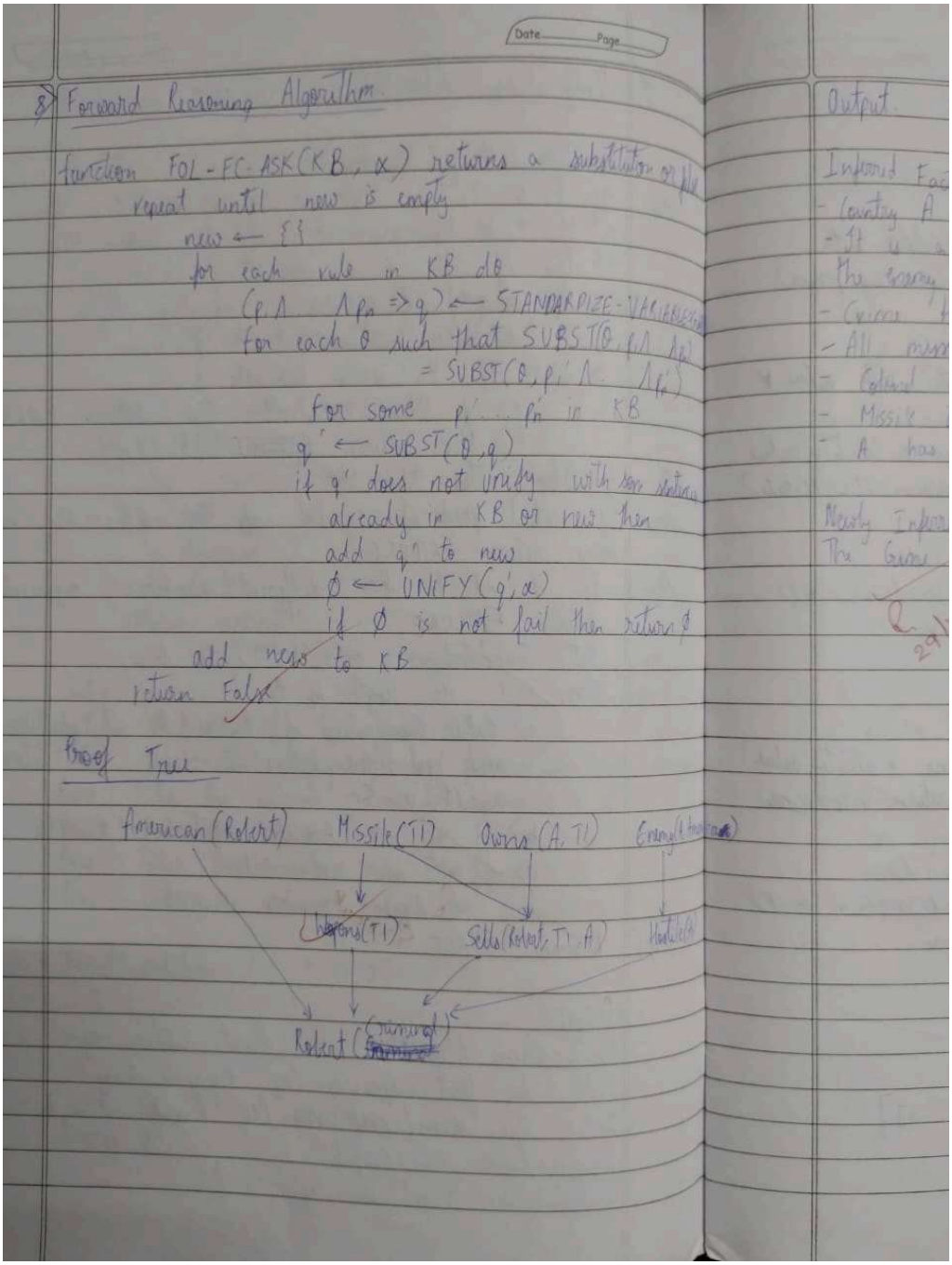
Output:

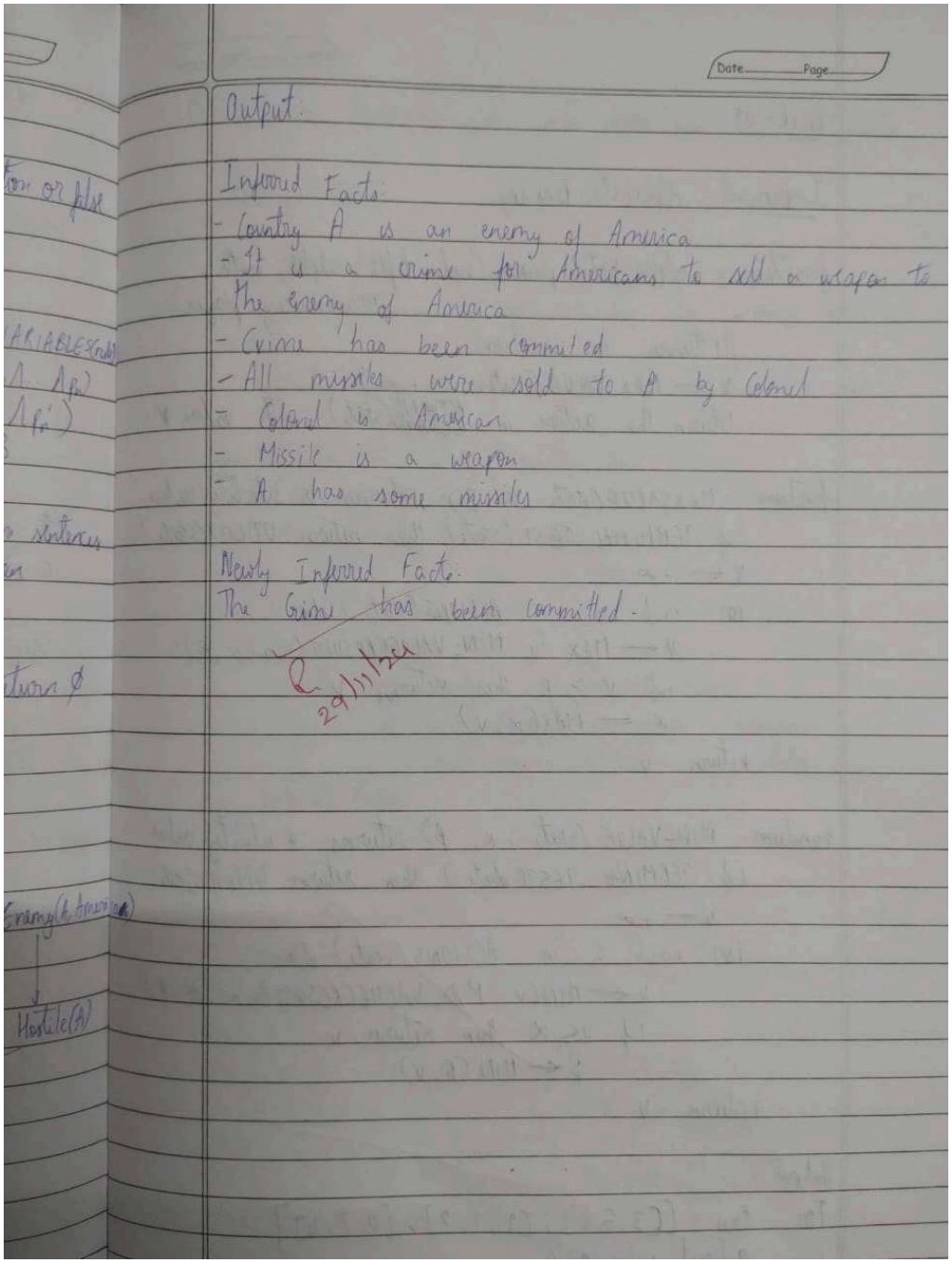
```
Unification successful:
Substitution: {'x': 'a', 'y': ('f', 'x')}
```

Program 10

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

Algorithm :





Code :

```
# Define the knowledge base as a list of rules and facts
class KnowledgeBase:
    def _init_(self):
self.facts = set()      # Set of known facts
        self.rules = []      # List of rules

def add_fact(self, fact):
```

```
        self.facts.add(fact)

    def add_rule(self, rule):
        self.rules.append(rule)

    def infer(self):
        inferred = True
        while inferred:
            inferred = False
            for rule in self.rules:
                if rule.apply(self.facts):
                    inferred = True

# Define the Rule class
class Rule:
    def _init_(self, premises, conclusion):
        self.premises = premises  # List of conditions
        self.conclusion = conclusion  # Conclusion to add if premises are met

    def apply(self, facts):
        if all(premise in facts for premise in
            self.premises): if self.conclusion not in facts:
                facts.add(self.conclusion)
                print(f"Inferred:
                {self.conclusion}") return True
        return False

# Initialize the knowledge base
kb = KnowledgeBase()

# Facts in the problem
kb.add_fact("American(Robert)")
kb.add_fact("Missile(T1)")
kb.add_fact("Owns(A, T1)")
kb.add_fact("Enemy(A, America)")

# Rules based on the problem
# 1. Missile(x) implies Weapon(x)
kb.add_rule(Rule(["Missile(T1)"], "Weapon(T1)"))

# 2. Enemy(x, America) implies Hostile(x)
kb.add_rule(Rule(["Enemy(A, America)"], "Hostile(A)"))

# 3. Missile(x) and Owns(A, x) imply Sells(Robert, x, A)
kb.add_rule(Rule(["Missile(T1)", "Owns(A, T1)"], "Sells(Robert, T1, A)"))

# 4. American(p) and Weapon(q) and Sells(p, q, r) and Hostile(r) imply Criminal(p)
```

```
kb.add_rule(Rule(["American(Robert)", "Weapon(T1)", "Sells(Robert, T1, A)",
"Hostile(A)"], "Criminal(Robert)"))

# Infer new facts based on the rules
kb.infer()

# Check if Robert is a criminal
if "Criminal(Robert)" in kb.facts:
    print("Conclusion: Robert is a criminal.")
else:
    print("Conclusion: Unable to prove Robert is a criminal.")
```

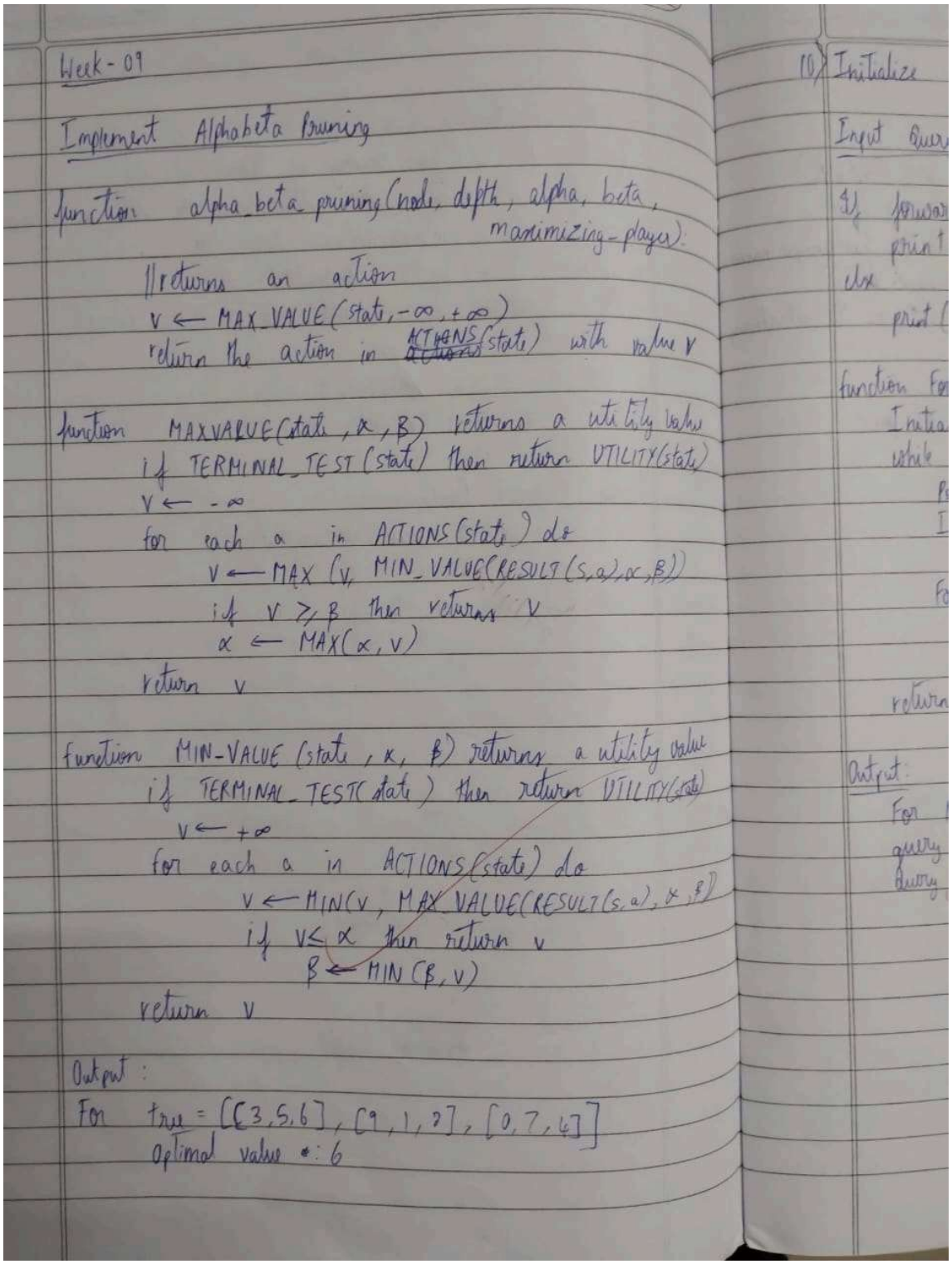
Output :

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

Program 11

Implement Alpha-Beta Pruning.

Algorithm :



Week - 09

Implement Alphabeta Pruning

function alpha_beta_pruning(node, depth, alpha, beta, maximizing_player):

//returns an action

v ← MAX_VALUE(state, -∞, +∞)

return the action in ACTIONS(state) with value v

function MAXVALUE(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

Output :

For true = [[3,5,6], [9,1,2], [0,7,4]]

Optimal value : 6

Code :

```
MAX, MIN = 1000, -1000

def minimax(depth, nodeIndex, maximizingPlayer,
      values, alpha, beta):

  if depth == 3:
    return values[nodeIndex]

  if maximizingPlayer:

    best = MIN

    # Recur for left and right children
    for i in range(0, 2):

      val = minimax(depth + 1, nodeIndex * 2 + i,
            False, values, alpha, beta)
      best = max(best, val)
      alpha = max(alpha,
      best)

      # Alpha Beta Pruning
      if beta <= alpha:
        break
    return best
  else:
    best = MAX

    # Recur for left and
    # right children
    for i in range(0, 2):

      val = minimax(depth + 1, nodeIndex * 2 + i,
              True, values, alpha, beta)
      best = min(best, val)
      beta = min(beta, best)

      # Alpha Beta Pruning
      if beta <= alpha:
        break

    return best
```

```
# Driver Code
if _name    == "_main_":

  values = [3, 5, 6, 9, 1, 2, 0, -1]
  print("The optimal value is :", minimax(0, 0, True, values, MIN, MAX))
```

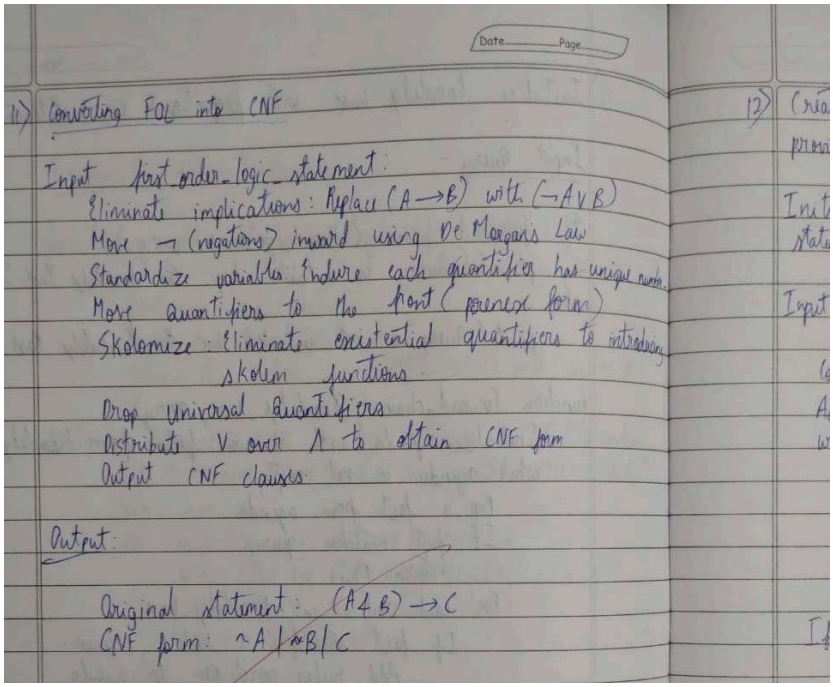
Output :

```
The optimal value is : 5
---------
```

Program 12

CONVERTING FOL TO CNF:

ALGORITHM:



CODE:

```
from sympy import symbols, Not, Or, And, Implies, Equivalent
from sympy.logic.boolalg import to_cnf

def fol_to_cnf(fol_expr):
      fol_expr = fol_expr.replace(Equivalent, lambda a, b: And(Implies(a,
b),Implies(b, a)))
    fol_expr = fol_expr.replace(Implies, lambda a, b: Or(Not(a), b))
      cnf_form = to_cnf(fol_expr, simplify=True)
      return cnf_form
```

```
def main():
      P = symbols("P")
    Q = symbols("Q")
    R = symbols("R")

      fol_expr1 = Implies(P, Q)
      print("Example 1: P → Q")
      print("Original FOL
Expression:")
      print(fol_expr1)

    cnf1 = fol_to_cnf(fol_expr1)
    print("\nCNF Form:")
      print(cnf1)

      fol_expr2 = Implies(Or(P, Not(Q)), Or(Q,
R))
      print("\nExample 2: (P ∨ ¬Q) → (Q ∨ R)")
    print("Original FOL Expression:")
    print(fol_expr2)

      cnf2 = fol_to_cnf(fol_expr2)
      print("\nCNF Form:")
      print(cnf2)

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

OUTPUT:

```
Example 1: P → Q
Original FOL Expression:
Implies(P, Q)

CNF Form:
Q | ~P

Example 2: (P ∨ ¬Q) → (Q ∨ R)
Original FOL Expression:
Implies(P | ~Q, Q | R)

CNF Form:
Q | R
```