B.M.S. COLLEGE OF ENGINEERING
BENGALURU Autonomous Institute, Affiliated to VTU

Lab Record

Artificial Intelligence

(22CS5PCAIN)

Bachelor of Technology
in
Computer Science and Engineering

Submitted by:

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B.M.S. COLLEGE OF ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

CERTIFICATE

This is to certify that the Artificial Intelligence (22CS5PCAIN) laboratory has beencarried out by Shashank M M(1BM21CS199) during the 5th Semester September-January 2021.

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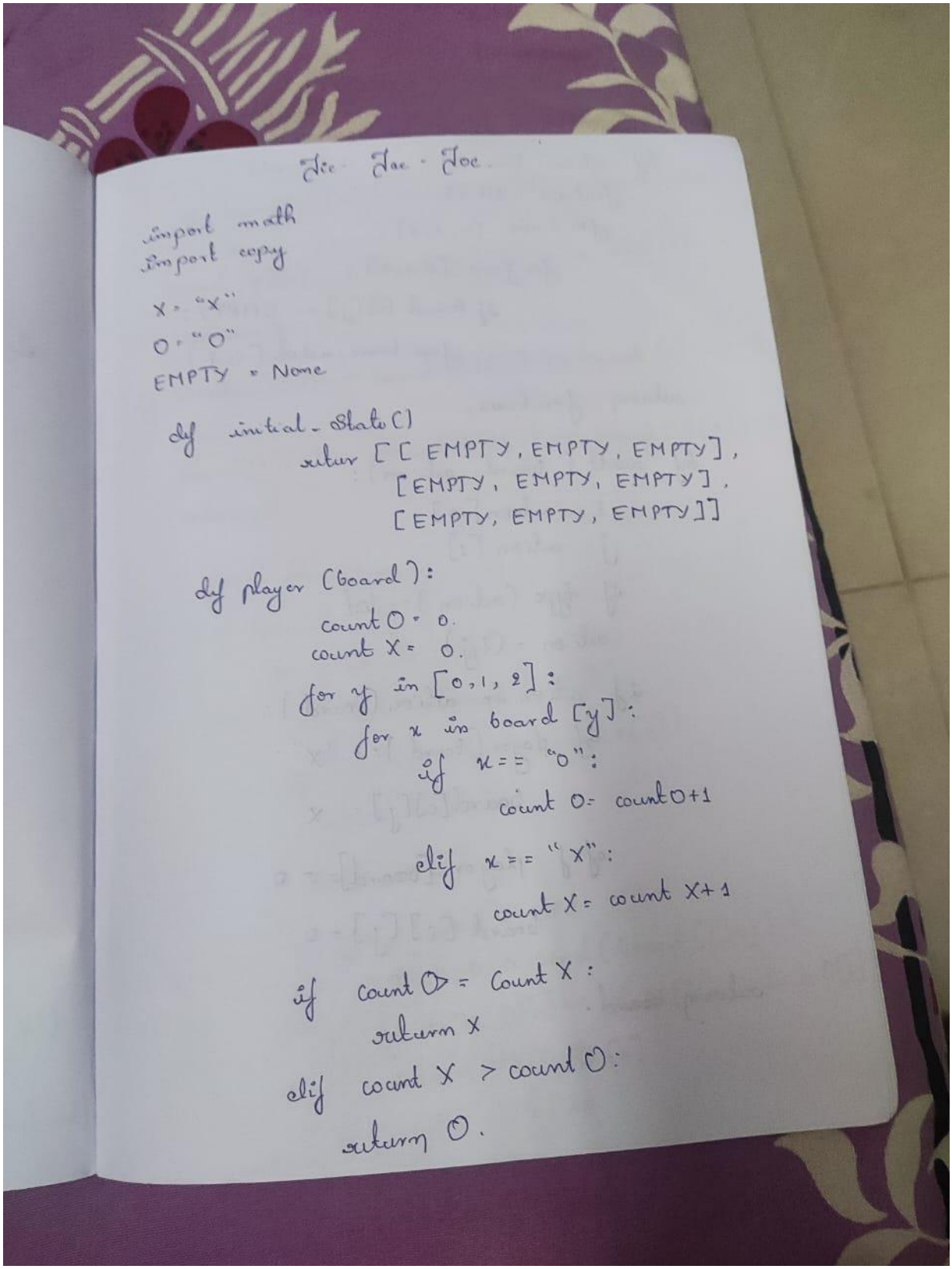


```
Tic - Tac - Toe

import math
import copy

X = "X"
O = "O"
EMPTY = None

def initial_state():
    return [[EMPTY, EMPTY, EMPTY],
            [EMPTY, EMPTY, EMPTY],
            [EMPTY, EMPTY, EMPTY]]

def player(board):
    countO = 0
    countX = 0
    for y in [0, 1, 2]:
        for x in board[y]:
            if x == "O":
                countO = countO+1
            elif x == "X":
                countX = countX+1

    if countO >= countX:
        return X
    elif countX > countO:
        return O
```

```
def actions(board):
    freeboxes = set()
    for i in [0, 1, 2]:
        for j in [0,1, 2]:
            if board[i][j] == EMPTY:
                free boxes.add(i, j)

return free boxes.

def result(board, action):
        i = action[0]
        j = action[1].
        if type(action) == list
         action = (i, j)
        if action in action(board):
            if player[board] == 'X'
                board[i][j] = X
            elif player[board] == 0.
                board[i][j] = 0.

return board.
```

```
def winner (board):
    if board[0][0] == board[0][1] == board[0][2] ==
        X or
    board[i][0] == board[1][j] == board[1][2] == X
    return X.
if board[0][0] == board[0][1] == board[0][2] == 0
    or
    board[i][0] == board[1][1] == board[1][2] == 0
    return O.
    for i in [0,1,2]
        S2 = [].
        for j in [0,1,2]:
            S2.append(board[i][j])
        if (S2[0] == S2[1] == S2[2])
            return S2[0].
        Strike D = [].
        for i in [0,1,2]
            Strike 0.append(board[i][j])
        if strike D[0] == strike[1] == strike D[2]
            return strike D[0].
    return if board[0][2] is
        None.
```

```
def terminal(board):
    Full = True
    for i in [0, 1, 2]:
        for j in board[i]:
            if j in Node:
                Full = False.

    if Full:
        return True
    if (winner(board) is not None):
        return True.
    return False.

def utility(board):
    if (winner(board) == X):
        return 1
    elif winner(board) == 0:
        return -1
    else:
        return 0.

def minimax - helper(board):
    isMaxTurn = True if player(board) == X else
                False
    if terminal(board):
        return utility(board)
    scores = [].
```

```
for move in actions (board):
    result (board, move)
    scores.append (minimax_helper (board))
    board [move[0]] [move[1]] = EMPTY
return max (scores) if isMaxturn else min(scores)

def minimax (board):
    isMaxTurn = True if player (board) == X
                else False

    bestMove = None
    if isMaxTurn:
        bestScore = -math.inf
        for move in actions (board):
            result (board, move)
            Score = minimax_helper (board)
            board [move[0]] [move[1]] = EMPTY
            if (score > best score):
                best Score = Score
                best Move = move

        return best Move.

    else:
        best Score = +math.inf
        for move in actions (board):
            result (board, move).
            score = minimax_helper (board)
            board [move[0]] [move[1]] = EMPTY.
            if (score < best Score):
```

= X else

```
        best_Score = score
        best_Move = move
    return best_Move

def print_board (board):
    for row in board:
        print (row)

game_board = initial_state()
print ("Initial Board:")
print_board (game_board)

while not terminal (game_board):
    if player (game_board) == X:
        user_input = input ("\n Enter your move
                            (row, column): ")
        row, col = map (int, user_input.split (','))
        result (game_board, (row, col))
    else:
        print ("\n AI is making a move...")
        move = minimax (copy, dup copy (game_board
        result (game_board, move)
    print ("\n Current Board:")
    print_board (game_board)
if winner (game_board) is not true None:
```

print ("\n The winner is :", winner(gameboard))

else:
print (" It's a tie !").

Output :

Initial board :
[None, None, None],
[None, None, None]
[None, None, None],

Enter your move (row, column) = 0, 1

current board:

[None , O, None]
[None , None , None]
[None, None , None]

AI is making a move:

Current board:
[None , None, None]
[None, None, None]
[X , None, None].

Implement Tic-Tac-Toe Game

Objective: The objective of tic-tac-toe is that players have to position their marks so that they make a continuous line of three cells horizontally, vertically or diagonally**.**

Code:

```
board = [' ' for x in range(10)]
def insertLetter(letter, pos):
    board[pos] = letter


def spaceIsFree(pos):
    return board[pos] == ' '


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

```
    print('   |   |')



def isWinner(bo, le):
    return (bo[7] == le and bo[8] == le and bo[9] == le) or (bo[4] == le and bo[5] == le and bo[6] == le) or (
            bo[1] == le and bo[2] == le and bo[3] == le) or (bo[1] == le and bo[4] == le and bo[7] == le) or (
                    bo[2] == le and bo[5] == le and bo[8] == le) or (
                    bo[3] == le and bo[6] == le and bo[9] == le) or (
                    bo[1] == le and bo[5] == le and bo[9] == le) or (bo[3] == le and bo[5] == le and bo[7] == le)



def playerMove():
    run = True
    while run:
        move = input('Please select a position to place an \'X\' (1-9): ')
        try:
            move = int(move)
            if move > 0 and move < 10:
                if spaceIsFree(move):
                    run = False
                    insertLetter('X', move)
                else:
                    print('Sorry, this space is occupied!')
            else:
                print('Please type a number within the range!')
        except:
```

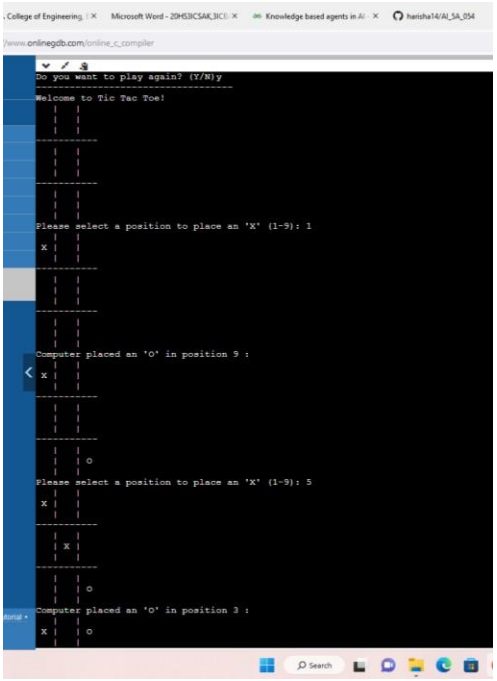
```
            print('Please type a number!')


def compMove():
    possibleMoves = [x for x, letter in enumerate(board) if letter == ' ' and x != 0]
    move = 0

    for let in ['O', 'X']:
        for i in possibleMoves:
            boardCopy = board[:]
            boardCopy[i] = let
            if isWinner(boardCopy, let):
                move = i
                return move

    cornersOpen = []
    for i in possibleMoves:
        if i in [1, 3, 7, 9]:
            cornersOpen.append(i)

    if len(cornersOpen) > 0:
        move = selectRandom(cornersOpen)
        return move

    if 5 in possibleMoves:
        move = 5
        return move
```

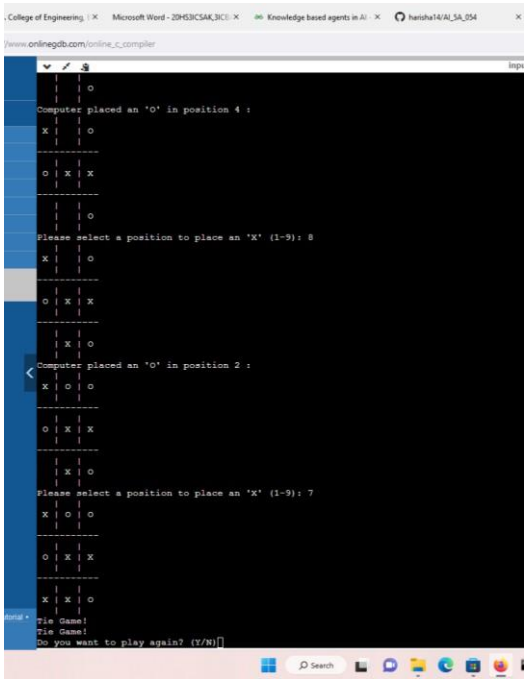
```
    edgesOpen = []
    for i in possibleMoves:
        if i in [2, 4, 6, 8]:
            edgesOpen.append(i)

    if len(edgesOpen) > 0:
        move = selectRandom(edgesOpen)

    return move


def selectRandom(li):
    import random
    ln = len(li)
    r = random.randrange(0, ln)
    return li[r]


def isBoardFull(board):
    if board.count(' ') > 1:
        return False
    else:
        return True


def main():
    print('Welcome to Tic Tac Toe!')
    printBoard(board)
```

```
    while not (isBoardFull(board)):
        if not (isWinner(board, 'O')):
            playerMove()
            printBoard(board)
        else:
            print('Sorry, O\'s won this time!')
            break

        if not (isWinner(board, 'X')):
            move = compMove()
            if move == 0:
                print('Tie Game!')
            else:
                insertLetter('O', move)
                print('Computer placed an \'O\' in position', move, ':')
                printBoard(board)
        else:
            print('X\'s won this time! Good Job!')
            break

    if isBoardFull(board):
        print('Tie Game!')



while True:
    answer = input('Do you want to play again? (Y/N)')
    if answer.lower() == 'y' or answer.lower == 'yes':
```

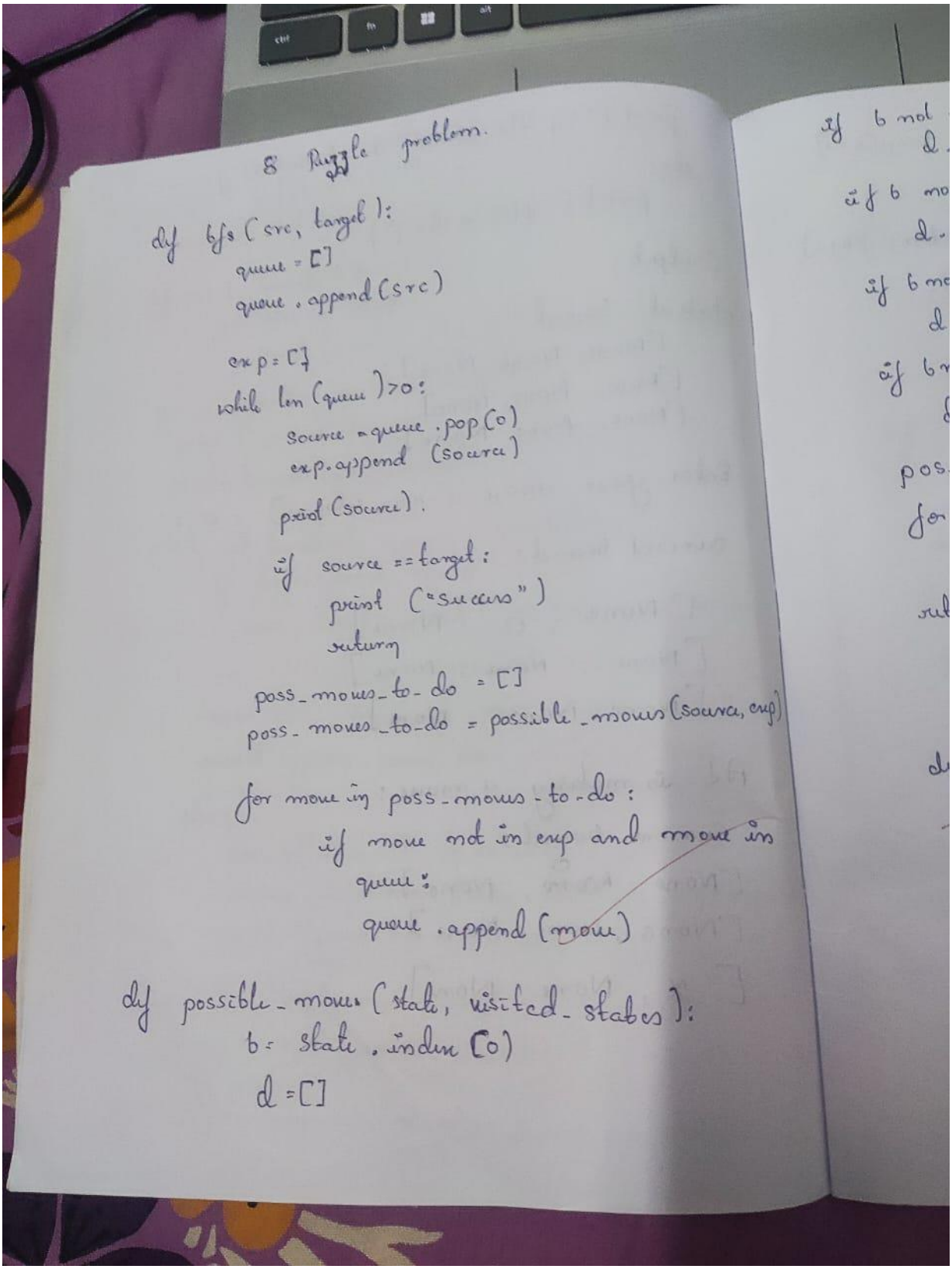
```
        board = [' ' for x in range(10)]
        print('_____')
        main()
    else:
        break;
```

Output:





Lab-Program-2



8 Puzzle problem.

```
def bfs(src, target):
    queue = []
    queue.append(src)

    exp = []
    while len(queue)>0:
        source = queue.pop(0)
        exp.append(source)

        print(source).

        if source == target:
            print("success")
            return

        poss_moves_to_do = []
        poss_moves_to_do = possible_moves(source, exp)

        for move in poss_moves_to_do:
            if move not in exp and move in
                queue:
                queue.append(move)

def possible_moves(state, visited_states):
    b = state.index(0)
    d = []
```

```
if b not in [0,1,2]:
    d.append('u')
if b not in [6,7,8]:
    d.append('d')
if b not in [0,3,6]:
    d.append('l')
if b not in [2,5,8]:
    d.append('r')
pos_moves_it_can = []
for i in d:
    pos_moves_it_can.append(gen(state,i,b))
return [move_it_can for move_it_can in
pos_moves_it_can if move_it_can not in
visited_states]

def gen(state, m, b):
    temp = state.copy()
    if m == 'd':
        temp[b+3], temp[b] = temp[b],
                             temp[b+3]
    if m == 'u':
        temp[b-3], temp[b] = temp[b],
                             temp[b-1]
```

```
if m=='l':
    temp[b-1], temp[b] = temp[b], temp[b-1]

if m=='r':
    temp[b+1], temp[b] = temp[b], temp[b+1]

return temp

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

# src = [2,0,3,1,8,4,7,6,5]
# target = [1,2,3,8,0,4,7,6,5]

bfs(src, target)
```

Output:

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

Solve 8 puzzle problem.

Objective: The objective of 8-puzzle problem is to reach the end state from the start state by considering all possible movements of the tiles without any heuristic.

Code:

```
import numpy as np
import os
class Node:
    def___init_(self, node_no, data, parent, act,
cost):
        self.data = data
        self.parent = parent
        self.act = act
        self.node_no = node_no
        self.cost = cost
def get_initial():
    print("Please enter number from 0-8, no number
should be repeated or be out of this range")
    initial_state = np.zeros(9)
    for i in range(9):
        states = int(input("Enter the " + str(i + 1)
+ " number: "))
        if states < 0 or states > 8:
            print("Please only enter states which are
[0-8], run code again")
            exit(0)
        else:
            initial_state[i] = np.array(states)
    return np.reshape(initial_state, (3, 3))
def find_index(puzzle):
    i, j = np.where(puzzle == 0)
    i = int(i)
    j = int(j)
    return i, j
def move_left(data):
```

```
    i, j = find_index(data)
    if j == 0:
        return None
    else:
        temp_arr = np.copy(data)
        temp = temp_arr[i, j - 1]
        temp_arr[i, j] = temp
        temp_arr[i, j - 1] = 0
        return temp_arr
def move_right(data):
    i, j = find_index(data)
    if j == 2:
        return None
    else:
        temp_arr = np.copy(data)
        temp = temp_arr[i, j + 1]
        temp_arr[i, j] = temp
        temp_arr[i, j + 1] = 0
        return temp_arr
def move_up(data):
    i, j = find_index(data)
    if i == 0:
        return None
    else:
        temp_arr = np.copy(data)
        temp = temp_arr[i - 1, j]
        temp_arr[i, j] = temp
        temp_arr[i - 1, j] = 0
        return temp_arr
def move_down(data):
    i, j = find_index(data)
    if i == 2:
        return None
    else:
        temp_arr = np.copy(data)
        temp = temp_arr[i + 1, j]
        temp_arr[i, j] = temp
        temp_arr[i + 1, j] = 0
        return temp_arr
```

```
def move_tile(action, data):
    if action == 'up':
        return move_up(data)
    if action == 'down':
        return move_down(data)
    if action == 'left':
        return move_left(data)
    if action == 'right':
        return move_right(data)
    else:
        return None
def print_states(list_final):  # To print the final
states on the console
    print("printing final solution")
    for l in list_final:
        print("Move : " + str(l.act) + "\n" + "Result
: " + "\n" + str(l.data) + "\t" + "node number:" +
str(l.node_no))


def write_path(path_formed):  # To write the final
path in the text file
    if os.path.exists("Path_file.txt"):
        os.remove("Path_file.txt")

    f = open("Path_file.txt", "a")
    for node in path_formed:
        if node.parent is not None:
            f.write(str(node.node_no) + "\t" +
str(node.parent.node_no) + "\t" + str(node.cost) +
"\n")
    f.close()
def write_node_explored(explored): # To write all
the nodes explored by the program
    if os.path.exists("Nodes.txt"):
        os.remove("Nodes.txt")

    f = open("Nodes.txt", "a")
    for element in explored:
```

```
            f.write('[')
            for i in range(len(element)):
                for j in range(len(element)):
                    f.write(str(element[j][i]) + " ")
            f.write(']')
            f.write("\n")
        f.close()
def write_node_info(visited): # To write all the
info about the nodes explored by the program
        if os.path.exists("Node_info.txt"):
            os.remove("Node_info.txt")

        f = open("Node_info.txt", "a")
        for n in visited:
            if n.parent is not None:
                f.write(str(n.node_no) + "\t" +
str(n.parent.node_no) + "\t" + str(n.cost) + "\n")
        f.close()
def path(node):  # To find the path from the goal
node to the starting node
        p = []  # Empty list
        p.append(node)
        parent_node = node.parent
        while parent_node is not None:
            p.append(parent_node)
            parent_node = parent_node.parent
        return list(reversed(p))
def path(node): # To find the path from the goal
node to the starting node
        p = []  # Empty list
        p.append(node)
        parent_node = node.parent
        while parent_node is not None:
            p.append(parent_node)
            parent_node = parent_node.parent
        return list(reversed(p))
def path(node):  # To find the path from the goal
node to the starting node
        p = []  # Empty list
```

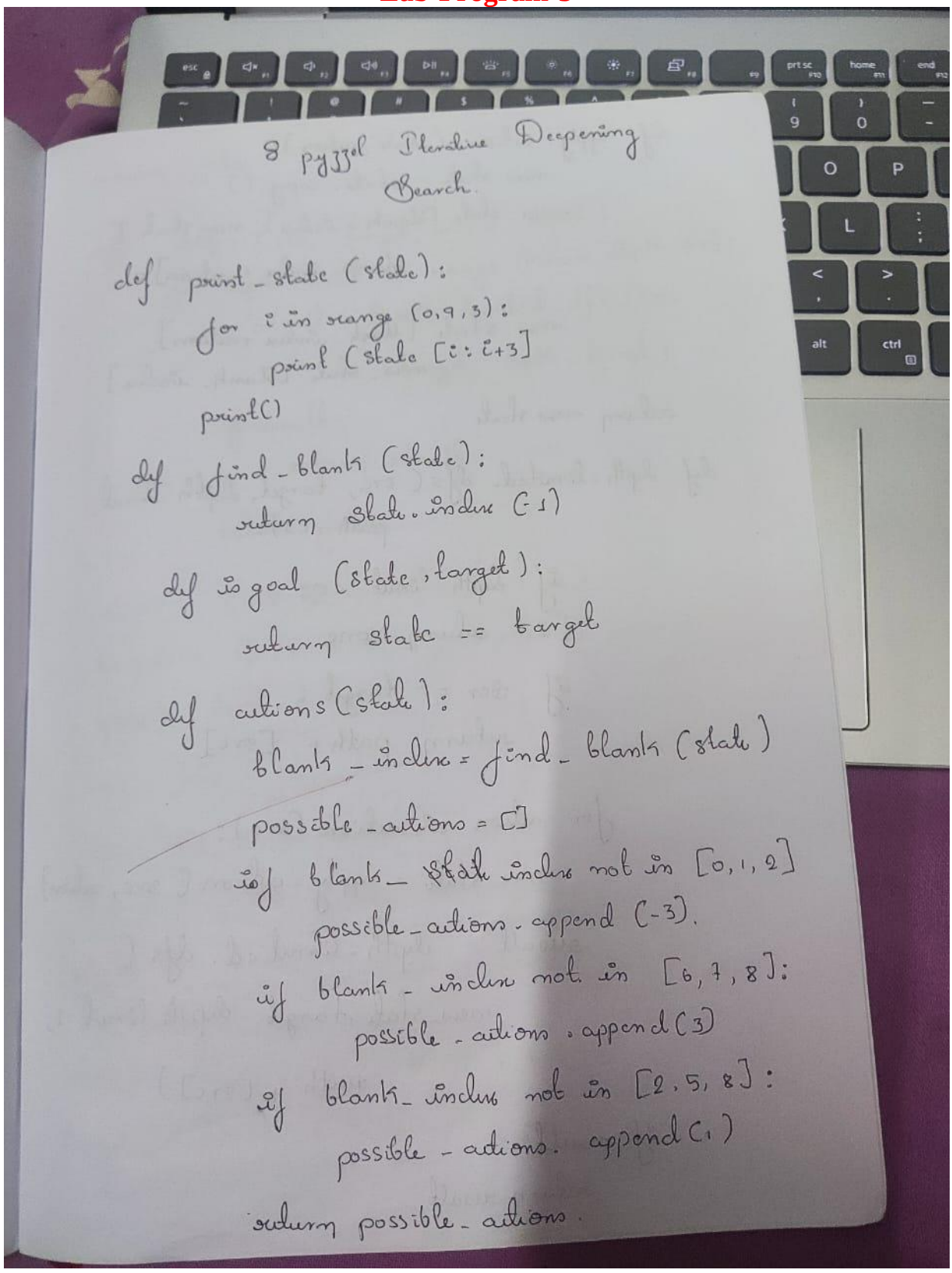
```
    p.append(node)
    parent_node = node.parent
    while parent_node is not None:
        p.append(parent_node)
        parent_node = parent_node.parent
    return list(reversed(p))
def check_correct_input(l):
    array = np.reshape(l, 9)
    for i in range(9):
        counter_appear = 0
        f = array[i]
        for j in range(9):
            if f == array[j]:
                counter_appear += 1
        if counter_appear >= 2:
            print("invalid input, same number entered
2 times")
            exit(0)
def check_solvable(g):
    arr = np.reshape(g, 9)
    counter_states  =  0
    for i in range(9):
        if not arr[i] == 0:
            check_elem = arr[i]
            for x in range(i + 1, 9):
                if check_elem < arr[x] or arr[x] ==
0:
                    continue
                else:
                    counter_states += 1
    if counter_states % 2 == 0:
        print("The puzzle is solvable, generating
path")
    else:
        print("The puzzle is insolvable, still
creating nodes")
k = get_initial()

check_correct_input(k)
```

```
check_solvable(k)

root = Node(0, k, None, None, 0)

# BFS implementation call
goal, s, v = exploring_nodes(root)

if goal is None and s is None and v is None:
    print("Goal State could not be reached, Sorry")
else:
    # Print and write the final output
    print_states(path(goal))
    write_path(path(goal))
    write_node_explored(s)
    write_node_info(v)
```

Output:

```
Please enter number from 0-8, no number should be repeated or be out of this range
Enter the 1 number: 1
Enter the 2 number: 3
Enter the 3 number: 2
Enter the 4 number: 5
Enter the 5 number: 4
Enter the 6 number: 6
Enter the 7 number: 0
Enter the 8 number: 7
Enter the 9 number: 8
The puzzle is solvable, generating path
Exploring Nodes
Goal_reached
printing final solution
Move : None
Result :
[[1. 3. 2.]
 [5. 4. 6.]
 [0. 7. 8.]]    node number:0
Move : up
Result :
[[1. 3. 2.]
 [0. 4. 6.]
 [5. 7. 8.]]    node number:1
Move : right
Result :
[[1. 3. 2.]
 [4. 0. 6.]
 [5. 7. 8.]]    node number:5
```

Lab-Program-3



8 puzzle Iterative Deepening Search

```
def print_state(state):
    for i in range(0,9,3):
        print(state[i:i+3])
    print()

def find_blank(state):
    return state.index(-1)

def is_goal(state, target):
    return state == target

def actions(state):
    blank_index = find_blank(state)
    possible_actions = []
    if blank_index not in [0,1,2]:
        possible_actions.append(-3)
    if blank_index not in [6,7,8]:
        possible_actions.append(3)
    if blank_index not in [2,5,8]:
        possible_actions.append(1)
    return possible_actions
```

```
def apply_action (state, action):
    new_state = state.copy ()
    new_state [blank_index], new_state [
        blank_index + action] =

    new_state [blank_index + action],
        new_state [blank_index]

    return new_state.

def depth_limited_dfs ( src, target, depth_limit,
                        path = []):

    if depth_limit < 0:
        return None

    if src == target :
        return path + [src]

    for action in action (src):
        new_state = apply_action ( src, ac

    result = depth_limited_dfs (
        new_state, target, depth limit
                        path + [src])

    if result :
        return result
```

return false.

```
def iddfs(src, target, max_depth):
    for depth_limit in range(max depth + 1):
        result = depth_limited_dfs(src,
                                   target, depth_limit)
        if result:
            return result
    return false.
```

Src 1 = [1, 2, 3, -1, 4, 5, 6, 7, 8]

target 1 = [1, 2, 3, 4, 5, -1, 6, 7, 8].

depth = 1

-> False.

Src 2: [3, 5, 2, 8, 7, 6, 4, 1, -1]

target 2 = [-1, 3, 7, 8, 1, 5, 4, 6, 2]

depth = 1

-> False

Src 3: [1, 2, 3, -1, 4, 5, 6, 7, 8]

target 3: [1, 2, 3, 6, 4, 5, -1, 7, 8]

depth 3 = 1

-> True.

2 Implement Iterative deepening search algorithm.

Objective: IDDFS combines depth first search's space efficiency and breadth first search's completeness. It improves depth definition, heuristic and score of searching nodes so as to improve efficiency.

Code:

```
import copy
inp=[[1,2,3],[4,-1,5],[6,7,8]]
out=[[1,2,3],[6,4,5],[-1,7,8]]
def move(temp, movement):
  if movement=="up":
    for i in range(3):
      for j in range(3):
        if(temp[i][j]==-1):
        if i!=0:
           temp[i][j]=temp[i-1][j]
           temp[i-1][j]=-1
         return temp
  if movement=="down":
    for i in range(3):
      for j in range(3):
        if(temp[i][j]==-1):
        if i!=2:
           temp[i][j]=temp[i+1][j]
           temp[i+1][j]=-1
         return temp
  if movement=="left":
    for i in range(3):
      for j in range(3):
        if(temp[i][j]==-1):
        if j!=0:
           temp[i][j]=temp[i][j-1]
           temp[i][j-1]=-1
         return temp
```

```
  if movement=="right":
    for i in range(3):
      for j in range(3):
        if(temp[i][j]==-1):
          if j!=2:
            temp[i][j]=temp[i][j+1]
            temp[i][j+1]=-1
          return temp
def ids():
  global  inp
  global  out
  global flag
  for limit in range(100):
    print('LIMIT -> '+str(limit))
    stack=[]
    inpx=[inp,"none"]
    stack.append(inpx)
    level=0
    while(True):
      if len(stack)==0:
        break
      puzzle=stack.pop(0)
      if level<=limit:
        print(str(puzzle[1])+" --> "+str(puzzle[0]))
        if(puzzle[0]==out):
          print("Found")
          print('Path cost='+str(level))
          flag=True
          return
        else:
          level=level+1
          if(puzzle[1]!="down"):
          temp=copy.deepcopy(puzzle[0])
          up=move(temp, "up")
          if(up!=puzzle[0]):
              upx=[up,"up"]
              stack.insert(0, upx)
```

```
        if(puzzle[1]!="right"):
          temp=copy.deepcopy(puzzle[0])
          left=move(temp, "left")
          if(left!=puzzle[0]):
          leftx=[left,"left"]
            stack.insert(0, leftx)
        if(puzzle[1]!="up"):
        temp=copy.deepcopy(puzzle[0])
        down=move(temp, "down")
        if(down!=puzzle[0]):
            downx=[down,"down"]
            stack.insert(0, downx)
        if(puzzle[1]!="left"):
          temp=copy.deepcopy(puzzle[0])
       right=move(temp, "right")
          if(right!=puzzle[0]):
          rightx=[right,"right"]
          stack.insert(0, rightx)
print('~~~~~~~~~~~~~ IDS ~~~~~~~~~~~~~')
ids()


import copy
inp=[[1,2,3],[4,-1,5],[6,7,8]]
out=[[1,2,3],[6,4,5],[-1,7,8]]
def move(temp, movement):
  if movement=="up":
    for i in range(3):
      for j in range(3):
        if(temp[i][j]==-1):
        if i!=0:
          temp[i][j]=temp[i-1][j]
          temp[i-1][j]=-1
        return temp
  if movement=="down":
    for i in range(3):
      for j in range(3):
        if(temp[i][j]==-1):
        if i!=2:
          temp[i][j]=temp[i+1][j]
```

```
            temp[i+1][j]=-1
          return temp
  if movement=="left":
    for i in range(3):
      for j in range(3):
        if(temp[i][j]==-1):
          if j!=0:
            temp[i][j]=temp[i][j-1]
            temp[i][j-1]=-1
          return temp
  if movement=="right":
    for i in range(3):
      for j in range(3):
        if(temp[i][j]==-1):
          if j!=2:
            temp[i][j]=temp[i][j+1]
            temp[i][j+1]=-1
          return temp
def ids():
  global  inp
  global  out
  global flag
  for limit in range(100):
    print('LIMIT -> '+str(limit))
    stack=[]
    inpx=[inp,"none"]
    stack.append(inpx)
    level=0
    while(True):
      if len(stack)==0:
        break
      puzzle=stack.pop(0)
      if level<=limit:
        print(str(puzzle[1])+" --> "+str(puzzle[0]))
        if(puzzle[0]==out):
          print("Found")
          print('Path cost='+str(level))
          flag=True
          return
        else:
          level=level+1
          if(puzzle[1]!="down"):
          temp=copy.deepcopy(puzzle[0])
```

```
            up=move(temp, "up")
            if(up!=puzzle[0]):
              upx=[up,"up"]
              stack.insert(0, upx)
          if(puzzle[1]!="right"):
            temp=copy.deepcopy(puzzle[0])
            left=move(temp, "left")
            if(left!=puzzle[0]):
            leftx=[left,"left"]
              stack.insert(0, leftx)
          if(puzzle[1]!="up"):
          temp=copy.deepcopy(puzzle[0])
          down=move(temp, "down")
          if(down!=puzzle[0]):
              downx=[down,"down"]
              stack.insert(0, downx)
          if(puzzle[1]!="left"):
            temp=copy.deepcopy(puzzle[0])
         right=move(temp, "right")
            if(right!=puzzle[0]):
            rightx=[right,"right"]
            stack.insert(0, rightx)
print('~~~~~~~~~~~~~ IDS ~~~~~~~~~~~~~')
ids()
```

Output:

```
#Test 1
src = [1,2,3,-1,4,5,6,7,8]
target = [1,2,3,4,5,-1,6,7,8]

depth = 1
iddfs(src, target, depth)
```

```
False
```

```
#Test 2
src = [3,5,2,8,7,6,4,1,-1]
target = [-1,3,7,8,1,5,4,6,2]

depth = 1
iddfs(src, target, depth)
```

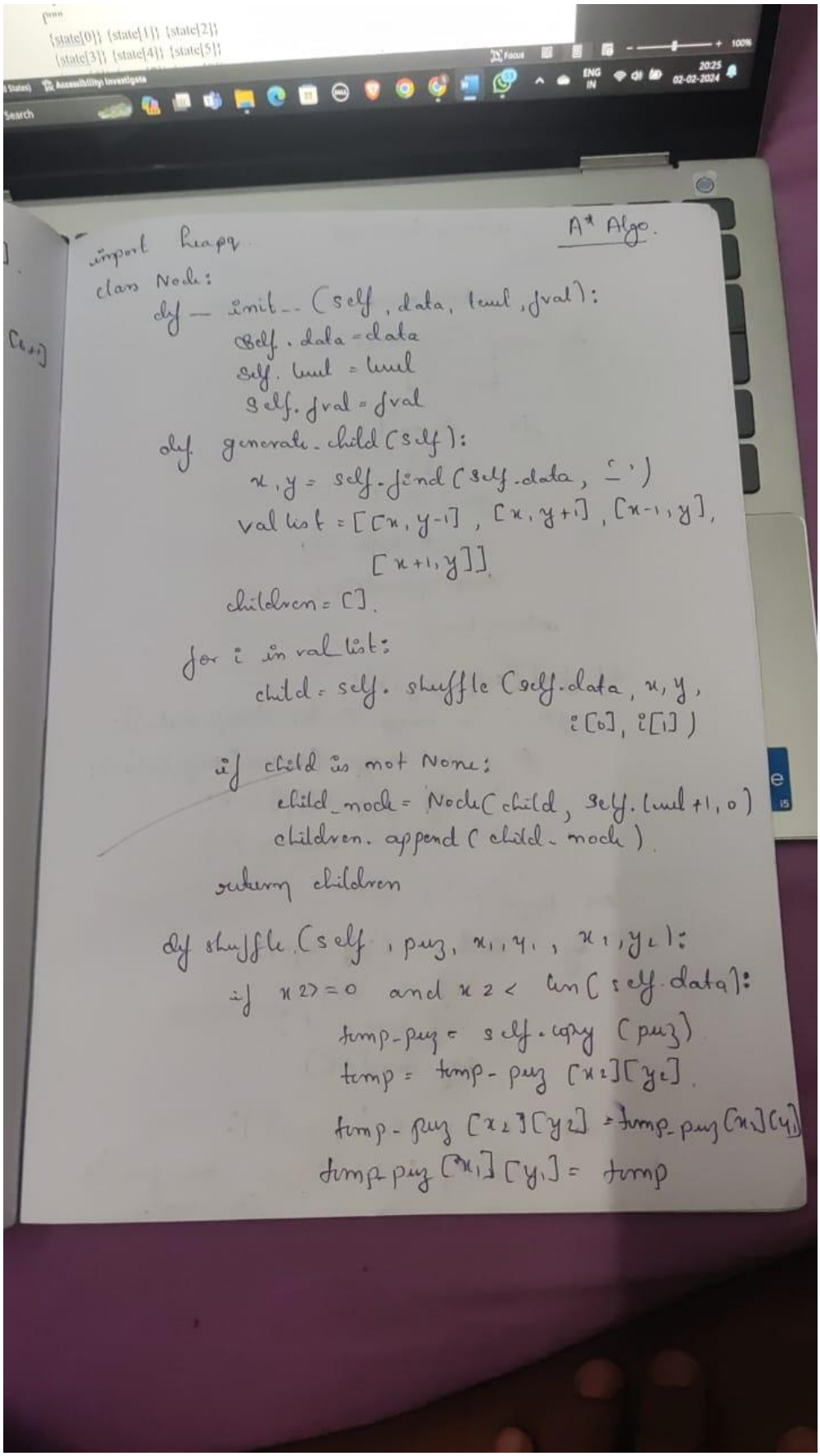
```
False
```

```
# Test 2
src = [1,2,3,-1,4,5,6,7,8]
target=[1,2,3,6,4,5,-1,7,8]

depth = 1
iddfs(src, target, depth)
```

```
src = [1, 2, 3, 4, 5, 6, 7, 8, -1]
target = [-1, 1, 2, 3, 4, 5, 6, 7, 8]

for i in range(1, 100):
    val = iddfs(src,target,i)
    print(i, val)
    if val == True:
        break
```

```
1 False
2 False
3 False
4 False
5 False
6 False
7 False
8 False
9 False
10 False
11 False
12 False
13 False
14 False
15 False
16 False
17 False
18 False
19 False
20 False
21 False
22 False
23 False
24 False
```

Lab Program 4



A* Algo.

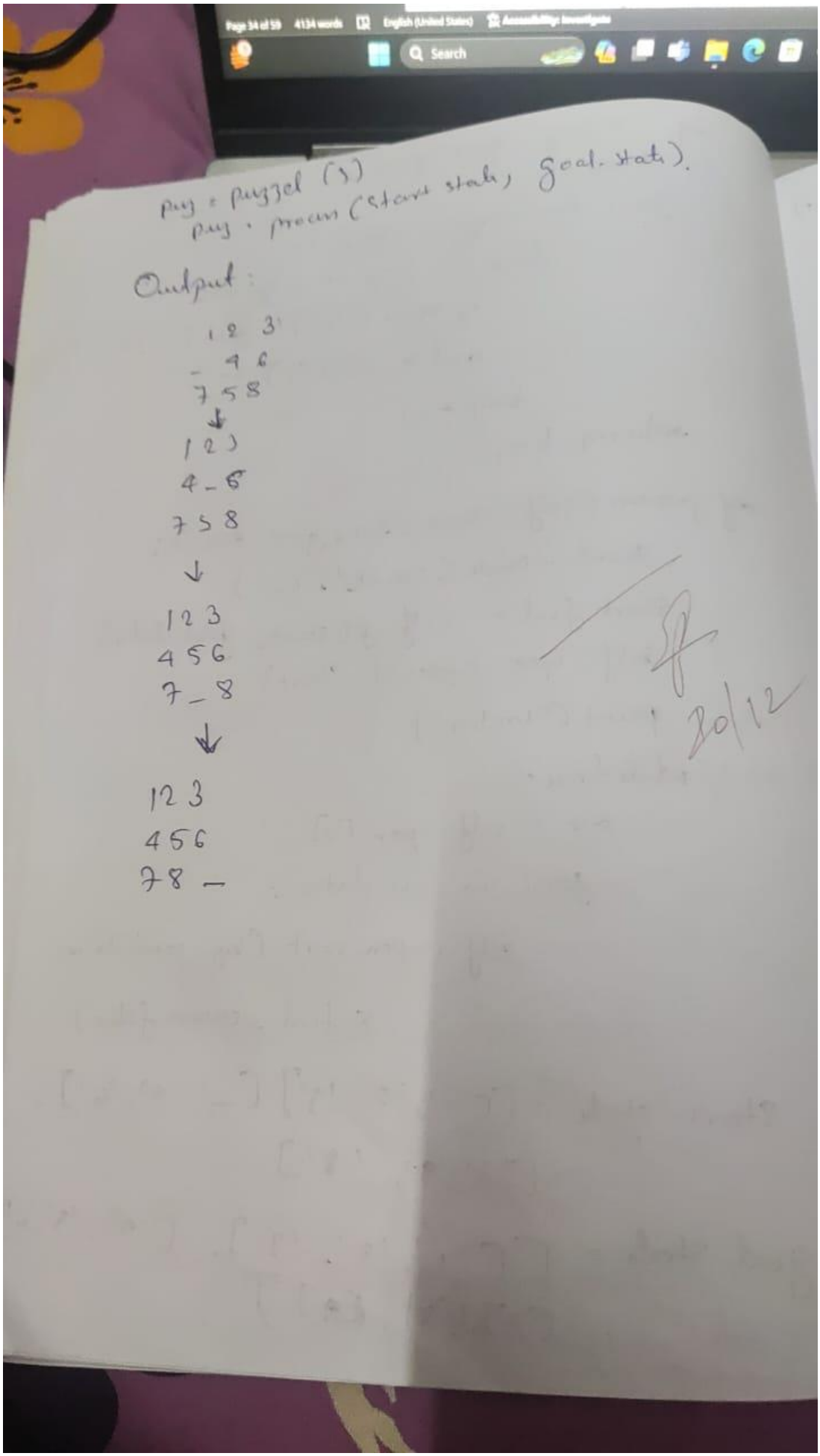
```
import heapq
class Node:
    def __init__(self, data, level, fval):
        self.data = data
        self.level = level
        self.fval = fval
    def generate_child(self):
        x, y = self.find(self.data, '_')
        val_list = [[x, y-1], [x, y+1], [x-1, y],
                    [x+1, y]]
        children = []
        for i in val_list:
            child = self.shuffle(self.data, x, y,
                                 i[0], i[1])
            if child is not None:
                child_node = Node(child, self.level+1, 0)
                children.append(child_node)
        return children
    def shuffle(self, puz, x1, y1, x2, y2):
        if x2 >= 0 and x2 < len(self.data):
            temp_puz = self.copy(puz)
            temp = temp_puz[x2][y2]
            temp_puz[x2][y2] = temp_puz[x1][y1]
            temp_puz[x1][y1] = temp
```

```
        return temp_puz.
    else:
        return none.
def copy (self, root):
    temp = []
    for i in root:
        t = []
        for j in i:
            t.append(j)
        temp.append(t)
    return temp.

def find (self, puz, x):
    for i in range (0, len (self.data)):
        for j in range (0, len (self.data)):
            if puz [i][j] == x:
                return i, j

class Puzzel:
    def __init__ (self, size):
        self.n = size
        self.open = [].
        self.closed = []

    def f(self, start, goal):
        return self.h (start.data, goal)+
                start.level.
```

```
def h(self, start, goal):
    temp = 0
    for i in range(0, self.n):
        for j in range(0, self.n):
            if start[i][j] != goal[i,j]
            and start[i][j] != '_':
                temp += 1
    return temp.

def process(self, start_data, goal_data):
    start = Node(start, data, 0, 0)
    start.fval = self.h(start, goal_data).
    self.open.append(start).
    print("\n\n")
    while True:
        cur = self.open[0].
        for i in cur.data:
            self.open.sort(key = lambda x:
                x.fval, reverse = False)
```

Start state = [['1', '2', '3'], ['_', '4', '6'],
['7', '5', '8']].

Goal state = [['1', '2', '3'], ['4',
['7'], ['8'], ['_']]


Page 34 of 59 4134 words English (United States)
Search
puy = puzzel (1)
puy . procm (start state, goal state).
Output:
1 2 3
- 4 6
7 5 8
1 2 3
4 5 6
7 5 8
1 2 3
4 5 6
7 _ 8
1 2 3
4 5 6
7 8 _
20/12

Implement A* search algorithm.

Objective: The a* algorithm takes into account both the cost to go to goal from present state as well the cost already taken to reach the present state. In 8 puzzle problem, both depth and number of misplaced tiles are considered to take decision about the next state that has to be visited.

Code:

```
def print_b(src):
    state = src.copy()
    state[state.index(-1)] = ' '
    print(
f"""
{state[0]} {state[1]} {state[2]}
{state[3]} {state[4]} {state[5]}
{state[6]} {state[7]} {state[8]}
 “””
    )
def h(state, target):
    count = 0
    i = 0
    for j in state:
        if state[i] != target[i]:
            count = count+1
    return count
def astar(state, target):
    states = [src]
    g = 0
    visited_states = []
    while len(states):
        print(f"Level: {g}")
        moves = []
        for state in states:
            visited_states.append(state)
            print_b(state)
            if state == target:
```

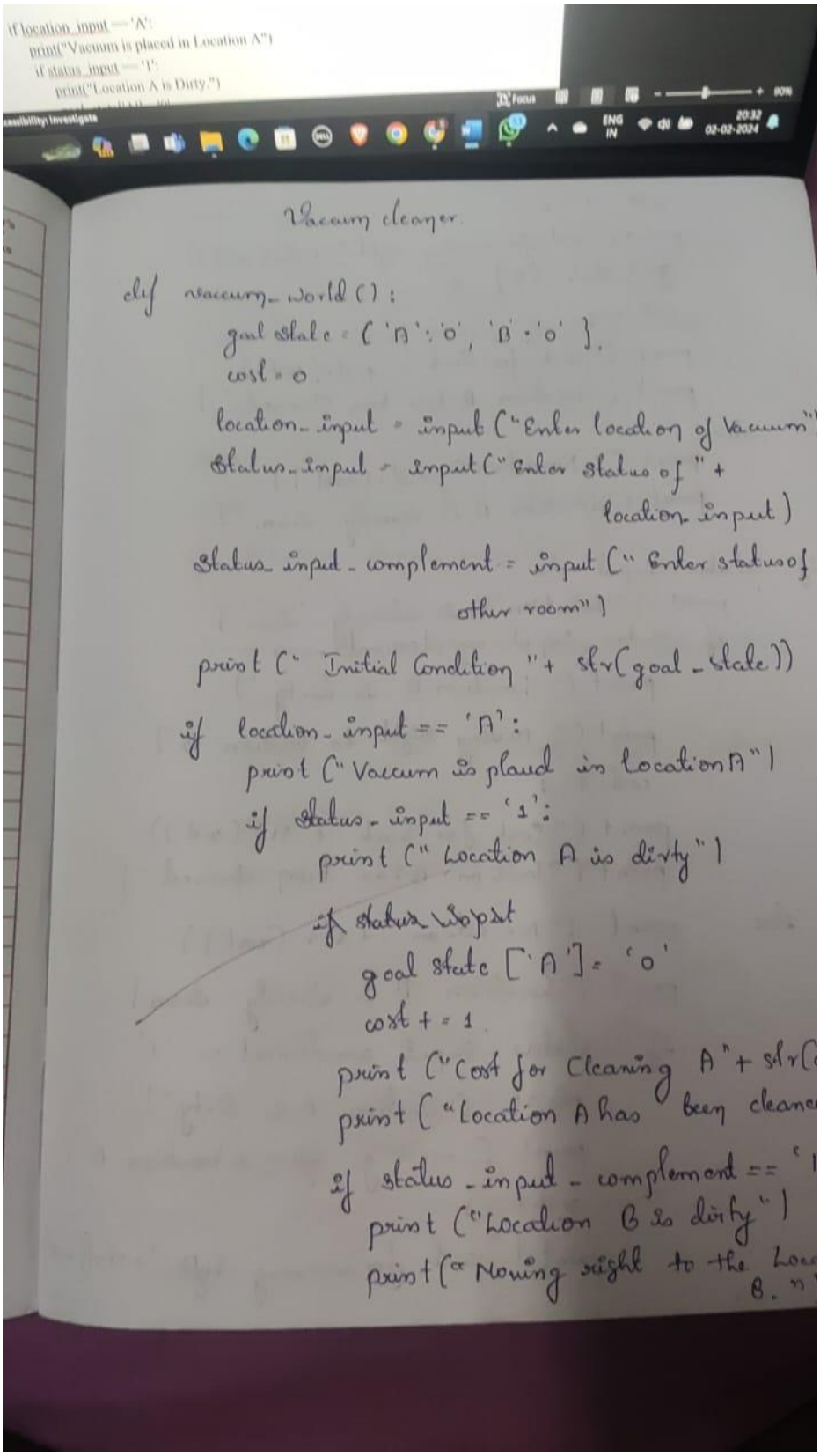
```
                print("Success")
                return
            moves += [move for move in possible_moves(
                state, visited_states) if move not in moves]
        costs = [g + h(move, target) for move in moves]
        states = [moves[i]
                  for i in range(len(moves)) if costs[i] == min(costs)]
        g += 1
    print("Fail")
def possible_moves(state, visited_state):
    b = state.index(-1)
    d = []
    if b - 3 in range(9):
        d.append('u')
    if b not in [0, 3, 6]:
        d.append('l')
    if b not in [2, 5, 8]:
        d.append('r')
    if b + 3 in range(9):
        d.append('d')
    pos_moves = []
    for m in d:
        pos_moves.append(gen(state, m, b))
    return [move for move in pos_moves if move not in visited_state]
def gen(state, m, b):
    temp = state.copy()
    if m == 'u':
        temp[b - 3], temp[b] = temp[b], temp[b - 3]
    if m == 'l':
        temp[b - 1], temp[b] = temp[b], temp[b - 1]
    if m == 'r':
        temp[b + 1], temp[b] = temp[b], temp[b + 1]
    if m == 'd':
        temp[b + 3], temp[b] = temp[b], temp[b + 3]
    return temp
src = [1, 2, 3, -1, 4, 5, 6, 7, 8]
target = [1, 2, 3, 4, 5,6, 7, 8,-1]
```

astar(src, target)

Output:

```
Enter the start state matrix

1 0 1 0
1 0 0 1
1 1 1 1
Enter the goal state matrix

1 1 0 1
1 0 0 1
1 1 1 0
|
  |
 \'/

1 0 1 0
1 0 0 1
1 1 1 1
```

Lab Program 5



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

Vacuum cleaner

```
def vacuum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    location_input = input("Enter location of vacuum")
    status_input = input("Enter status of " +
                         location_input)
    status_input_complement = input("Enter status of
                              other room")
    print("Initial Condition " + str(goal_state))
    if location_input == 'A':
        print("Vacuum is placed in location A")
        if status_input == '1':
            print("Location A is dirty")
            if status_input
                goal_state['A'] = '0'
                cost += 1
            print("Cost for Cleaning A" + str(
            print("Location A has been cleane
            if status_input_complement == '1
                print("Location B is dirty")
                print("Moving right to the Loc
                                    B.")
```

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

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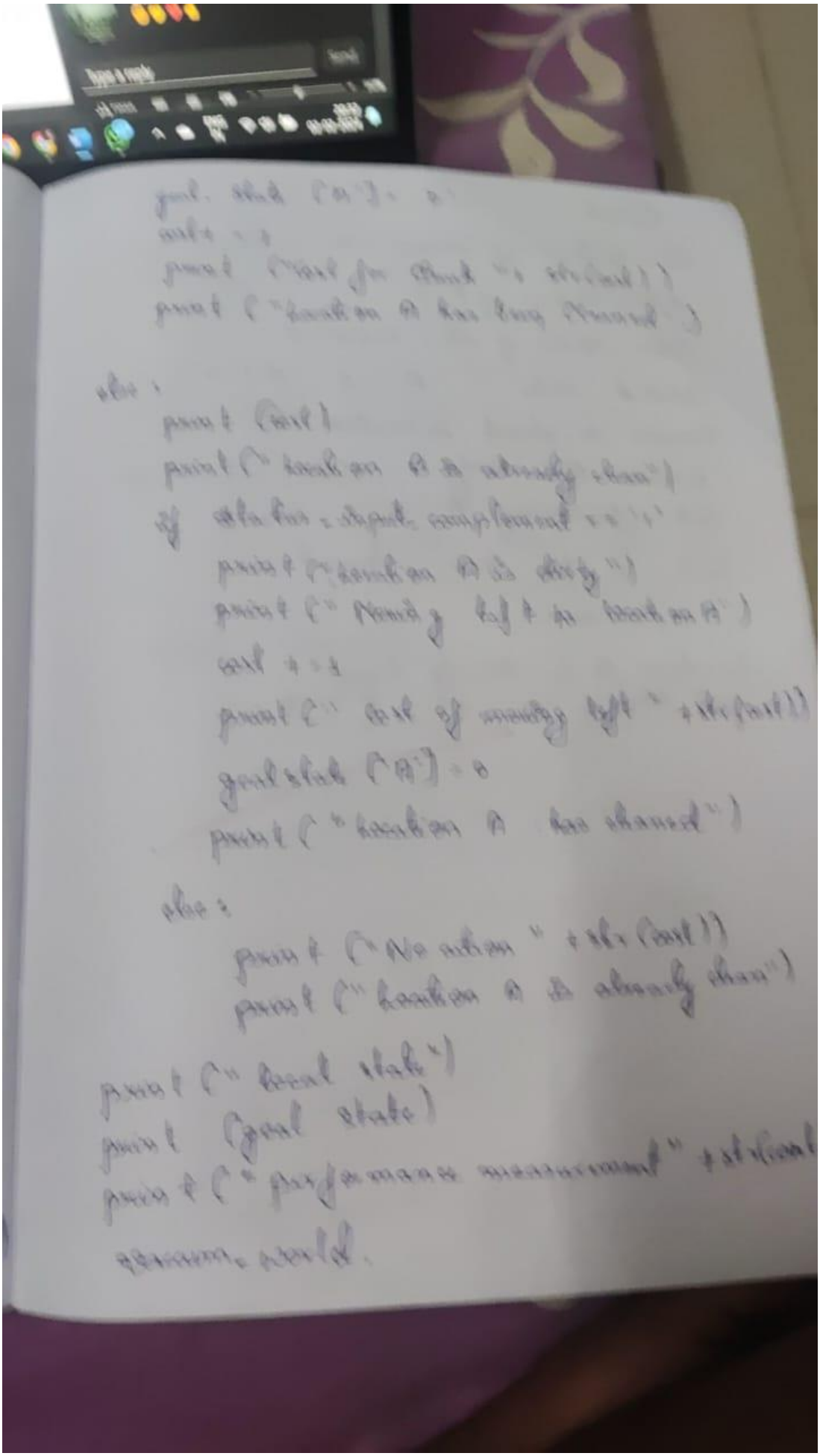
```
        cost += 1
        print("Cost for moving right " + str(cost))
        goal state['B'] = '0'
        cost += 1
        print("Cost for Suck " + str(cost))
        print("Location B has been Cleaned.")
    else:
        print("No action " + str(cost))
        print("Location B is already clean.")

if status_input == '0':
    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 Suck" + str(cost))
        print("Location B has been cleaned")
else: print("No action " + str(cost))
    print("Location B is already clean")
    if status_input complement == '1':
        print("Location A is dirty")
        print("moving left to location
        cost += 1
        print("cost for moving left "+st
```



B : " + str(status_input

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

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Search

Output :

Enter location of Vacuum : A
Enter status of A : 1
Enter Status of other room : 0
Initial state : 'A' : 0 ; 'B' : '0'
Vacuum is placed in Location A
location A is Dirty.
Cost for cleaning A : 1
Locate A has been cleaned.
No action.
location B is already clean.
Goal State is 'A' : '0' ; 'B' : '0'

Implement vacuum cleaner agent.

Objective: The objective of the vacuum cleaner agent is to clean the whole of two rooms by performing any of the actions – move right, move left or suck. Vacuum cleaner agent is a goal based agent.

Code:

```
def vacuum_world():

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

    location_input = input("Enter Location of Vacuum: ")
    status_input = input("Enter status of " + location_input+ " : ")
    status_input_complement = input("Enter status of other room : ")
    print("Initial Location Condition {A : " + str(status_input_complement) + ",
B : " + str(status_input) + " }" )

    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                    #cost for suck
            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 the 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. ")
```

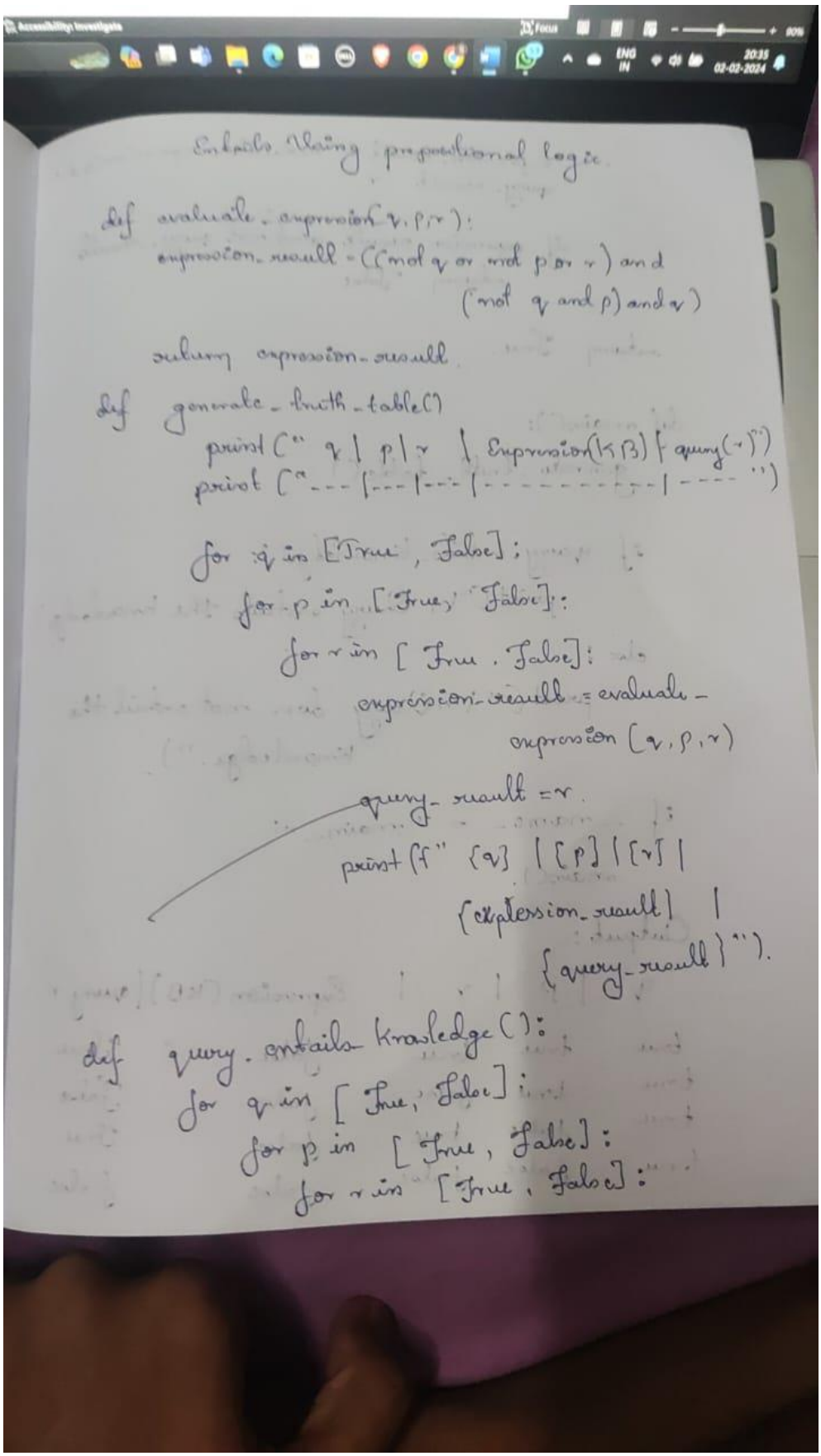
```
        else:
            print("No action" + str(cost))
            print("Location B is already clean.")

    if status_input == '0':
        print("Location A is already clean ")
        if status_input_complement == '1':
            print("Location B is Dirty.")
            print("Moving RIGHT to the 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("No action " + str(cost))
            print(cost)
            print("Location B is already clean.")

else:
    print("Vacuum is placed in location B")
    if status_input == '1':
        print("Location B is Dirty.")
        goal_state['B'] = '0'
        cost += 1
        print("COST for CLEANING " + str(cost))
        print("Location B has been Cleaned.")

        if status_input_complement == '1':
            print("Location A is Dirty.")
            print("Moving LEFT to the 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(cost)
            print("Location B is already clean.")

            if status_input_complement == '1':
                print("Location A is Dirty.")
                print("Moving LEFT to the 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("No action " + str(cost))
                print("Location A is already clean.")

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

vacuum_world()
```

Output:

```
Enter Location of Vacuum: A
Enter status of A : 0
Enter status of other room : 1
Initial Location Condition {A : 1, B : 0 }
Vacuum is placed in Location A
Location A is already clean
Location B is Dirty.
Moving RIGHT to the Location B.
COST for moving RIGHT 1
Cost for SUCK2
Location B has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 2
```

Lab Program 6



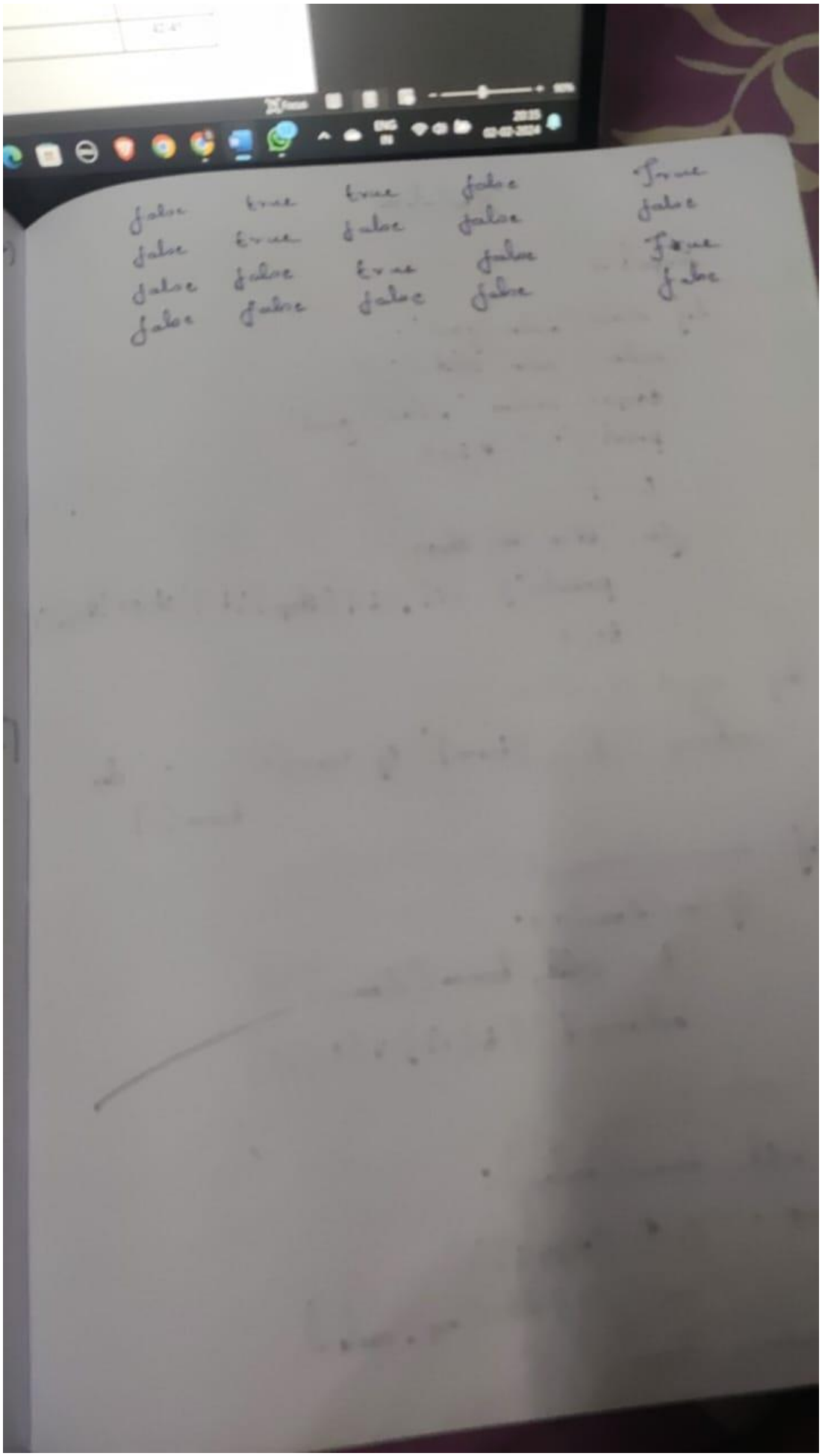
Entails Using propositional logic

```
def evaluate_expression(q, p, r):
    expression_result = ((not q or not p or r) and
                         (not q and p) and r)

    return expression_result

def generate_truth_table():
    print("| q | p | r | Expression(KB) | query(r) |")
    print("|---|---|---|----------------|----------|")

    for q in [True, False]:
        for p in [True, False]:
            for r in [True, False]:
                expression_result = evaluate_
                                    expression(q, p, r)
                query_result = r
                print(f"| {q} | {p} | {r} |
                      {expression_result} |
                      {query_result} |").

def query_entails_knowledge():
    for q in [True, False]:
        for p in [True, False]:
            for r in [True, False]:
```

```
        expression_result = evaluate_expression(
        query_result = r.
        if expression_result and not query_result:
            return False.
    return True.

def main():
    generate_truth_table()

    if query.entails_knowledge():
        print("In Query entails the knowledge
    else:
        print("In Query does not entail the
                knowledge.")

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

Output:

P	r	Expression(KB)	query
true	true	true	false	Tru
true	true	false	false	Fal
true	false	true	false	Tru
true	false	false	false	fal


false true true false true
false true false false false
false false true false true
false false false false false

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

Objective: The objective of this program is to see if the given query entails a knowledge base. A query is said to entail a knowledge base if the query is true for all the models where knowledge base is true.

Code:

```
combinations=[(True,True,
True),(True,True,False),(True,False,True),(True,False, False),(False,True,
True),(False,True, False),(False, False,True),(False,False, False)]
variable={'p':0,'q':1, 'r':2}
kb="
q="
priority={'~':3,'v':1,'^':2}
def input_rules():
    global kb, q
    kb = (input("Enter rule: "))
    q = input("Enter the Query: ")
def entailment():
    global kb, q
    print("*10+"Truth Table Reference"+"*10)
    print('kb','alpha')
    print('*'*10)
    for comb in combinations:
        s = evaluatePostfix(toPostfix(kb), comb)
        f = evaluatePostfix(toPostfix(q), comb)
        print(s, f)
        print('-'*10)
        if s and not f:
            return False
    return True
def isOperand(c):
    return c.isalpha() and c!='v'

def isLeftParanthesis(c):
```

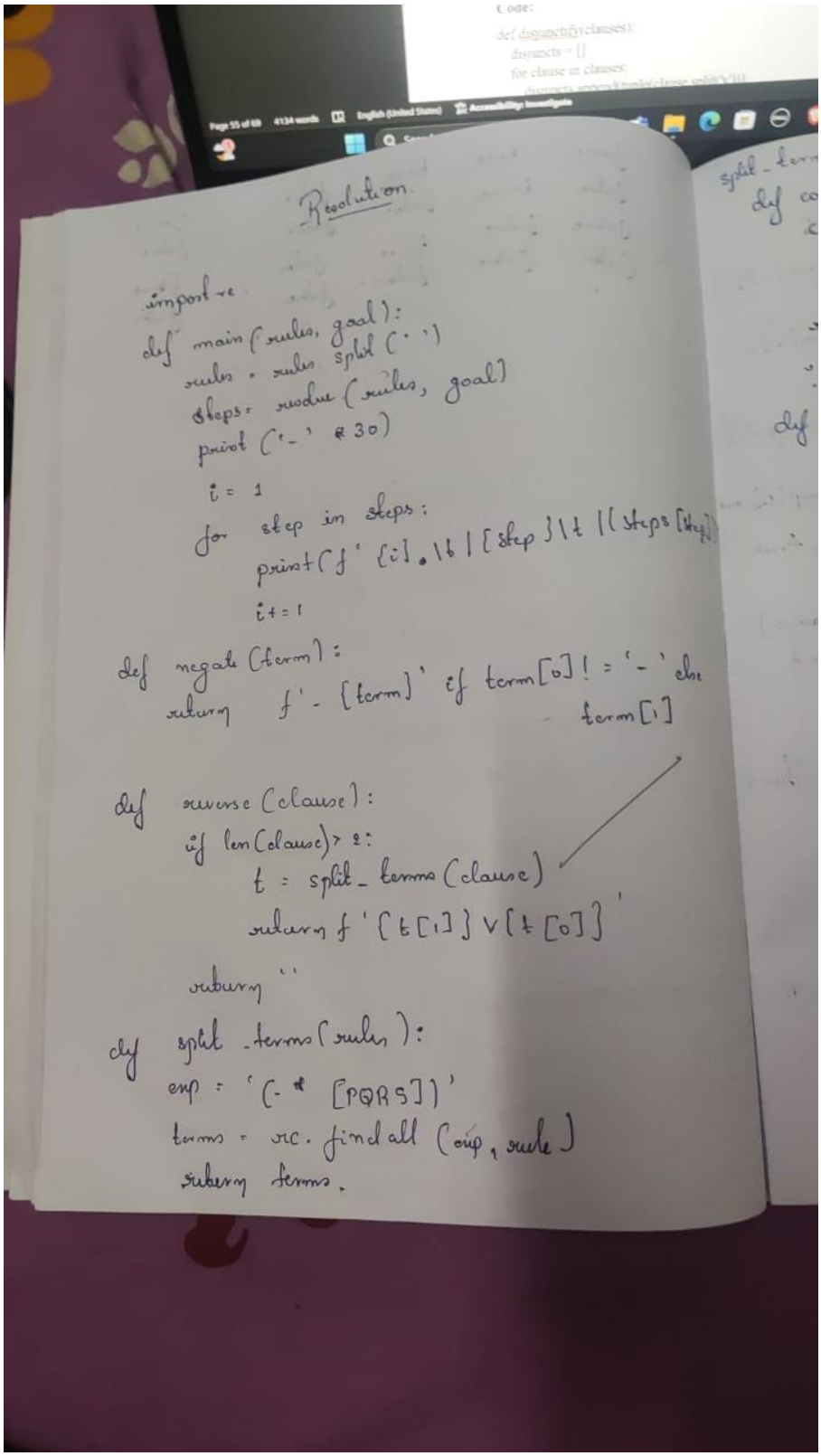
```
    return c == '('

def isRightParanthesis(c):
    return c == ')'

def isEmpty(stack):
    return len(stack) == 0

def peek(stack):
    return stack[-1]

def hasLessOrEqualPriority(c1, c2):
    try:
        return priority[c1]<=priority[c2]
    except KeyError:
        return False
def toPostfix(infix):
    stack = []
    postfix = ''
    for c in infix:
        if isOperand(c):
            postfix += c
        else:
            if isLeftParanthesis(c):
                stack.append(c)
            elif isRightParanthesis(c):
                operator = stack.pop()
                while not isLeftParanthesis(operator):
                    postfix += operator
                    operator = stack.pop()
            else:
                while (not isEmpty(stack)) and hasLessOrEqualPriority(c,
peek(stack)):
                    postfix += stack.pop()
                stack.append(c)
    while (not isEmpty(stack)):
        postfix += stack.pop()
```

```
    return postfix
def evaluatePostfix(exp, comb):
    stack = []
    for i in exp:
        if isOperand(i):
            stack.append(comb[variable[i]])
        elif i == '~':
            val1 = stack.pop()
            stack.append(not val1)
        else:
            val1 = stack.pop()
            val2 = stack.pop()
            stack.append(_eval(i,val2,val1))
    return stack.pop()
def _eval(i, val1, val2):
    if i == '^':
        return val2 and val1
    return val2 or val1
#Test 1
input_rules()
ans = entailment()
if ans:
    print("Knowledge Base entails query")
else:
    print("Knowledge Base does not entail query")
#Test 2
input_rules()
ans = entailment()
if ans:
    print("Knowledge Base entails query")
else:
    print("Knowledge Base does not entail query")
```

Output:

```
Enter rule: (~qv~pvr)^(~q^p)^q
Enter the Query: r
Truth Table Reference
kb alpha
**********
False True
----------
False False
----------
False True
----------
False False
----------
False True
----------
False False
----------
False True
----------
False False
----------
Knowledge Base entails query
```

Lab Program 7



Resolution

```
import re
def main(rules, goal):
    rules = rules.split('.')
    steps = resolve(rules, goal)
    print('_' * 30)
    i = 1
    for step in steps:
        print(f'{i}. {step}\t{steps[step]}')
        i += 1

def negate(term):
    return f'-{term}' if term[0] != '-' else
                                    term[1]

def reverse(clause):
    if len(clause) > 2:
        t = split_terms(clause)
        return f'{t[1]} v {t[0]}'
    return ''

def split_terms(rules):
    exp = '(-*[PQRS])'
    terms = re.findall(exp, rule)
    return terms.
```

```
split_terms ('~PVR')
def contradiction (goal, clause):
    contradiction = [f'{goal}v{negate(goal)}',
                     f'{negate(goal)}v{goal}']

    return clause in contradiction or reverse(clause)
                in contradiction

def resolve (rules, copy(), goal):
    temp = rules.copy()
    temp += [negate(goal)]
    steps = dict()
    for rule in temp:
        steps[rule] = 'given'
    steps[negate(goal)] = 'Negated Conclusion'
    i=0
    while i < len(temp):
        n = len(temp)
        j = (i+1)%n
        clauses = []
        while j != i:
            terms1 = split_terms(temp[i])
            terms2 = split_terms(temp[j])
            for c in terms1:
                if negate(c) in terms2:
                    t1 = [t for t in terms1 if t != c]
                    t2 = [t for t in terms if t ! negate(c
```

```
gen = i1 + i2
if len(gen) == 2:
    if gen[0] != negate(gen[1]):
        clauses += [f'{gen[0]} v {gen[1]}']
    else:
        if contradiction (goal, f'{gen[0]} v {gen[1]}'):
            temp.append(f'{gen[0]} v {gen[1]}')
            steps[''] = f'Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is a contradiction' + str(steps)
            return steps
for clause in clauses:
    if clause not in temp and clause != reverse(clause) and reverse(clause) not in temp:
        temp.append(clause)
        steps[clause] = f'Resolved from {temp[i]} and {temp[j]}.'
    j = (j+1) % n
i += 1
return steps

rules = 'R v ~P  Rv~Q  ~RvP  ~RvQ'  # (P^Q)=>R
goal = 'R'
main(rules, goal)
```

Output:

Step	Clause	Derivation
1	R ∨ ~P	Given
2	R ∨ ~Q	Given
3	~R ∨ P	Given
4	~R ∨ Q	Given
5	~R	Negated conclusion

Resolved R ∨ P and ~R ∨ P to R ∨ R, which in turn null. A contradiction is found when ~R is as assumed as true. Hence R is true

Create a knowledgebase using prepositional logic and prove the given query using resolution

Objective: The resolution takes two clauses and produces a new clause which includes all the literals except the two complementary literals if exists. The knowledge base is conjuncted with the not of the give query and then resolution is applied.

Code:

```
def disjunctify(clauses):
    disjuncts = []
    for clause in clauses:
        disjuncts.append(tuple(clause.split('v')))
    return disjuncts

def getResolvant(ci, cj, di, dj):
    resolvant = list(ci) + list(cj)
    resolvant.remove(di)
    resolvant.remove(dj)
    return tuple(resolvant)

def resolve(ci, cj):
    for di in ci:
        for dj in cj:
            if di == '~' + dj or dj == '~' + di:
                return getResolvant(ci, cj, di, dj)

def checkResolution(clauses, query):
    clauses += [query if query.startswith('~') else '~' + query]
    proposition = '^'.join(['(' + clause + ')' for clause in clauses])
    print(f'Trying to prove {proposition} by contradiction ... ')

    clauses = disjunctify(clauses)
    resolved = False
```

```
    new = set()

    while not resolved:
        n = len(clauses)
        pairs = [(clauses[i], clauses[j]) for i in range(n) for j in range(i + 1, n)]
        for (ci, cj) in pairs:
            resolvant = resolve(ci, cj)
            if not resolvant:
                resolved = True
                break
            new = new.union(set(resolvents))
        if new.issubset(set(clauses)):
            break
        for clause in new:
            if clause not in clauses:
                clauses.append(clause)

    if resolved:
        print('Knowledge Base entails the query, proved by resolution')
    else:
        print("Knowledge Base doesn't entail the query, no empty set produced
after resolution")
clauses = input('Enter the clauses ').split()
query = input('Enter the query: ')
checkResolution(clauses, query)
```

Output:

```
#Test1
TELL(['implies', 'p', 'q'])
TELL(['implies', 'r', 's'])
ASK(['implies',['or','p','r'], ['or', 'q', 's']])
```

```
True
```

```
CLEAR()
```

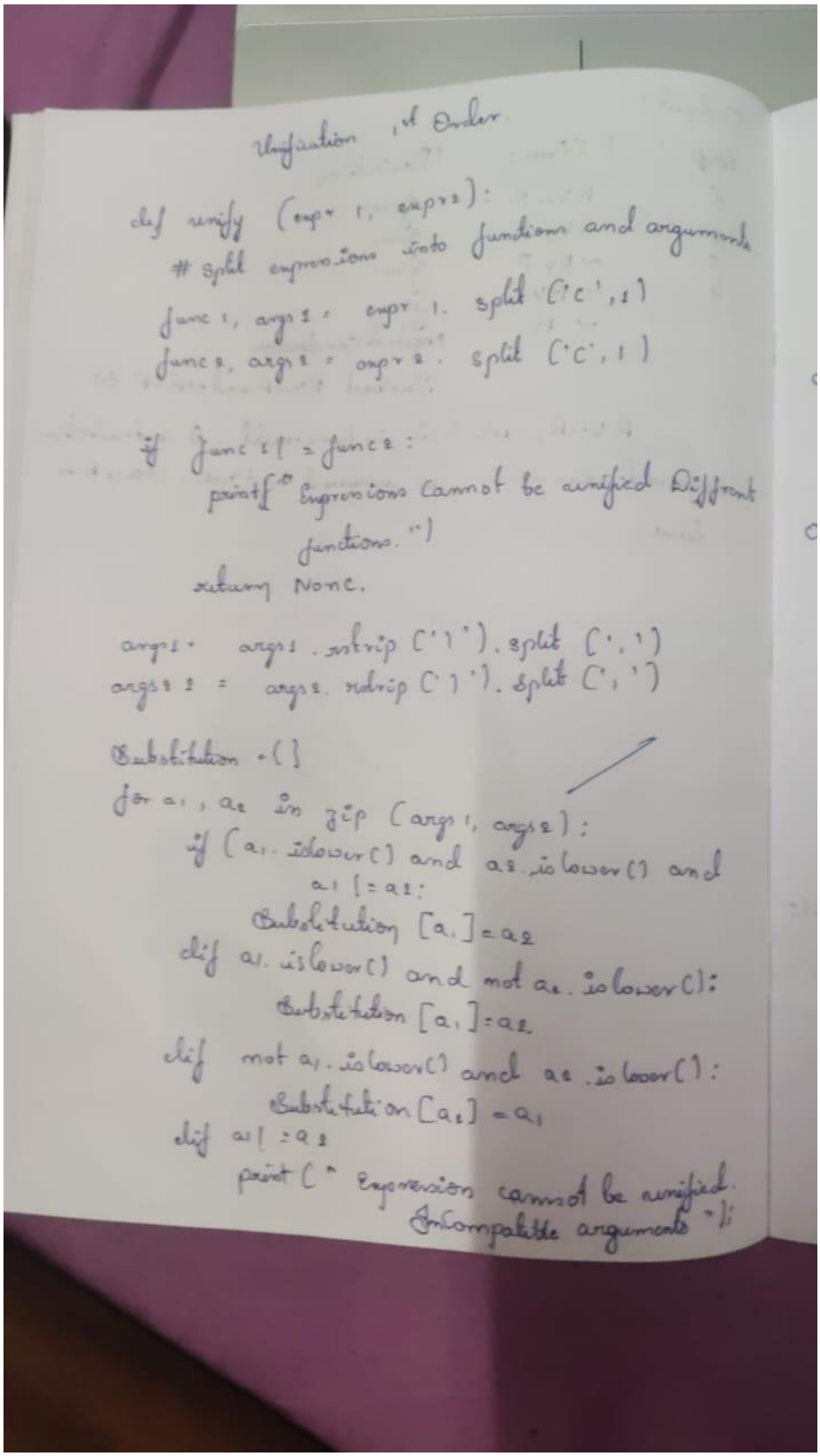
```
#Test2
TELL('p')
TELL(['implies',['and','p','q'],'r'])
TELL(['implies',['or','s','t'],'q'])
TELL('t')
ASK('r')
```

```
True
```

```
CLEAR()
```

```
#Test3
TELL('a')
TELL('b')
TELL('c')
TELL('d')
ASK(['or', 'a', 'b', 'c', 'd'])
```

Lab Program 8



Unification 1st Order

```
def unify (expr 1, expr 2):
    # Split expressions into functions and arguments
    func 1, args 1 = expr 1. split ('(', 1)
    func 2, args 2 = expr 2. split ('(', 1)

    if func 1 != func 2:
        print("Expressions cannot be unified Diffrent
              functions.")
        return None.

    args 1 = args 1 .rstrip (')'). split (',')
    args 2 2 = args 2. rstrip (')'). split (',')

    Substitution = {}
    for a1, a2 in zip (args 1, args 2):
        if (a1. islower() and a2. islower() and
                a1 != a2:
            Substitution [a1] = a2
        elif a1. islower() and not a2. islower():
            Substitution [a1] = a2
        elif not a1. islower() and a2. islower():
            Substitution [a2] = a1
        elif a1 != a2
            print (" Expression cannot be unified.
                    Incompatible arguments ");
```

returning Substitution

```
def apply_substitution(expr, substitution):
    for key, value in substitution.items():
        expr = expr.replace(key, value)
returning expr
```

O/P: Enter 1st expr : Sin(x)
Enter 2nd expr : cos(a)
Expression cannot be unified. Diff'rnt functions.

O/P: Enter 1st expr : add(x,y)
Enter 2nd expr : add(a,b)
x/a ← Substitution
y/b ← Substitution
add(a,b)
add(a,b)

Pallavi
17/11

Implement unification in first order logic

Objective: Unification can find substitutions that make different logical expressions identical. Unify takes two sentences and make a unifier for the two if a unification exist.

Code:

```
import re
def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression.split(")")[:-1]
    expression = ")".join(expression)
    attributes = expression.split(',')
    return attributes

def getInitialPredicate(expression):
    return expression.split("(")[0]

def isConstant(char):
    return char.isupper() and len(char) == 1

def isVariable(char):
    return char.islower() and len(char) == 1

def replaceAttributes(exp, old, new):
    attributes = getAttributes(exp)
    predicate = getInitialPredicate(exp)
    for index, val in enumerate(attributes):
        if val == old:
            attributes[index] = new
    return predicate + "(" + ",".join(attributes) + ")"

def apply(exp, substitutions):
    for substitution in substitutions:
```

```
        new, old = substitution
        exp = replaceAttributes(exp, old, new)
    return exp

def checkOccurs(var, exp):
    if exp.find(var) == -1:
        return False
    return True
def getFirstPart(expression):
    attributes = getAttributes(expression)
    return attributes[0]
def getRemainingPart(expression):
    predicate = getInitialPredicate(expression)
    attributes = getAttributes(expression)
    newExpression = predicate + "(" + ",".join(attributes[1:]) + ")"
    return newExpression
def unify(exp1, exp2):
    if exp1 == exp2:
        return []
    if isConstant(exp1) and isConstant(exp2):
        if exp1 != exp2:
            print(f"{exp1} and {exp2} are constants. Cannot be unified")
            return []

    if isConstant(exp1):
        return [(exp1, exp2)]

    if isConstant(exp2):
        return [(exp2, exp1)]

    if isVariable(exp1):
        return [(exp2, exp1)] if not checkOccurs(exp1, exp2) else []

    if isVariable(exp2):
        return [(exp1, exp2)] if not checkOccurs(exp2, exp1) else []

    if getInitialPredicate(exp1) != getInitialPredicate(exp2):
```

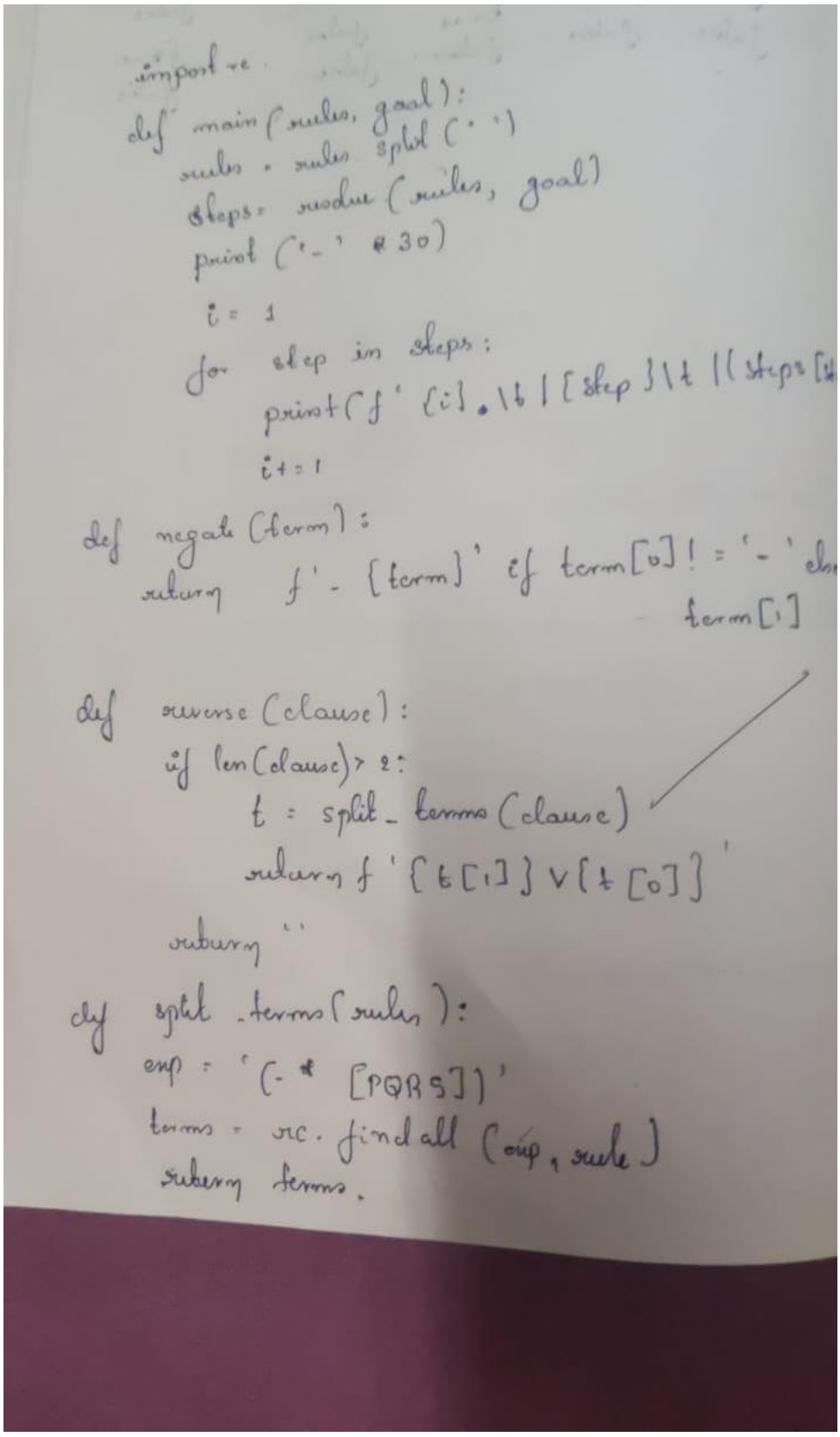
```
        print("Cannot be unified as the predicates do not match!")
        return []

    attributeCount1 = len(getAttributes(exp1))
    attributeCount2 = len(getAttributes(exp2))
    if attributeCount1 != attributeCount2:
        print(f"Length of attributes {attributeCount1} and {attributeCount2} do
not match. Cannot be unified")
        return []

    head1 = getFirstPart(exp1)
    head2 = getFirstPart(exp2)
    initialSubstitution = unify(head1, head2)
    if not initialSubstitution:
        return []
    if attributeCount1 == 1:
        return initialSubstitution

    tail1 = getRemainingPart(exp1)
    tail2 = getRemainingPart(exp2)

    if initialSubstitution != []:
        tail1 = apply(tail1, initialSubstitution)
        tail2 = apply(tail2, initialSubstitution)

    remainingSubstitution = unify(tail1, tail2)
    if not remainingSubstitution:
        return []

    return initialSubstitution + remainingSubstitution

if__name__== "__main__":
    print("Enter the first expression")
    e1 = input()
    print("Enter the second expression")
    e2 = input()
    substitutions = unify(e1, e2)
```

```
print("The substitutions are:")
print([' / '.join(substitution) for substitution in substitutions])
```

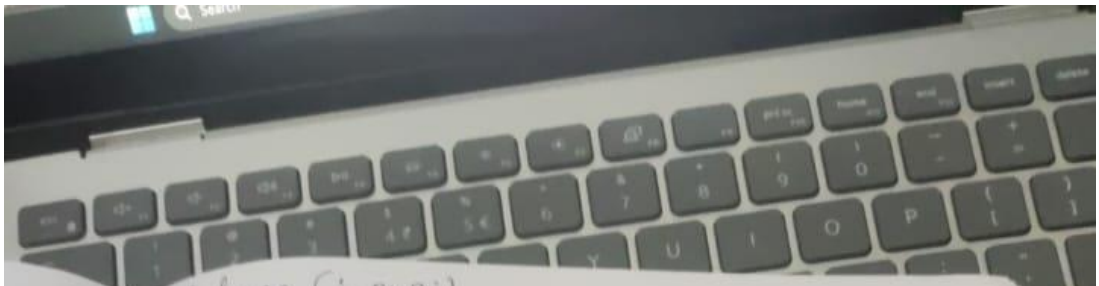
Output:

```
Enter the first expression
king(x)
Enter the second expression
king(john)
The substitutions are:
['john / x']
```

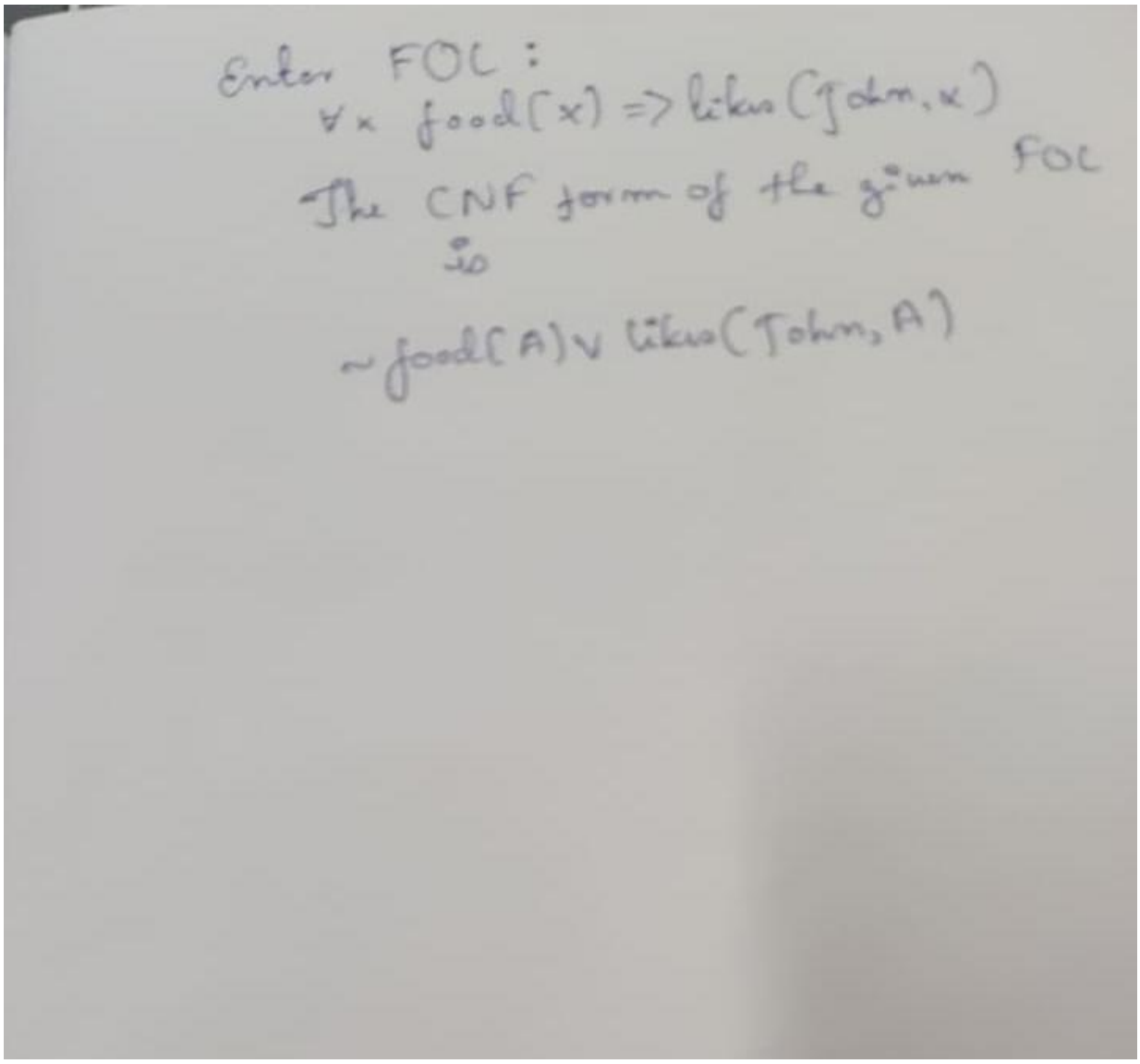
Lab Program 9



```
import re
def main(rules, goal):
    rules = rules.split('\n')
    steps = resolve(rules, goal)
    print('-' * 30)
    i = 1
    for step in steps:
        print(f' {i}. \t {step} \t {steps[
        i += 1

def negate(term):
    return f'~{term}' if term[0] != '~' el
                                  term[1]

def reverse(clause):
    if len(clause) > 2:
        t = split_terms(clause)
        return f'{t[1]} v {t[0]}'
    return ''

def split_terms(rule):
    exp = '(~*[PQRS])'
    terms = re.findall(exp, rule)
    return terms
```



```
split_terms ('~PVR')
def contradiction (goal, clause):
    contradiction = [f'{goal}v{negate(goal)}',
                     f'{negate(goal)}v{goal}']
    return clause in contradictions or reverse(clause)
        in contradiction

def resolve (rules, copy(i) goal):
    temp = rules.copy()
    temp += [negate(goal)]
    steps = dict()
    for rule in temp:
        steps[rule] = 'given'
    steps[negate(goal)] = 'Negated Conclusion'
    i=0
    while i < len(temp):
        n = len(temp)
        j = (i+1)%n
        clauses = []
        while j != i:
            terms1 = split_terms(temp[i])
            terms2 = split_terms(temp[j])
            for c in terms1:
                if negate(c) in terms2:
                    t1 = [t for t in terms1 if t != c]
                    t2 = [t for t in terms if t != negate(c)]
```



Convert given first order logic statement into Conjunctive Normal Form (CNF).

Objective: FOL logic is converted to CNF makes implementing resolution theorem easier.

Code:

```
import re

def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return [m for m in str(matches) if m.isalpha()]

def getPredicates(string):
```

```
    expr = '[a-z~]+\([A-Za-z,]+\)'
    return re.findall(expr, string)

def DeMorgan(sentence):
    string = ''.join(list(sentence).copy())
    string = string.replace('~~','')
    flag = '[' in string
    string = string.replace('~[','')
    string = string.strip(']')
    for predicate in getPredicates(string):
        string = string.replace(predicate, f'~{predicate}')
    s = list(string)
    for i, c in enumerate(string):
        if c == 'V':
            s[i] = '^'
        elif c == '^':
            s[i] = 'V'
    string = ''.join(s)
    string = string.replace('~~','')
    return f'[{string}]' if flag else string
```

```
def Skolemization(sentence):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    statement = ''.join(list(sentence).copy())
    matches = re.findall('[∀∃].', statement)
    for match in matches[::-1]:
        statement = statement.replace(match, '')
        statements = re.findall('\[\[^]]+\]]', statement)
        for s in statements:
            statement = statement.replace(s, s[1:-1])
        for predicate in getPredicates(statement):
            attributes = getAttributes(predicate)
            if ''.join(attributes).islower():
                statement =
statement.replace(match[1],SKOLEM_CONSTANTS.pop(0))
            else:
                aL = [a for a in attributes if a.islower()]
                aU = [a for a in attributes if not a.islower()][0]
                statement = statement.replace(aU,
f'{SKOLEM_CONSTANTS.pop(0)}({aL[0] if len(aL) else match[1]})')
    return statement

def fol_to_cnf(fol):

    statement = fol.replace("<=>", "_")
    while '_' in statement:
        i = statement.index('_')
        new_statement = '[' + statement[:i] + '=>' + statement[i+1:] + ']^['+
statement[i+1:] + '=>' + statement[:i] + ']'
        statement = new_statement
    statement = statement.replace("=>", "-")
    expr = '\[([^]]+)\]'
    statements = re.findall(expr, statement)
    for i, s in enumerate(statements):
        if '[' in s and ']' not in s:
            statements[i] += ']'
    for s in statements:
```

```
        statement = statement.replace(s, fol_to_cnf(s))
    while '-' in statement:
        i = statement.index('-')
        br = statement.index('[') if '[' in statement else 0
        new_statement = '~' + statement[br:i] + 'V' + statement[i+1:]
        statement = statement[:br] + new_statement if br > 0 else new_statement
    while '~∀' in statement:
        i = statement.index('~∀')
        statement = list(statement)
        statement[i], statement[i+1], statement[i+2] = '∃', statement[i+2], '~'
        statement = ''.join(statement)
    while '~∃' in statement:
        i = statement.index('~∃')
        s = list(statement)
        s[i], s[i+1], s[i+2] = '∀', s[i+2], '~'
        statement = ''.join(s)
    statement = statement.replace('~[∀','[~∀')
    statement = statement.replace('~[∃','[~∃')
    expr = '(~[∀V∃].)'
    statements = re.findall(expr, statement)
    for s in statements:
        statement = statement.replace(s, fol_to_cnf(s))
    expr = '~\[[^]]+\]'
    statements = re.findall(expr, statement)
    for s in statements:
        statement = statement.replace(s, DeMorgan(s))
    return statement

def main():
    print("Enter FOL:")
    fol = input()
    print("The CNF form of the given FOL is: ")
    print(Skolemization(fol_to_cnf(fol)))
```

main()

Output:

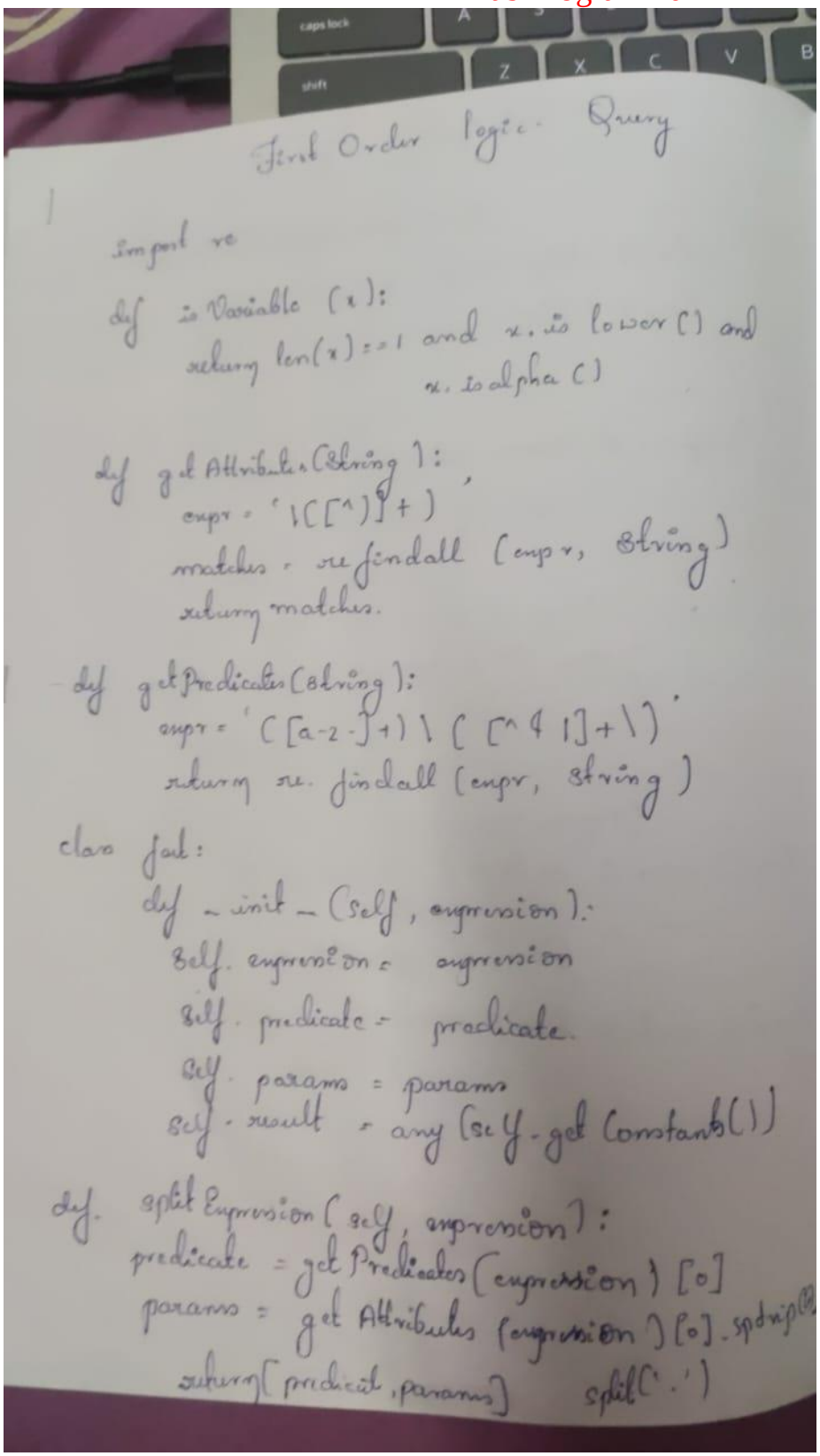
```
main()
```

```
Enter FOL:
∀x food(x) => likes(John, x)
The CNF form of the given FOL is:
~ food(A) V likes(John, A)
```

```
main()
```

```
Enter FOL:
∀x[∃z[loves(x,z)]]
The CNF form of the given FOL is:
[loves(x,B(x))]
```

Lab Program 10



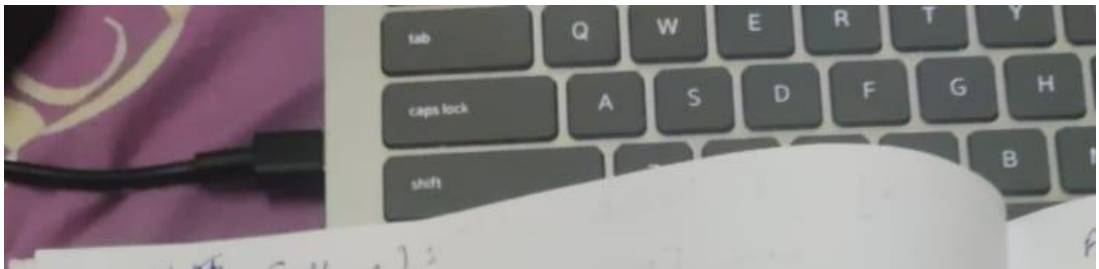
First Order logic Query

```
import re

def isVariable(x):
    return len(x)==1 and x.islower() and
                         x.isalpha()

def getAttributes(string):
    expr = '\([^)]+)'
    matches = re.findall(expr, string)
    return matches

def getPredicates(string):
    expr = '([a-zA-Z]+)\([^&|]+\)'
    return re.findall(expr, string)

class Fact:
    def __init__(self, expression):
        self.expression = expression
        self.predicate = predicate
        self.params = params
        self.result = any(self.getConstants())

def splitExpression(self, expression):
    predicate = getPredicates(expression)[0]
    params = getAttributes(expression)[0].strip()
    return [predicate, params]
                                    split(',')
```

```
def getConstants(self):
    return [None if isVariable(c) else c for
            c in self.params]

def substitute(self, constants):
    c = constants.copy()
    f = f"{self.predicate}({','.join([constants.pop(0)
        if isVariable(p) else p for p in self.
        params.
```

```
class Implication:
    def __init__(self, expression):
        self.expression = expression.
        self.rhs = Fact([1])

def evaluate(self, facts):
    constants = {}
    new_lhs = [].
    for fact in facts:
        if v:
            constant[v] = fact.getConstants()[i
        new_lhs.append(fact)
    return fact(expr) if(in(new_lhs) and all
            ([f.getresult() for f in
            new_lhs])) else None.
```

```
class KB:
    def __init__(self):
        self.facts = set()
        self.implications = set()
```



```
def tell(self, e):
    if '=>' in e:
        self.implications.append(Implication(e))
    else:
        self.facts.add(Fact(e))

    if res:
        self.facts.add(res)


def display(self):
    print("All facts:")
    for i, f in enumerate(set([f.expression
                               for f in self.facts])):
        print(f'{i+1}. {f}')


kb = KB()
kb.tell('king(x) & greedy(x) => evil(x)')
kb.tell('king(John)')
kb.tell('greedy(John)')
kb.tell('king(Richard)')
kb.query('evil(x)')
```

Output:

All facts :

p_1 = king (John)

p_1' = king (x)

p_2' = greedy (x)

p_2 = greedy (y)

p_3 : (x ∨ ¬John ∨ y ∨ ¬John)

q = Evil (x).

⇒ evil (John).

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

Objective: A forward-chaining algorithm will begin with facts that are known. It will proceed to trigger all the inference rules whose premises are satisfied and then add the new data derived from them to the known facts, repeating the process till the goal is achieved or the problem is solved.

Code:

```
import re
def isVariable(x):
    return len(x) == 1 and x.islower() and x.isalpha()

def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return matches

def getPredicates(string):
    expr = '([a-z~]+)\([^&|]+\)'
    return re.findall(expr, string)

class Fact:

    def__init__(self, expression):
        self.expression = expression
        predicate, params = self.splitExpression(expression)
        self.predicate = predicate
        self.params = params
        self.result = any(self.getConstants())

    def splitExpression(self, expression):
        predicate = getPredicates(expression)[0]
        params = getAttributes(expression)[0].strip('()').split(',')
        return [predicate, params]
```

```
    def getResult(self):
        return self.result

    def getConstants(self):
        return [None if isVariable(c) else c for c in self.params]

    def getVariables(self):
        return [v if isVariable(v) else None for v in self.params]

    def substitute(self, constants):
        c = constants.copy()
        f = f"{self.predicate}({','.join([constants.pop(0) if isVariable(p) else p for p
in self.params])})"
        return Fact(f)

class Implication:

    def__init__(self,    expression):
        self.expression = expression
        l = expression.split('=>')
        self.lhs = [Fact(f) for f in l[0].split('&')]
        self.rhs = Fact(l[1])

    def evaluate(self, facts):
        constants = {}
        new_lhs = []
        for fact in facts:
            for val in self.lhs:
                if val.predicate == fact.predicate:
                    for i, v in enumerate(val.getVariables()):
                        if v:
                            constants[v] = fact.getConstants()[i]
                    new_lhs.append(fact)
        predicate, attributes = getPredicates(self.rhs.expression)[0],
str(getAttributes(self.rhs.expression)[0])
        for key in constants:
            if constants[key]:
```

```
                attributes = attributes.replace(key, constants[key])
        expr = f'{predicate}{attributes}'
        return Fact(expr) if len(new_lhs) and all([f.getResult() for f in new_lhs])
else None

class KB:

    def__init__(self):
        self.facts = set()
        self.implications = set()

    def tell(self, e):
        if '=>' in e:
            self.implications.add(Implication(e))
        else:
            self.facts.add(Fact(e))
        for i in self.implications:
            res = i.evaluate(self.facts)
            if res:
                self.facts.add(res)

    def ask(self, e):
        facts = set([f.expression for f in self.facts])
        i = 1
        print(f'Querying {e}:')
        for f in facts:
            if Fact(f).predicate == Fact(e).predicate:
                print(f'\t{i}. {f}')
                i += 1

    def display(self):
        print("All facts: ")
        for i, f in enumerate(set([f.expression for f in self.facts])):
            print(f'\t{i+1}. {f}')

def main():
    kb = KB()
```

```
print("Enter the number of FOL expressions present in KB:")
n = int(input())
print("Enter the expressions:")
for i in range(n):
    fact = input()
    kb.tell(fact)
print("Enter the query:")
query = input()
kb.ask(query)
kb.display()
```

Output:

```
Querying criminal(x):
1. criminal(West)
All facts:
    1. american(West)
    2. sells(West,M1,Nono)
    3. owns(Nono,M1)
    4. missile(M1)
    5. enemy(Nono,America)
    6. weapon(M1)
    7. hostile(Nono)
    8. criminal(West)
Querying evil(x):
    1. evil(John)
```