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 been carried out by Shravanth J(1BM21CS206) during the 5th Semester September-January 2021.

Signature of the Faculty In charge:
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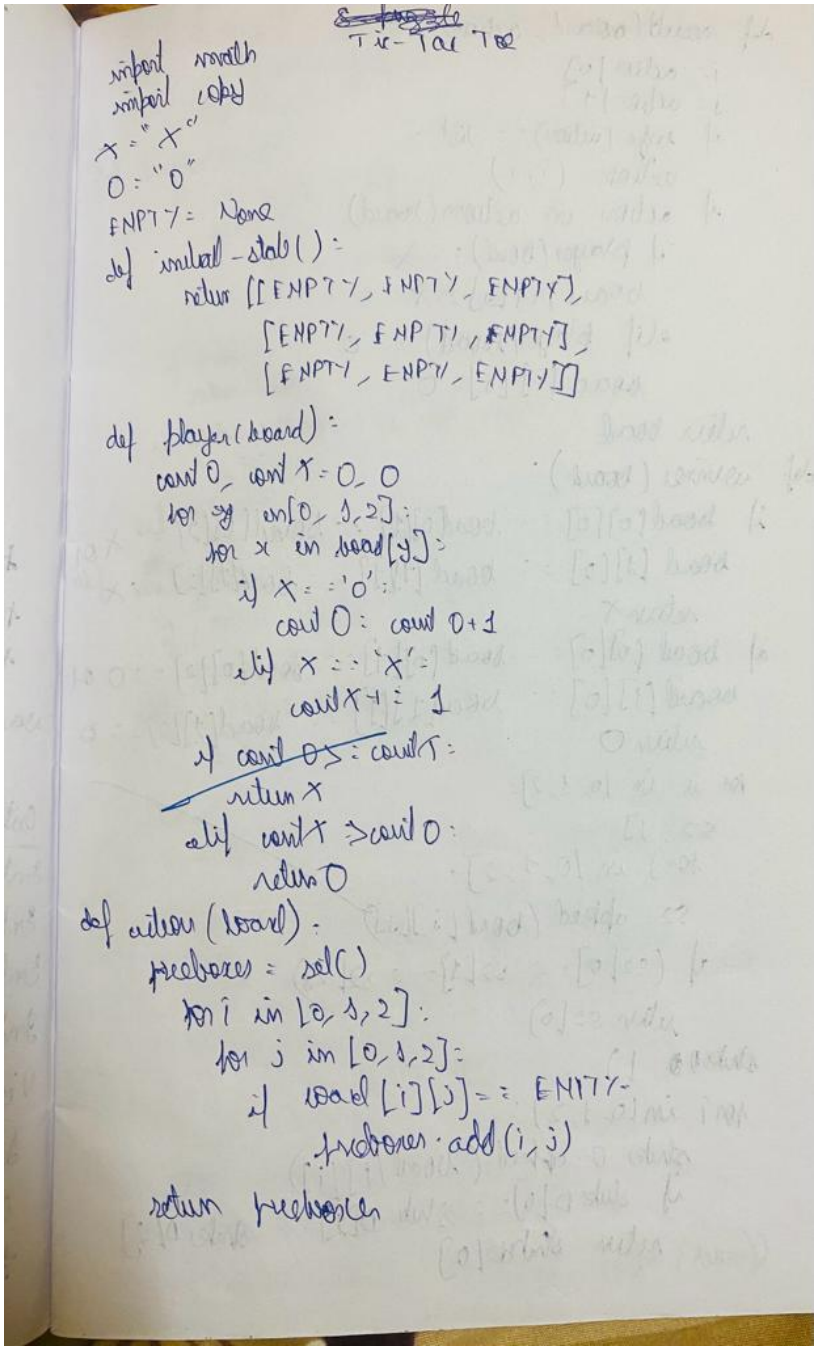
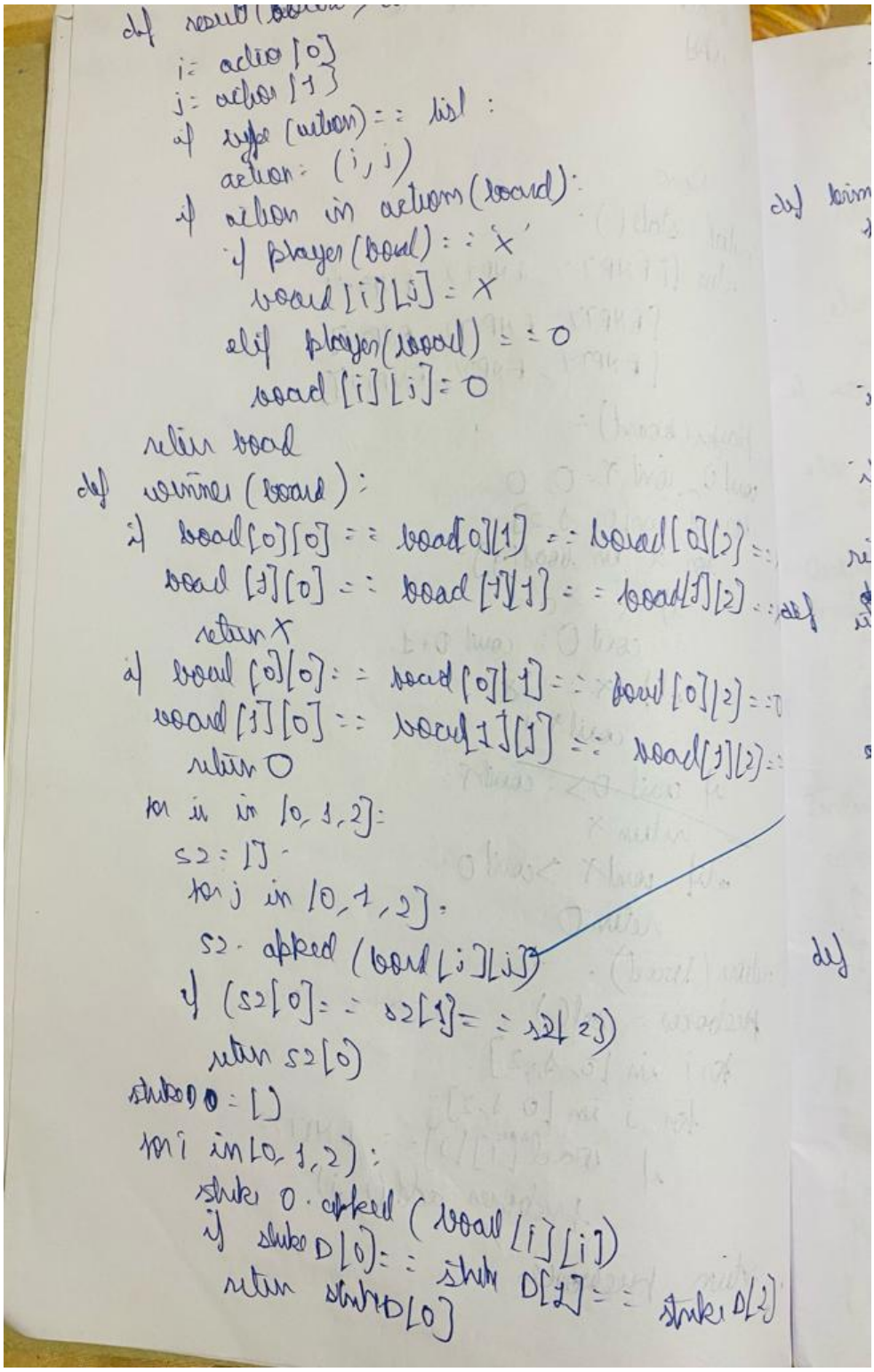
Lab-Program-1

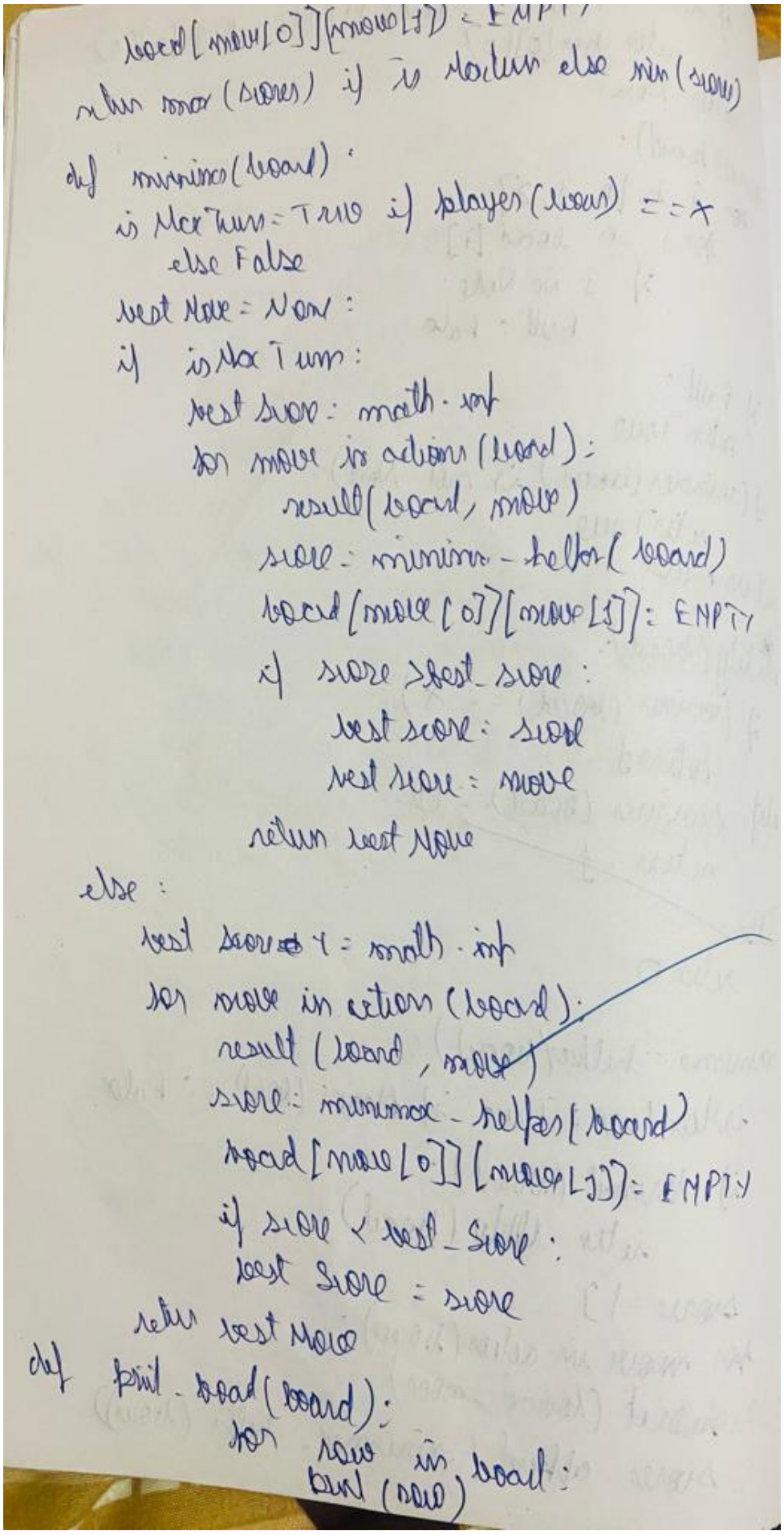


```
Tic-Tac Toe
import numpy
import copy
X = "X"
O = "O"
EMPTY = None
def initial_state():
    return [[EMPTY, EMPTY, EMPTY],
            [EMPTY, EMPTY, EMPTY],
            [EMPTY, EMPTY, EMPTY]]

def player(board):
    count O, count X = 0, 0
    for sy in on[0, 1, 2]:
        for x in board[y]:
            if x == 'O':
                count O = count O + 1
            elif x == 'X':
                count X = 1
    if count O > count X:
        return X
    elif count X >= count O:
        return O
def action(board):
    freeboxes = set()
    for i in [0, 1, 2]:
        for j in [0, 1, 2]:
            if board[i][j] == EMPTY:
                freeboxes.add(i, j)

    return freeboxes
```



```
def result(board, action):
    i = action[0]
    j = action[1]
    if type(action) == list:
        action = (i, j)
    if action in actions(board):
        if player(board) == 'X':
            board[i][j] = X
        elif player(board) == O
            board[i][j] = O
    return board
def winner(board):
    if board[0][0] == board[0][1] == board[0][2] ==
       board[1][0] == board[1][1] == board[1][2] ==
        return X
    if board[0][0] == board[0][1] == board[0][2] ==
       board[1][0] == board[1][1] == board[1][2] ==
        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]
    stub0 = []
    for i in [0, 1, 2]:
        stub0.append(board[i][i])
        if stub0[0] == stub0[1] == stub0[2]
            return stub0[0]
```

```
    if board[0][2] == board[1][1] == board[2][0]:
        return board[0][2]
    return None

def terminal(board):
    for i in [0, 1, 2]:
        for j in board[i]:
            if j is None:
                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) == O):
        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 is_max_turn else min(scores)

def minimax(board):
    is_max_turn = True if player(board) == X
        else False
    best_move = None
    if is_max_turn:
        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:
                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:
                best_score = score
        return best_move
def print_board(board):
    for row in board:
        print(row)
```

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]
```

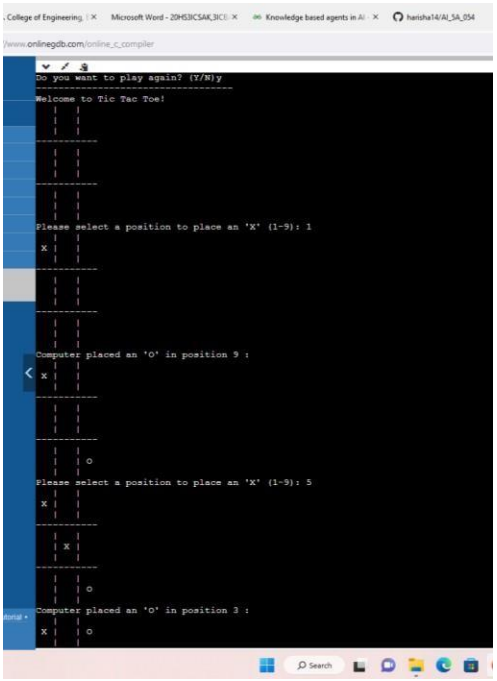
```
== le and bo[7] == le) or ( bo[2] == le and bo[5] == le and bo[8] == le) or (
                    bo[3] == le and bo[6] == le and bo[9] == le) or ( bo[1] == le
                    and bo[5] == le and bo[9] == le) or (bo[3] == le and
bo[5] == le and bo[7] == le)


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
```

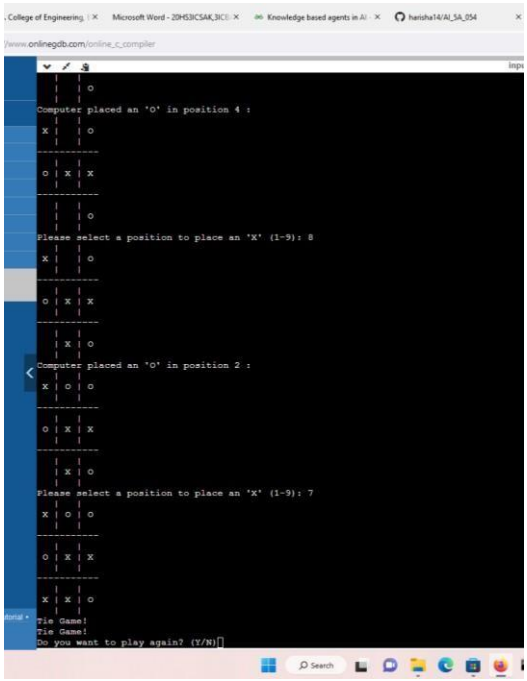
```
    for let in ['O', 'X']:
        for i in possibleMoves:
            boardCopy = board[:]
            boardCopy[i] = let if
            isWinner(boardCopy, let):
                move = i
                return move


    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
```

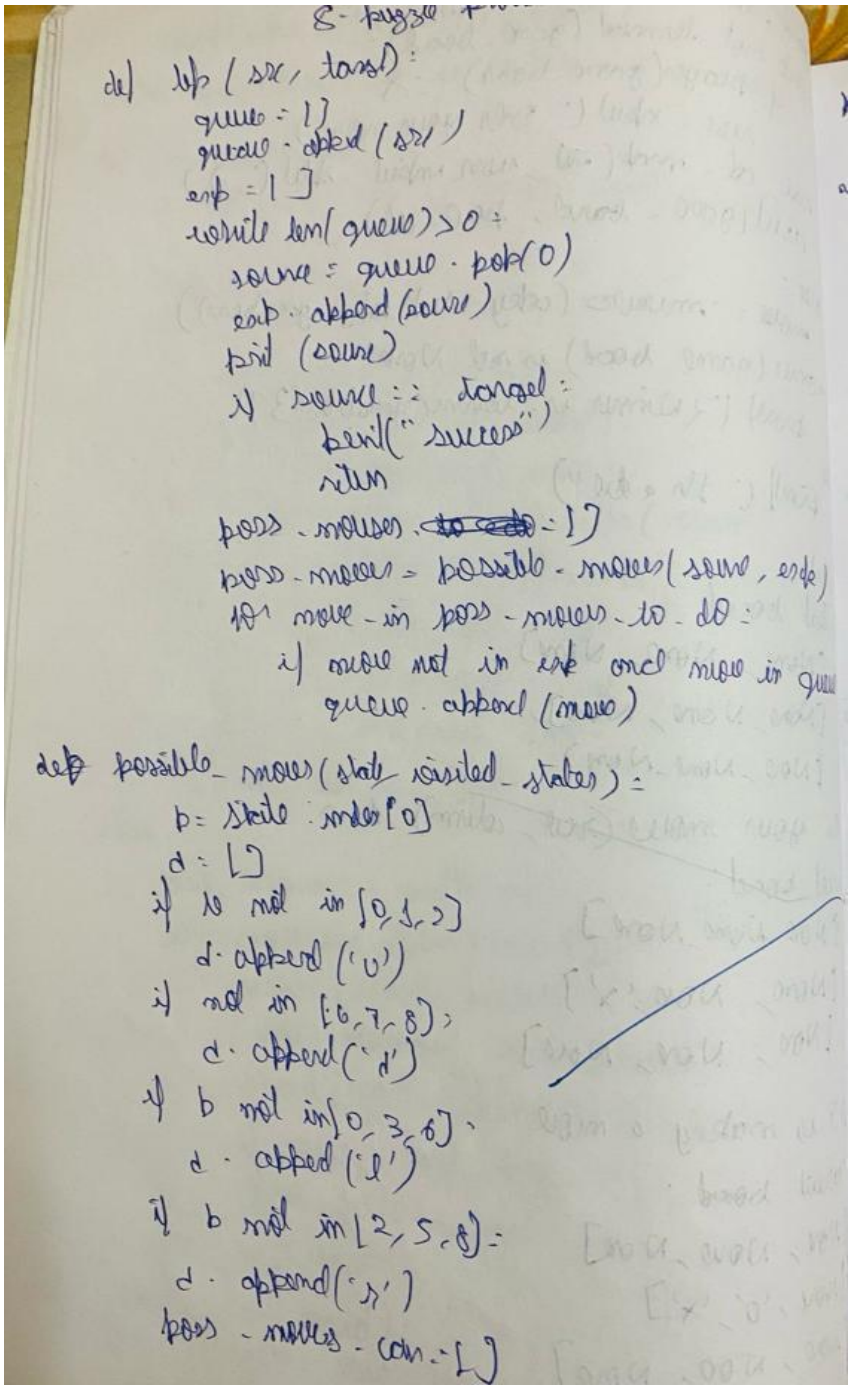
```
if not (isWinner(board, 'X')):
        move = compMove() if
        move == 0:
                print('Tie Game!')
            else:
                insertLetter('O', move) print('Computer placed an
                \'O\' in position', move, ':') printBoard(board)
        else: print('X\'s won this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


Do you want to play again? (Y/N)y
Welcome to Tic Tac Toe!
Please select a position to place an 'X' (1-9): 1
Computer placed an 'O' in position 9 :
Please select a position to place an 'X' (1-9): 5
Computer placed an 'O' in position 3 :


Computer placed an 'O' in position 4 :
Please select a position to place an 'X' (1-9): 8
Computer placed an 'O' in position 2 :
Please select a position to place an 'X' (1-9): 7
Tie Game!
Tie Game!
Do you want to play again? (Y/N)

Lab-Program-2



```
8- puzzle
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 = 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 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')
    poss_moves.(can.[])
```

for i in d: ~~& toggle problem~~

pass - moves . can . append (gen(state , i , b)).

action [move - it - can for move it - can in pass - moves can
if move . it . can not in visited - state]

def gen(state, m, b):
temp : state copy()
if m == 'd':
temp [b-1 3], temp [b] = temp[b], temp [b+2]
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]
return temp

Output:

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

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

fail 6/12/23.

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

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

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

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

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

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

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

[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")
```

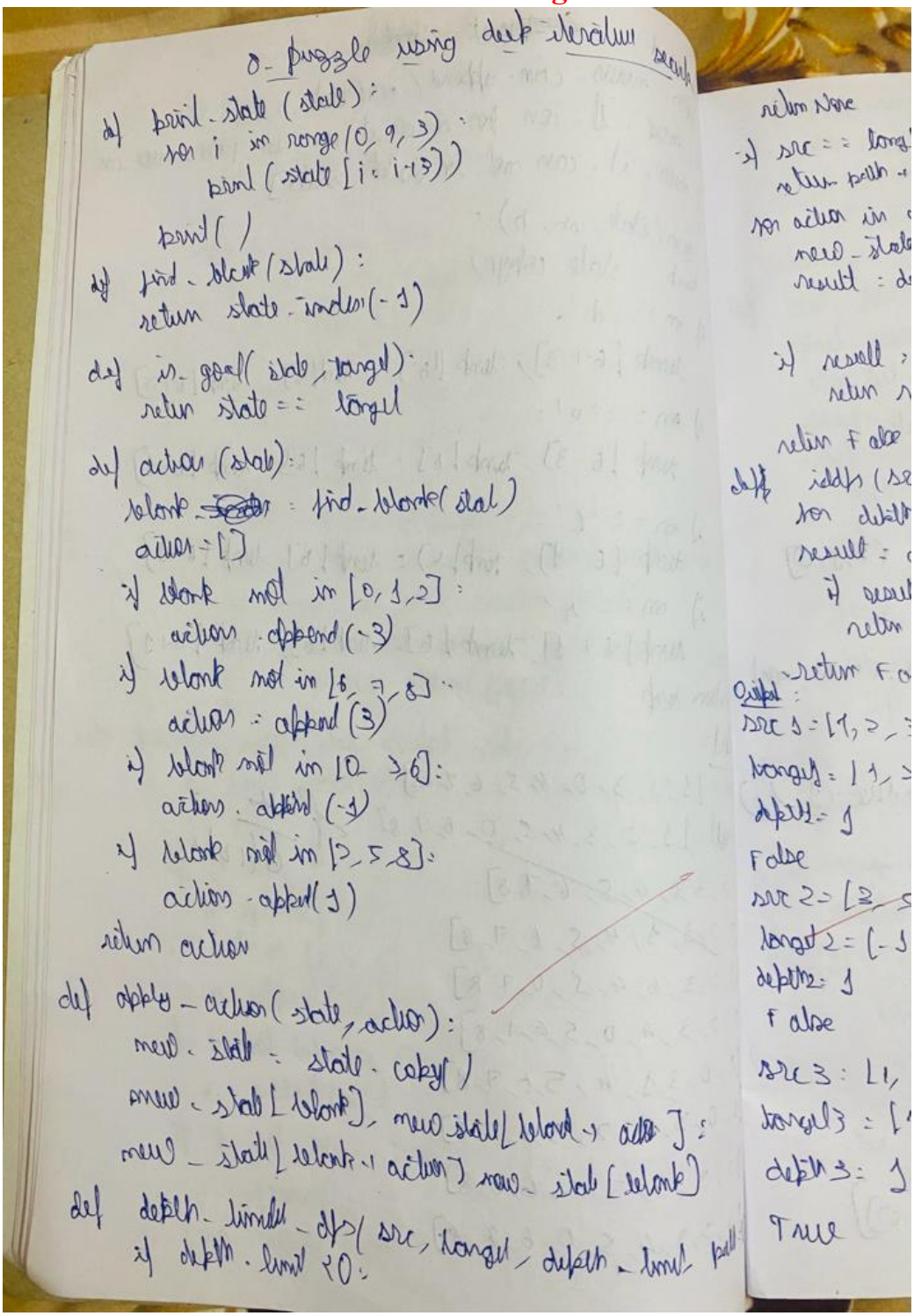
```
 f = open("Node_info.txt", "a") for
    n in visited:
        if n.parent is not None:
            f.write(str(n.node_no) + "\t" +
str(n.parent.node_no) + "\t" + str(n.cost) + "\n")
    f.close()
def path(node): # To find the path from the goal
node to the starting node p = [] # Empty list
p.append(node)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

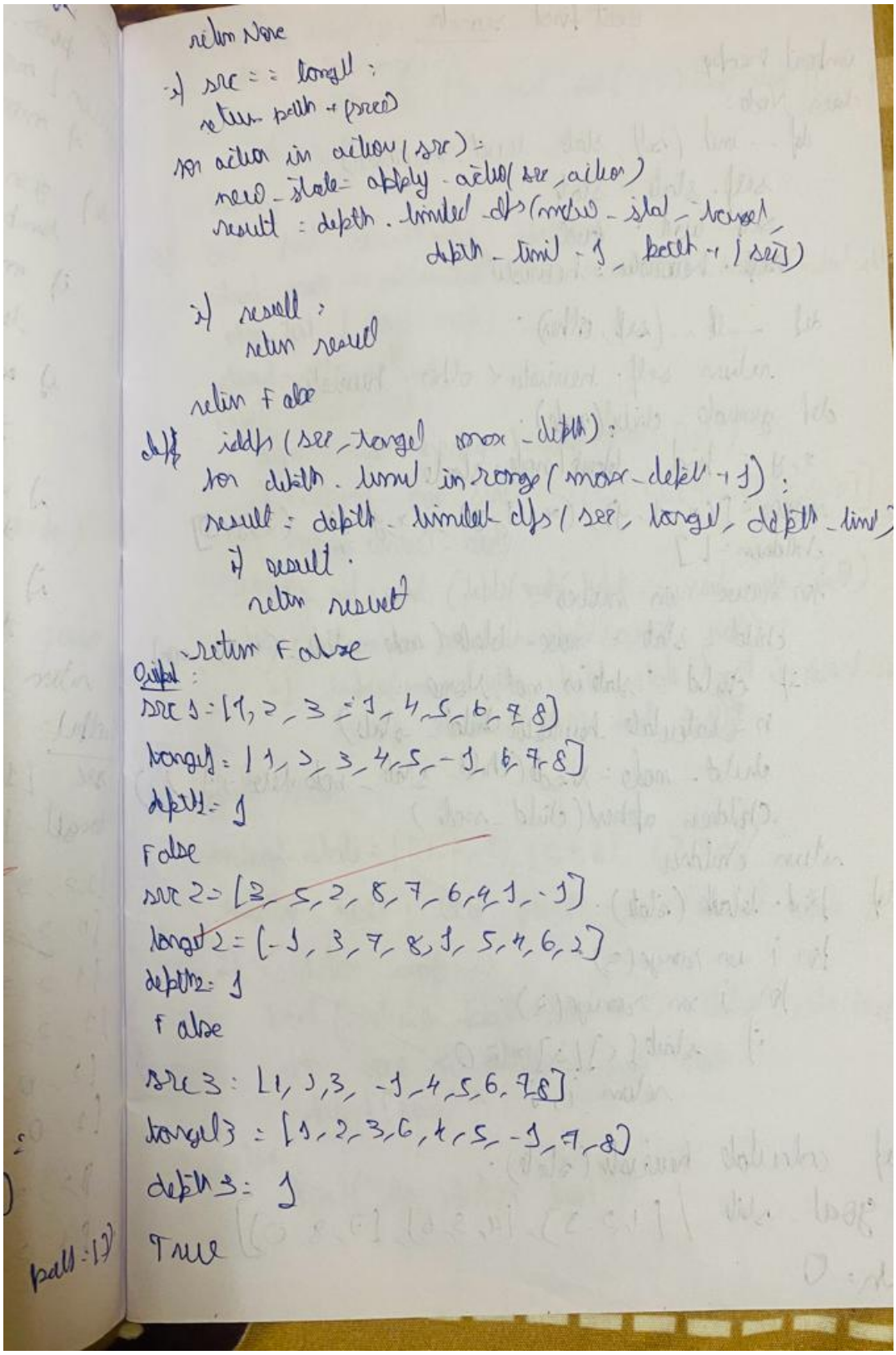
```
Please enter number from 0-8, no number should be repeated or be out of this range
Enter the 1 number: 1
Enter the 2 number: 3
Enter the 3 number: 2
Enter the 4 number: 5
Enter the 5 number: 4
Enter the 6 number: 6
Enter the 7 number: 0
Enter the 8 number: 7
Enter the 9 number: 8
The puzzle is solvable, 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 using dept iterative
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 = find_blank(state)
    actions = []
    if blank not in [0,1,2]:
        actions.append(-3)
    if blank not in [6,7,8]:
        actions.append(3)
    if blank not in [0,3,6]:
        actions.append(-1)
    if blank not in [2,5,8]:
        actions.append(1)
    return actions
def apply_action(state, action):
    new_state = state.copy()
    new_state[blank], new_state[blank+a] =
    new_state[blank+a] = new_state[blank]
def depth_limited_dfs(src, target, depth_limit
    if depth_limit >0:
```

```
return None
    if src == target:
    return path +
    for action in
        new_state
        result = d
    if result
        return
    return False
def iddfs(
    for depth
    result =
    if result
    return
return False
Output:
src 1 = [1, 2,
target = [1,
depth = 1
False
src 2 = [2,
target 2 = [-1
depth = 1
False
src 3 = [1,
target 3 = [
depth 3 = 1
True
```



return None
if src == target:
return path + [src]
for action in actions(src):
new_state = apply_action(src, action)
result = depth_limited_dfs(new_state, target,
depth_limit - 1, 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
Output:
src 1 = [1, 2, 3, -1, 4, 5, 6, 7, 8]
target 1 = [1, 2, 3, 4, 5, -1, 6, 7, 8]
depth 1 = 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 2 = 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
path = 1)

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)
```

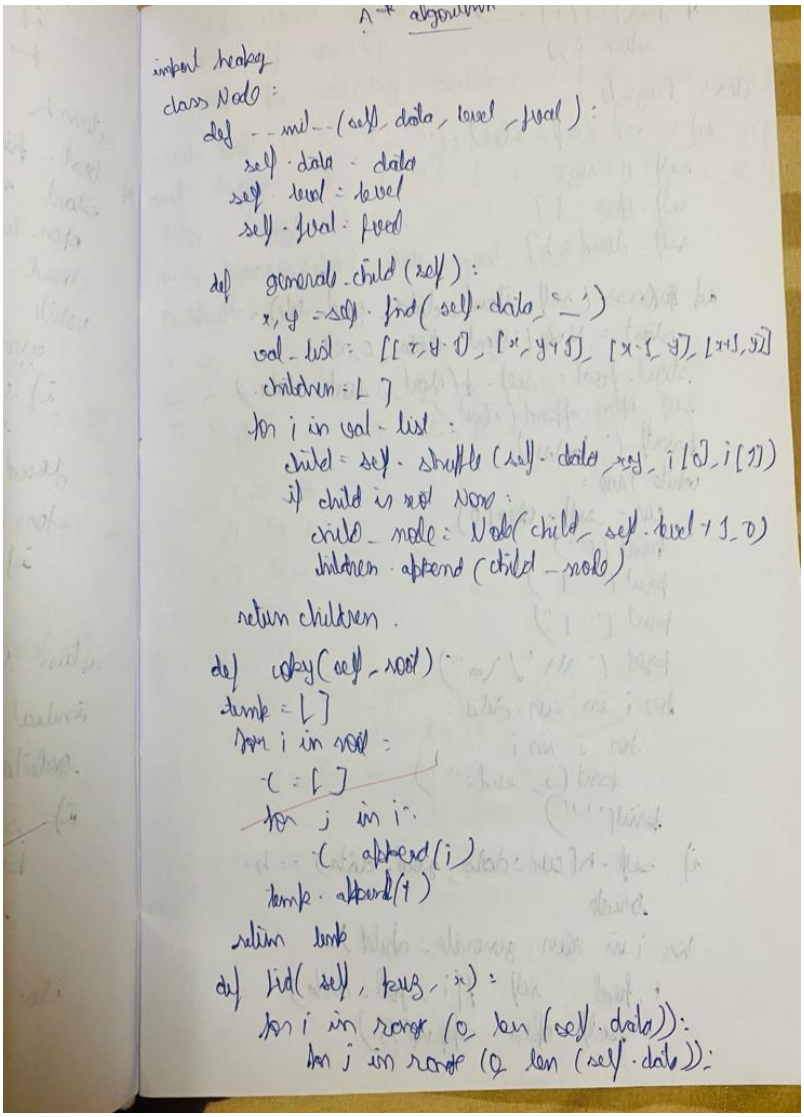
```
False
```

```
# 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)
```

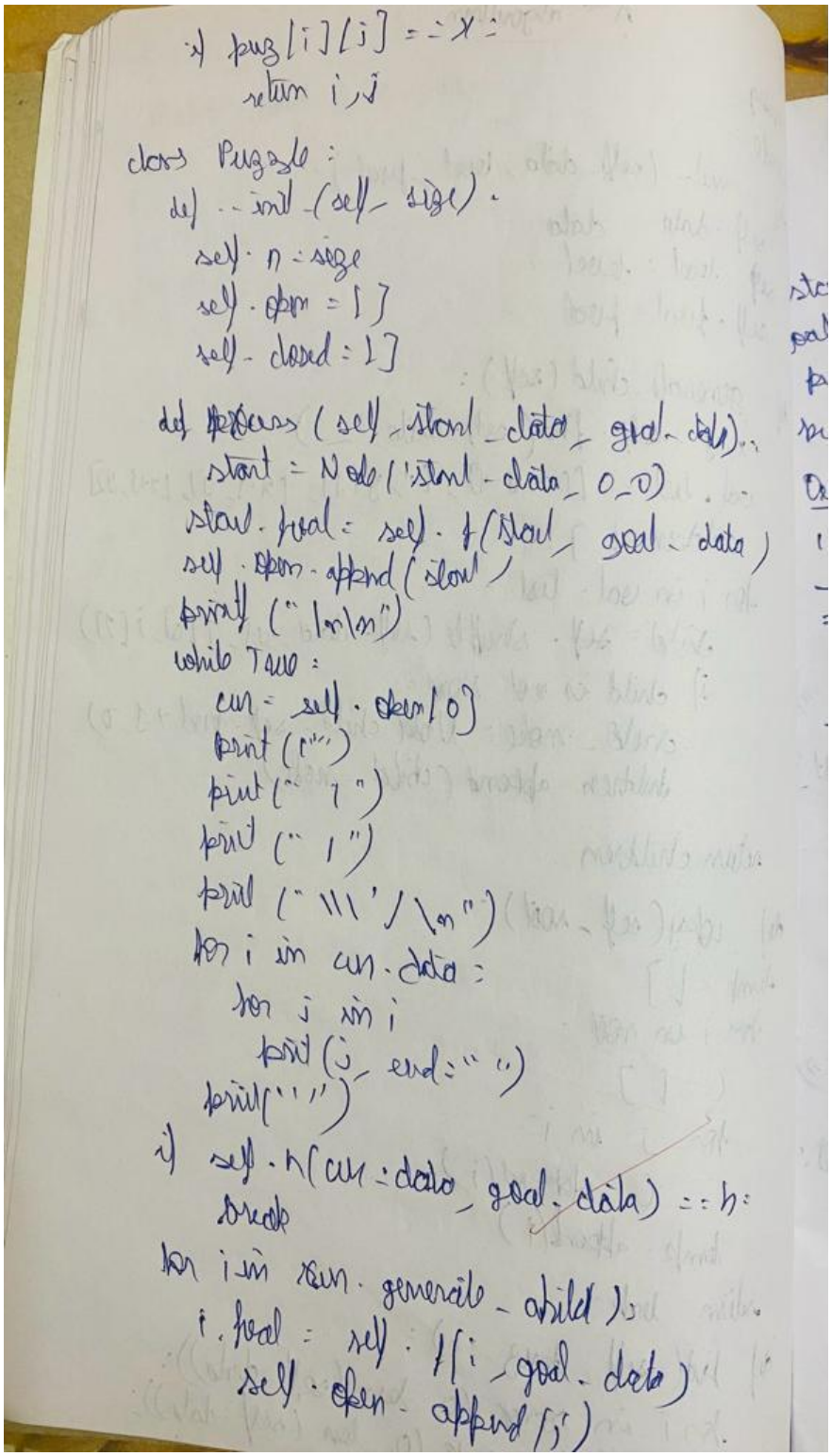
```
src = [1, 2, 3, 4, 5, 6, 7, 8, -1]
target = [-1, 1, 2, 3, 4, 5, 6, 7, 8]

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
```

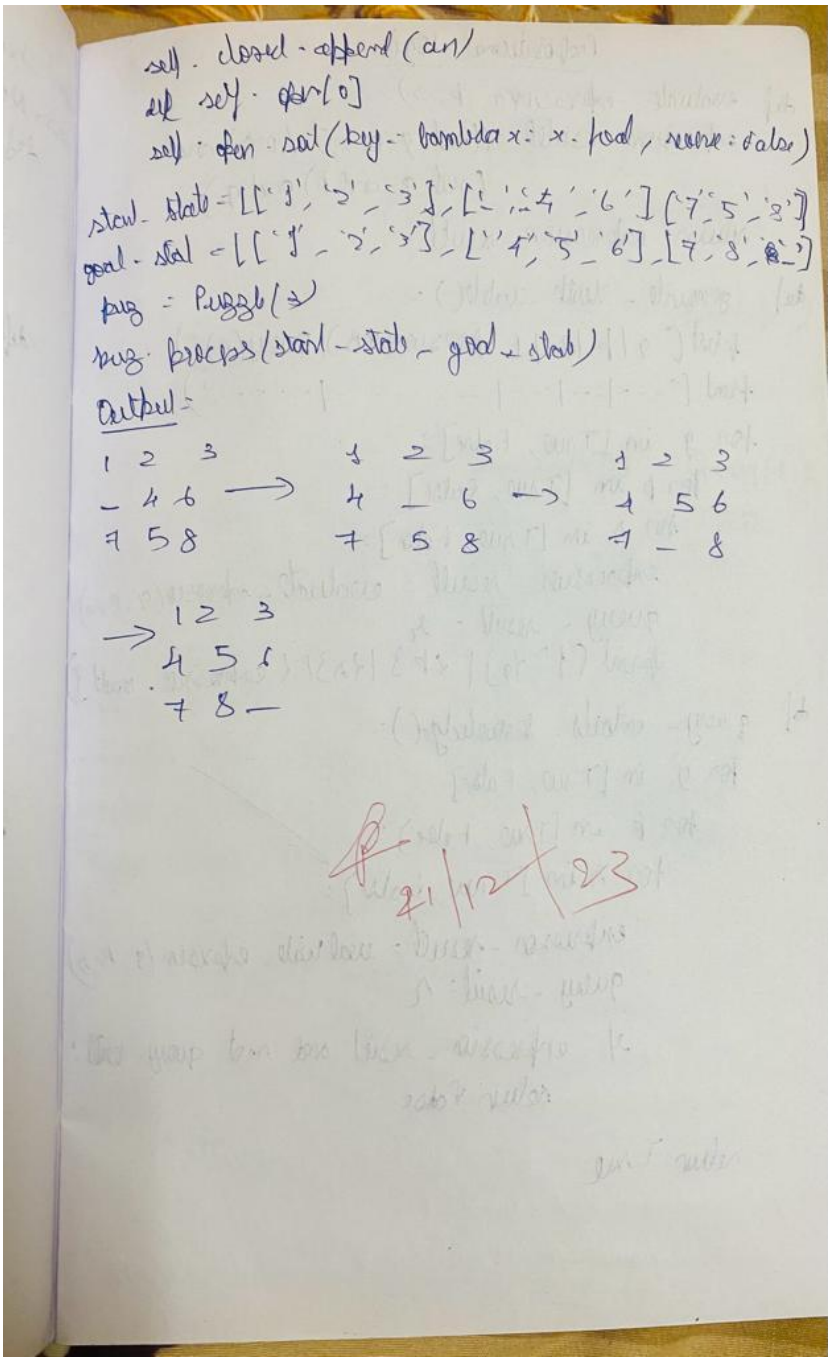
Lab Program 4



```
A* algorithm
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 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 Puzzle:
    def __init__(self, size):
        self.n = size
        self.open = []
        self.closed = []

    def process(self, start_data, goal_data):
        start = Node(start_data, 0, 0)
        start.heal = self.h(start, goal_data)
        self.open.append(start)
        print("\n\n")
        while True:
            cur = self.open[0]
            print("")
            print("  |")
            print("  |")
            print(" \|/ \n")
            for i in cur.data:
                for j in i:
                    print(j, end=" ")
                print("")
            if self.h(cur.data, goal_data) == 0:
                break
            for i in cur.generate_child():
                i.heal = self.h(i, goal_data)
                self.open.append(i)
```



```
self.closed.append(an)
while self.open[0]
self.open.sort(key=lambda x: x.food, reverse=False)

start_state = [['1','2','3'],['_','4','6'],['7','5','8']]
goal_state = [['1','2','3'],['4','5','6'],['7','8','_']]
prog = Puzzle()
prog.process(start_state, goal_state)
```

Output:

```
1 2 3        1 2 3        1 2 3
_ 4 6  ---->  4 _ 6  ---->  4 5 6
7 5 8        7 5 8        7 _ 8

  1 2 3
--> 4 5 6
    7 8 _
```

21/12/23

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:

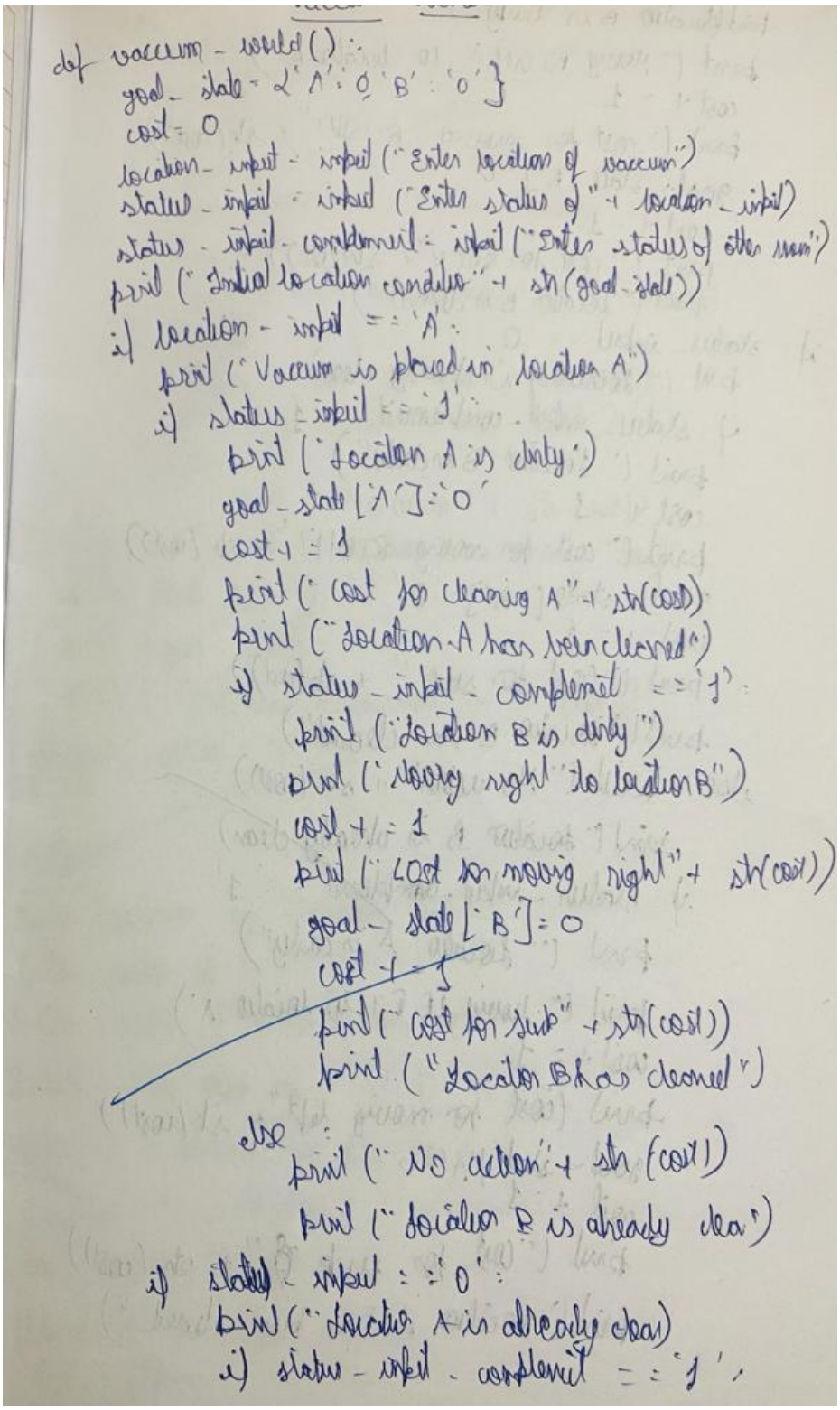
```
def print_b(src):
state = src.copy()
state[state.index(-1)] = ' '
print(
f"""
{state[0]} {state[1]} {state[2]}
{state[3]} {state[4]} {state[5]}
{state[6]} {state[7]} {state[8]}
 “””
   ) def h(state,
target):
   count = 0 i
   = 0 for j in
   state:
      if state[i] != target[i]:
         count = 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)
```

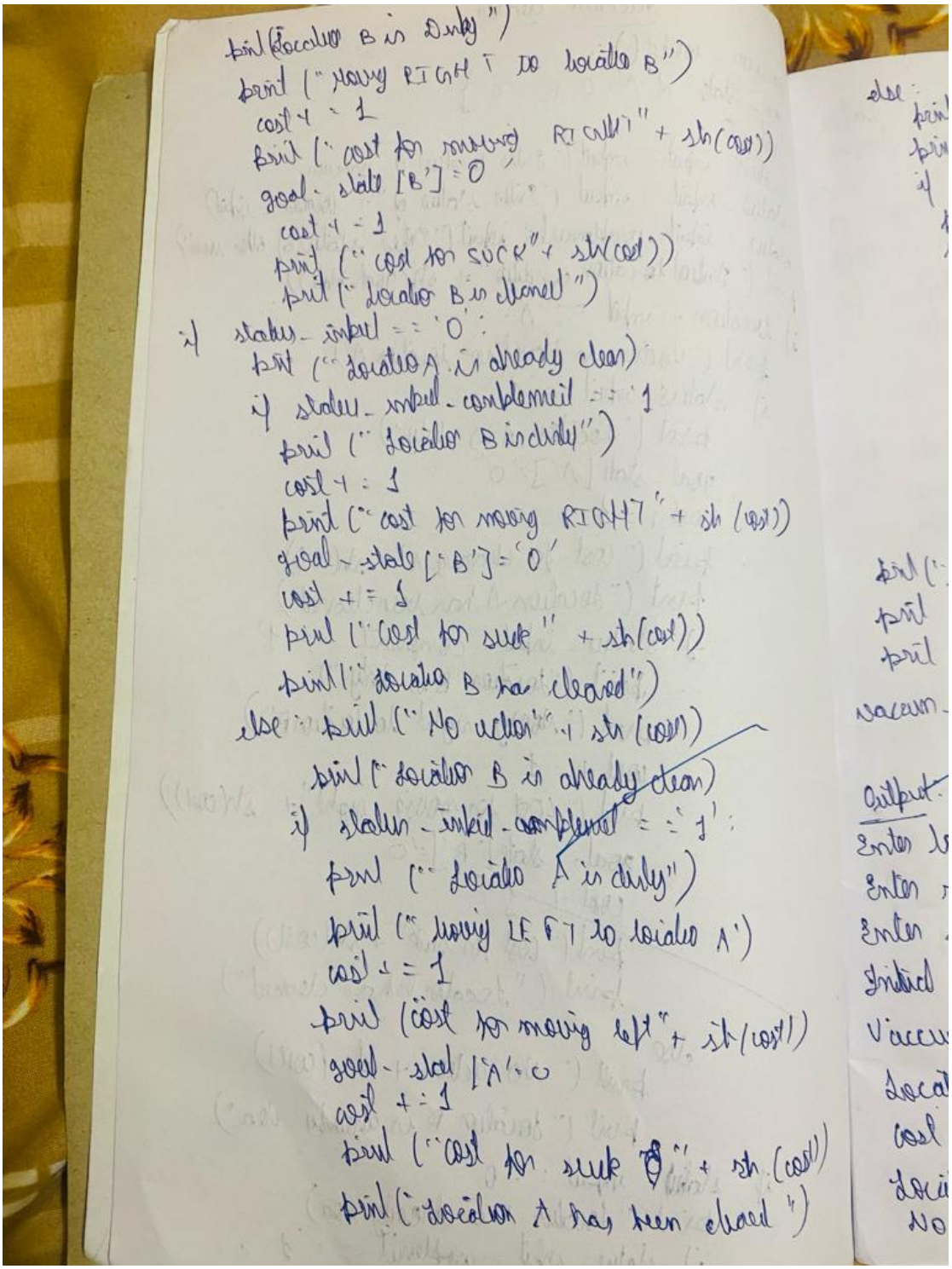
Output:

```
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
```

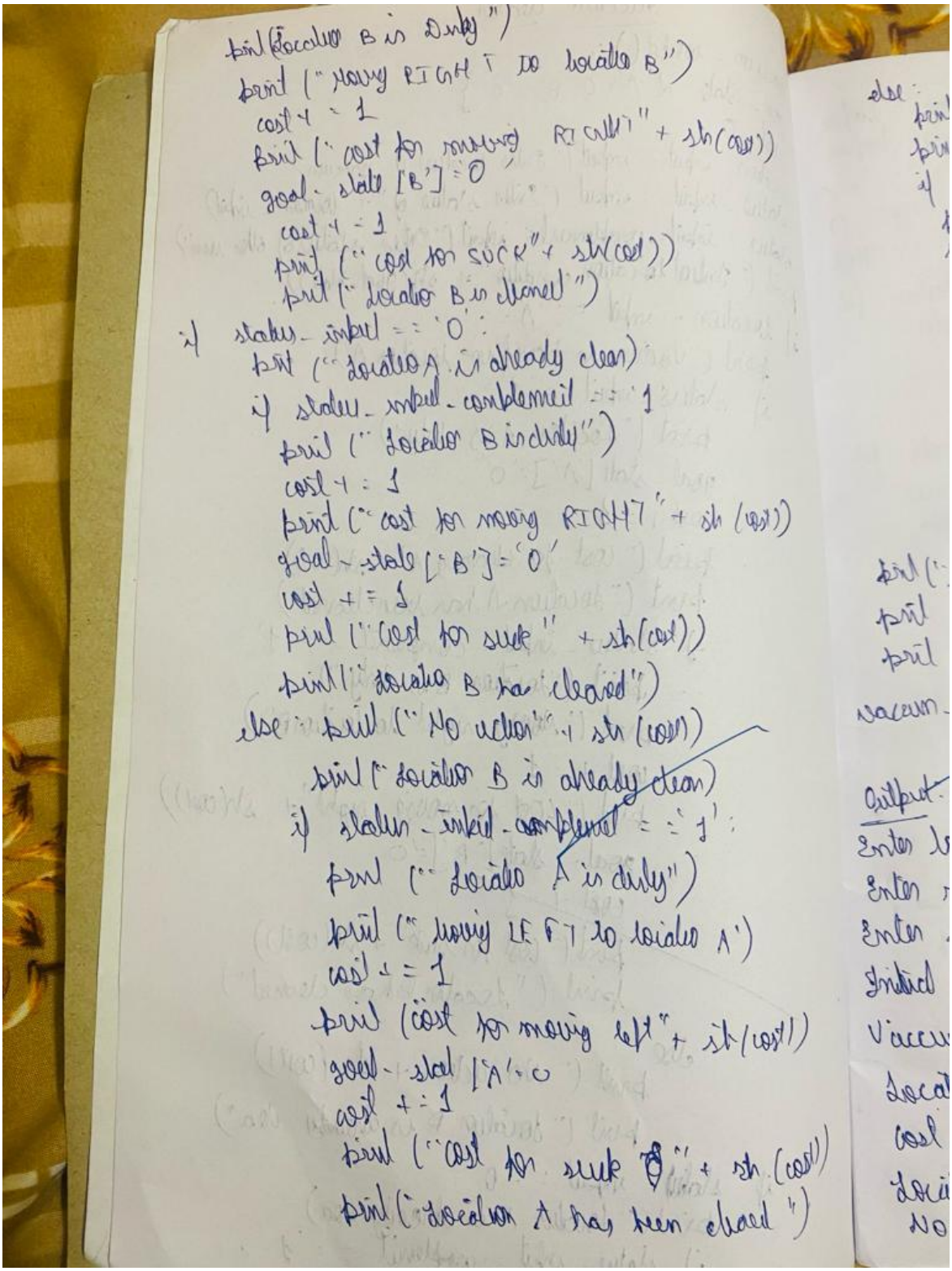
Lab Program 5



```
def vaccum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    location_input = input("Enter location of vaccum")
    status_input = input("Enter status of" + location_input)
    status_input_complement = input("Enter status of other room")
    print("Initial location condition" + str(goal_state))
    if location_input == 'A':
        print("Vaccum 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("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 I DO 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 is cleaned")
if status_input == '0':
    print("location A is already clean")
    if status_input_complement == '1':
        print("location B is dirty")
        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 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 A")
        cost = 1
        print("cost for moving left" + str(cost))
        goal_state['A'] = 0
        cost += 1
        print("cost for suck 0" + str(cost))
        print("location A has been cleaned")
```



```
print("location B is Dirty")
print("moving RIGHT I DO 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 is cleaned")
if state_input == '0':
print("location A is already clean")
if state_input_complement == '1':
print("location B is dirty")
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 cleared")
else: print("No action" + str(cost))
print("location B is already clean")
if state_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")
```

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:
```

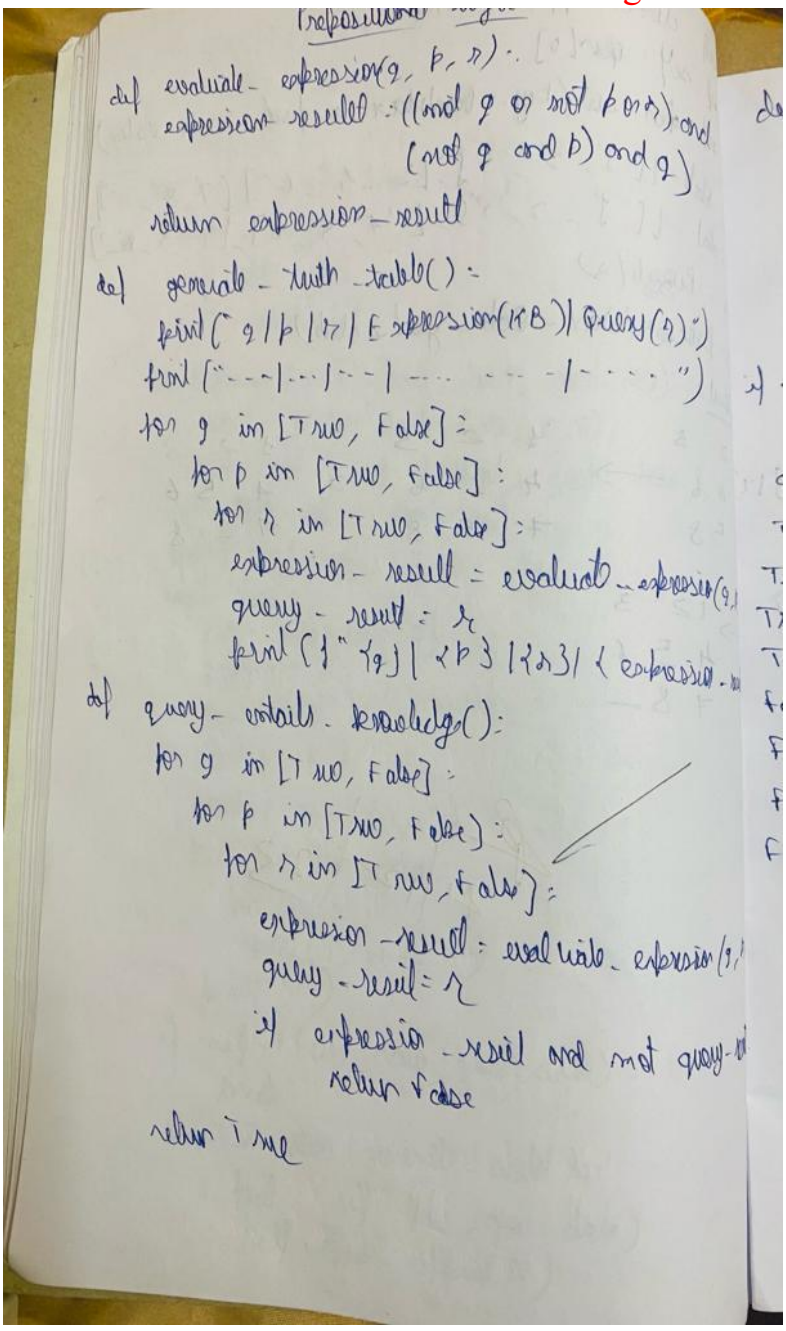
```
            print("No action" + str(cost))
            print("Location B is already clean.")

        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



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

def generate_truth_table():
    print("q | p | r | Expression(A->B) | Query(r)")
    print("---|---|---|---|---")
    for q in [True, False]:
        for p in [True, False]:
            for r in [True, False]:
                expression_result = evaluate_expression(q,
                query_result = r
                print(f"{q} | {p} | {r} | {expression_
def query_entails_knowledge():
    for q in [True, False]:
        for p in [True, False]:
            for r in [True, False]:
                expression_result = evaluate_expression(q,
                query_result = r
                if expression_result and not query_
                    return False
    return True
```

```
def main():
    generate_truth_table()
    if query_entail_knowledge():
        print("In Query entails the knowledge")
    else:
        print("In Query does not entail the knowledge")
if __name__ == "main":
    main()
```

q	p	r	Expression(KB)	Query(α)
True	True	True	False	True
True	True	False	False	False
True	False	True	False	True
True	False	False	False	False
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
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False True
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False False
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False True
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False False
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False True
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False False
----------
Knowledge Base entails query
```
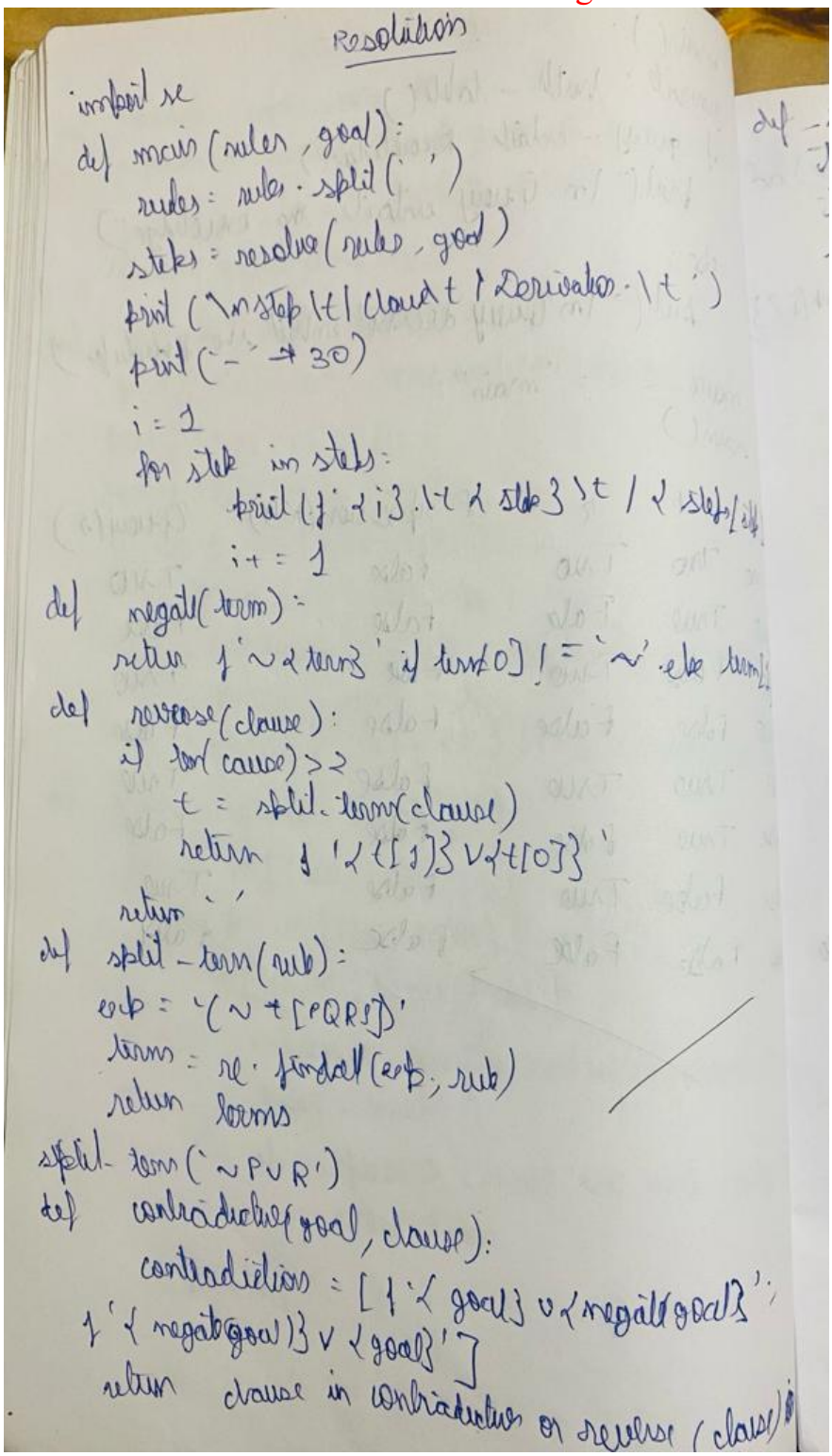
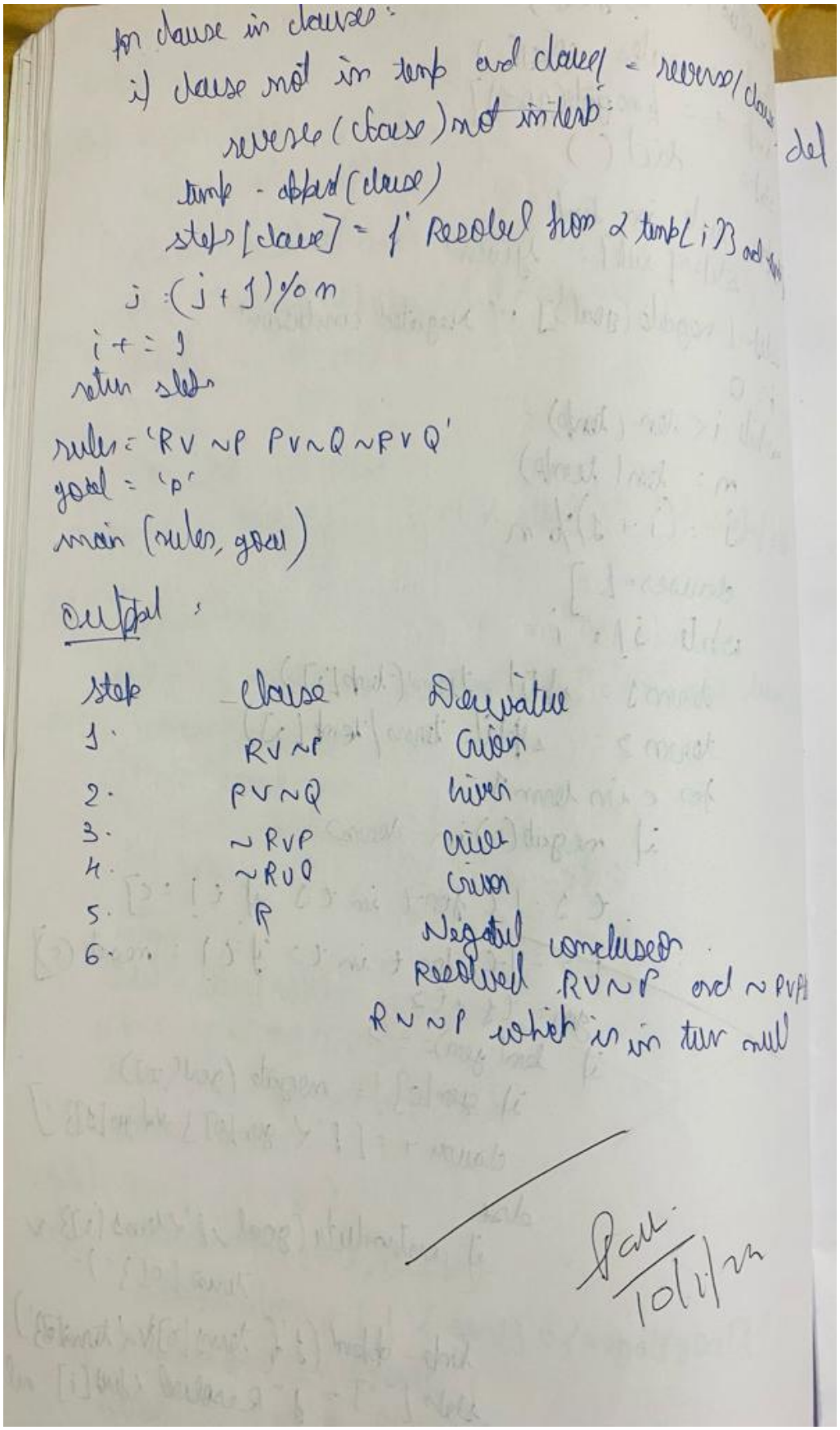

Lab Program 7



Resolution

```
import re
def main(rules, goal):
    rules = rules.split(' ')
    steps = resolve(rules, goal)
    print('\nStep\t|Clause\t|Derivation\t')
    print('-'*30)
    i = 1
    for step in steps:
        print(f'{i}.\t|{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_term(clause)
        return f'{t[1]} v {t[0]}'
    return ''
def split_term(rule):
    exp = '(~*[PQRS])'
    terms = re.findall(exp, rule)
    return terms
split_term('~PvR')
def contradiction(goal, clause):
    contradictions = [f'{goal} v {negate(goal)}',
    f'{negate(goal)} v {goal}']
    return clause in contradictions or reverse(clause)
```

```
def _resolve(rules, 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 t1 if t != c]
                    t2 = [t for t in t2 if t != negate(c)]
                    gen = t1 + t2
                    if len(gen) == 2:
                        if gen[0] != negate(gen[1]):
                            clauses += ['('+gen[0]+'v'+gen[1]+')']
                        else:
                            if contradict(goal, '('+terms1[0]+'v'+
                                          terms2[0]+')'):
                                temp.append('('+terms[0]+'v'+terms2[0]+')')
                                steps[''] = "Resolved "+terms[i] and
            temp = []
            temp = gen
        return steps
```



```
for clause in clauses:
    if clause not in temp and clause = reverse(clause)
        reverse(clause) not in temp:
        temp = dfs(clause)
        steps[clause] = 'Resolved from ' + temp[i] + ' and ' + ...
    j = (j + 1) % n
i += 1
return steps

rules = 'RV~P PV~Q ~PVQ'
goal = 'P'
main(rules, goal)
```

Output:

Step	Clause	Derivation
1.	RV~P	Given
2.	PV~Q	Given
3.	~RVP	Given
4.	~RVQ	Given
5.	R	Negated conclusion
6.		Resolved RV~P and ~PVR to RV~R which is in turn null

Part 10(i)/m

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()
```

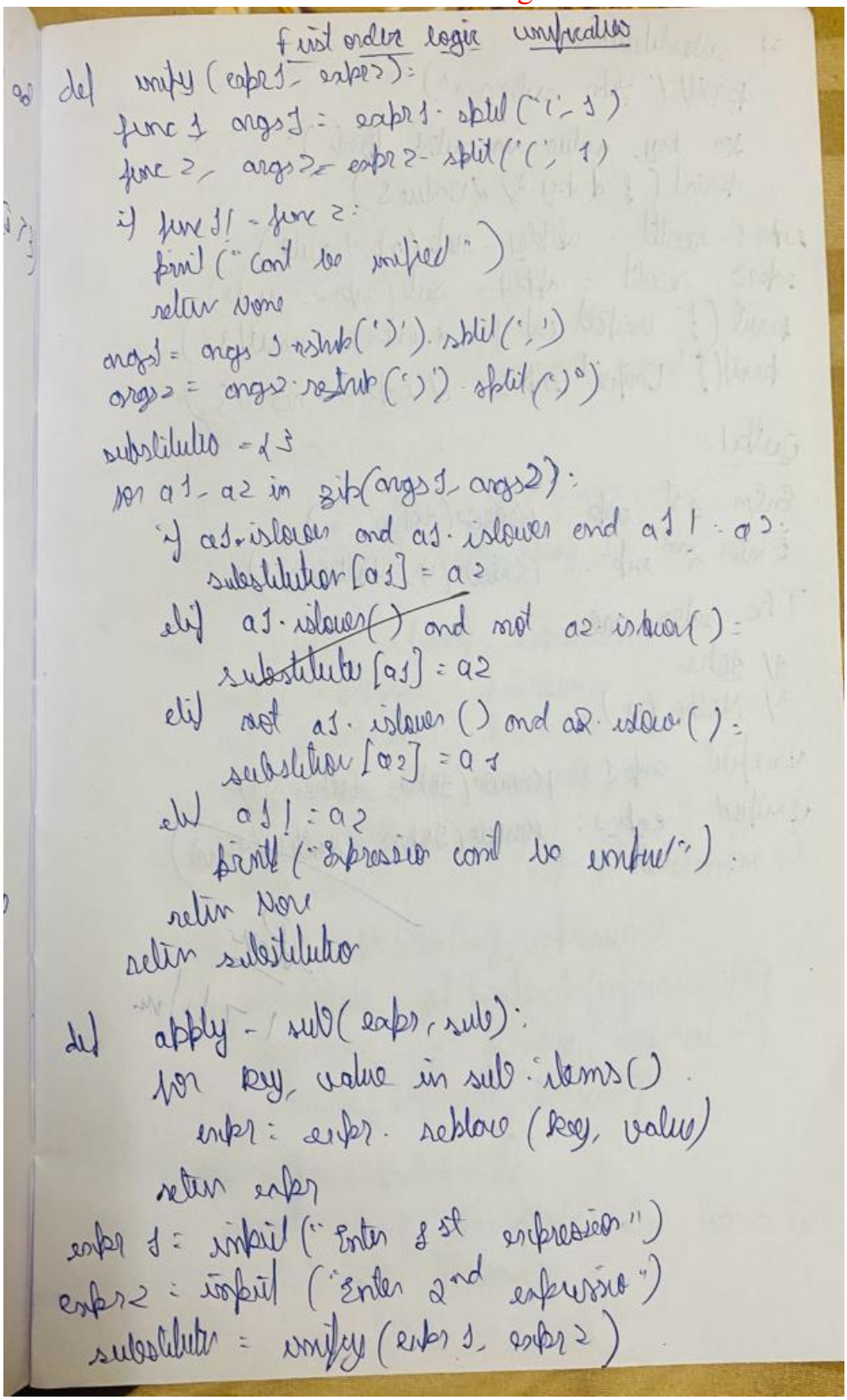
```
#Test2
TELL('p')
TELL(['implies',['and','p','q'],'r'])
TELL(['implies',['or','s','t'],'q'])
TELL('t')
ASK('r')
```

```
True
```

```
CLEAR()
```

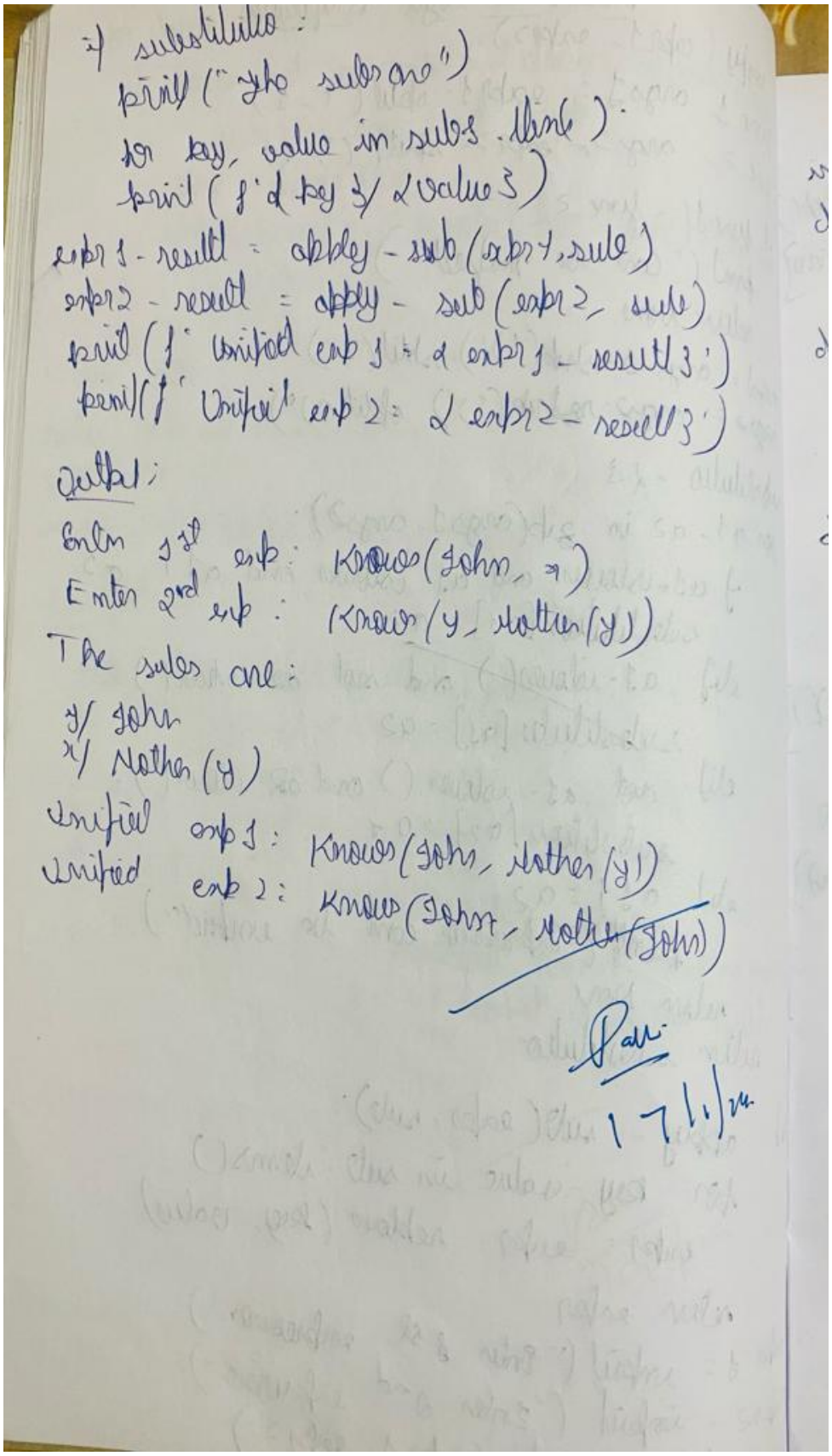
```
#Test3
TELL('a')
TELL('b')
TELL('c')
TELL('d')
ASK(['or', 'a', 'b', 'c', 'd'])
```

Lab Program 8



first order logic unification

```
def unify(expr1, expr2):
    func1, args1 = expr1.split('(', 1)
    func2, args2 = expr2.split('(', 1)
    if func1 != func2:
        print("Cant be unified")
        return None
    args1 = args1.rstrip(')').split(',')
    args2 = args2.rstrip(')').split(',')

    substitutions = {}
    for a1, a2 in zip(args1, args2):
        if a1.islower() and a1.islower() and a1 != a2:
            substitutions[a1] = a2
        elif a1.islower() and not a2.islower():
            substitutions[a1] = a2
        elif not a1.islower() and a2.islower():
            substitutions[a2] = a1
        elif a1 != a2:
            print("Expression cant be unified")
            return None
        return substitutions

def apply_sub(expr, sub):
    for key, value in sub.items():
        expr = expr.replace(key, value)
    return expr

expr1 = input("Enter 1st expression")
expr2 = input("Enter 2nd expression")
substitutions = unify(expr1, expr2)
```



```
# substitute :
print("The subs are")
for key, value in subs.items():
    print(f"{key} / {value}")
expr1_result = apply_sub(expr1, subs)
expr2_result = apply_sub(expr2, subs)
print(f"Unified exp 1 : {expr1_result}")
print(f"Unified exp 2 : {expr2_result}")
```

Output:

Enter 1st exp : Knows(John, x)
Enter 2nd exp : Knows(y, Mother(y))
The subs are :
y / John
x / Mother(y)
Unified exp 1 : Knows(John, Mother(y))
Unified exp 2 : Knows(John, Mother(John))

Pass
17/1/24

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 []
```

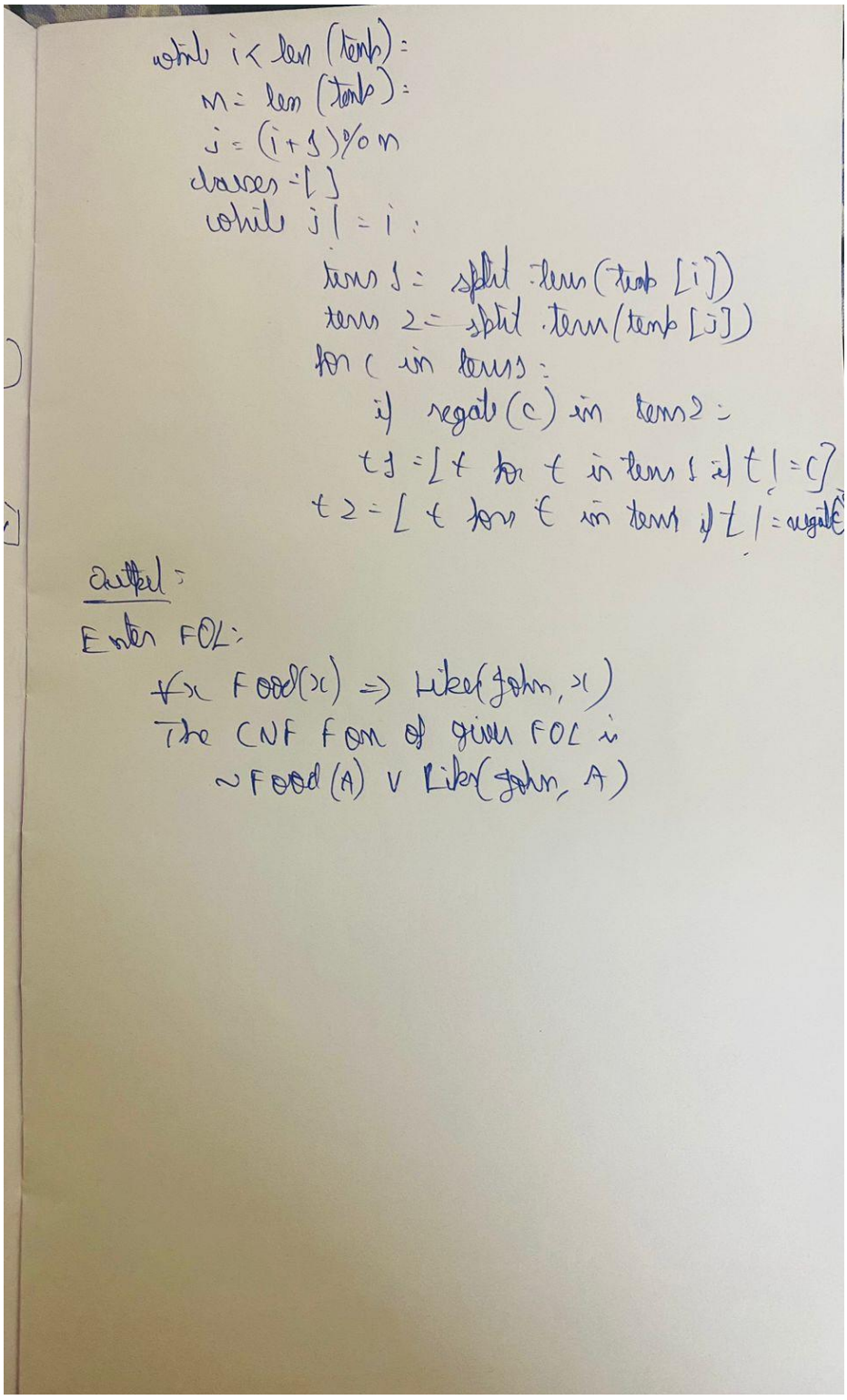
```
    attributeCount1 = len(getAttributes(exp1)) attributeCount2 =
    len(getAttributes(exp2)) if attributeCount1 != attributeCount2:
    print(f"Length of attributes {attributeCount1} and {attributeCount2} do
not match. Cannot be unified")
        return []

    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']
```

FOL to CNF

```
import re
def main(rules, goal):
    rules = rules.split(' ')
    steps = resolve(rules, goal)
    print('-', 30)
    i = 1
    for step in steps:
        print(f'{i}. 16| {step}|t| {steps[i]}')
        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]}'
def split_terms(rules):
    exp = '(.* [PQRS])'
    terms = re.findall(exp, rule)
    return terms
def resolve(rules, 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 :
          term 1 = split term(temp [i])
          term 2= split term(temp [j])
          for c in term1:
              if negate(c) in term2:
            t1 =[t for t in term1 if t != c]
          t2 =[ t for t in term if t != negate
```

output:

Enter FOL:

$\forall x$ Food(x) => Like(John, x)

The CNF Form of given FOL is

~Food(A) V Like(John, A)

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()
```

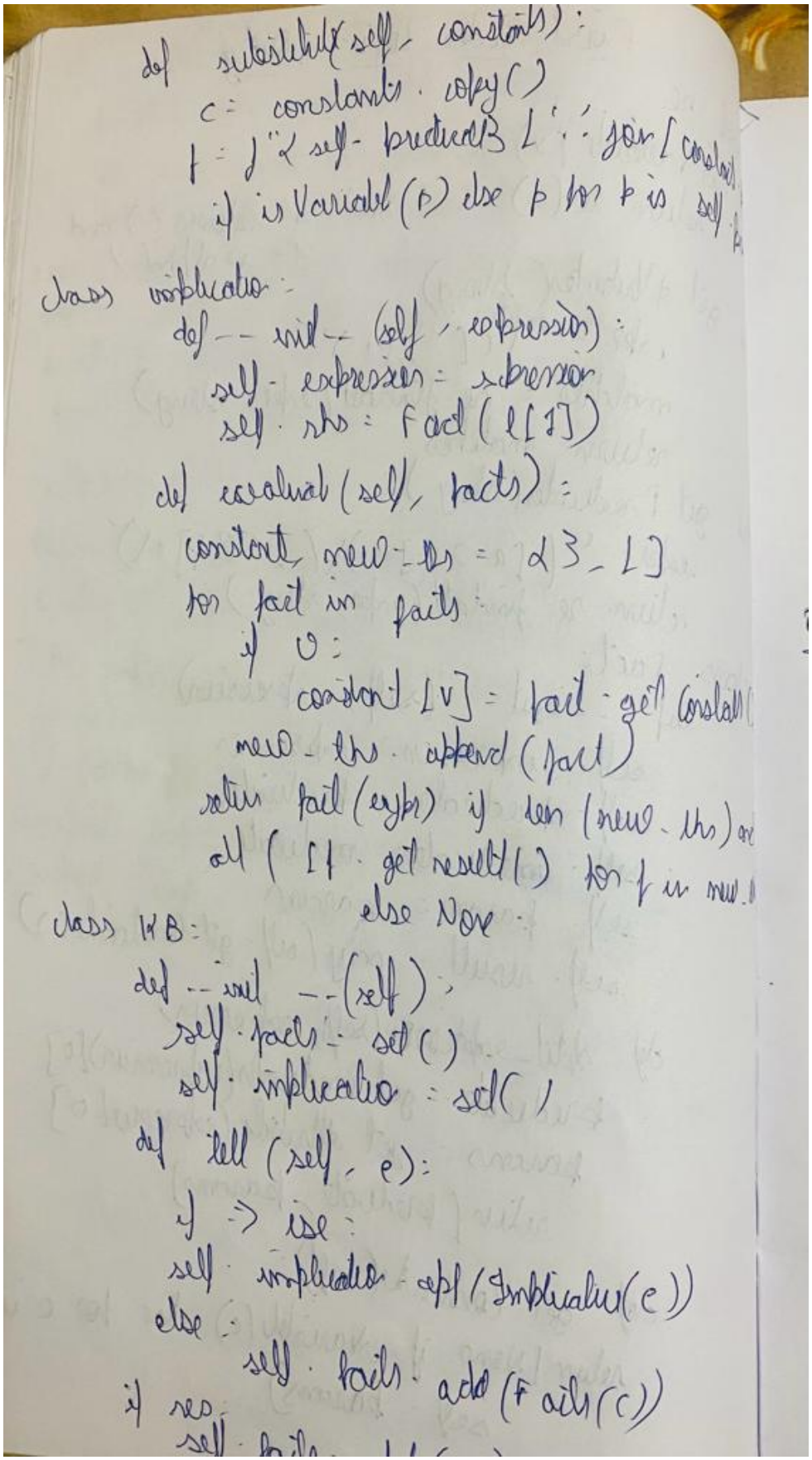
```
Enter FOL:
∀x food(x) => likes(John, x)
The CNF form of the given FOL is:
~ food(A) V likes(John, A)
```

```
main()
```

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

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.medicate = medicate
        self.param = param
        self.result = any(self.getConstants())
    def splitExpression(self, expression):
        predicate = getPredicates(expression)[0]
        params = getAttributes(expression)[0]
        return [predicate, params]
    def getConstants(self):
        return [None if isVariable(c) else for c in
                self.params)
```



```
def substitute(self, constants):
    c = constants.copy()
    f = f"{self.predicate}({','.join([constants[p] if is_variable(p) else p for p in self.
class Implication:
    def __init__(self, expression):
        self.expression = expression
        self.rhs = Fact(l[1])
    def evaluate(self, facts):
        constants, new_lhs = {}, []
        for fact in facts:
            if v:
                constants[v] = fact.get_constant(
            new_lhs.append(fact)
        return fact(expr) if len(new_lhs) == 0
        all([f.get_result() for f in new_l
                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))
    if 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.fact}")
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:

$p_1 = King(John)$

$p_1' = King(x)$

$p_2 = Greedy(y)$

$p_2' = Greedy(x)$

$p_3 = (x/John, y/John)$

$q = Evil(x)$

$\Rightarrow Evil(John)$

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("Ente
    r the
    number of
    FOL
    expressions
    present in
    KB:") n =
    int(input())
```

```
print("Ente
r 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)
```