VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
On

ARTIFICIAL INTELLIGENCE

Submitted by

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in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
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CERTIFICATE

This is to certify that the Lab work entitled **"ARTIFICIAL INTELLIGENCE"** carried out by **SAMRITH SANJOO.S(1BM21CS185)**, who is bonafide student of **B. M. S. College of Engineering**. It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2022-23. The Lab report has been approved as it satisfies the academic requirements in respect of Artificial Intelligence Lab - **(22CS5PCAIN)**work prescribed for the said degree.

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1.Implement Tic –Tac –Toe Game.

```
tic=[]
import random
def board(tic):
    for i in range(0,9,3):
        print("+"+"-"*29+"+")
        print("|"+" "*9+"|"+" "*9+"|"+" "*9+"|")
        print("|"+" "*3,tic[0+i]," "*3+"|"+" "*3,tic[1+i]," "*3+"|"+" "*3,tic[2+i]," "*3+"|")
        print("|"+" "*9+"|"+" "*9+"|"+" "*9+"|")
    print("+"+"-"*29+"+")



def update_comp():
    global tic,num
    for i in range(9):
        if tic[i]==i+1:
            num=i+1
            tic[num-1]='X'
            if winner(num-1)==False:
                #reverse the change
                tic[num-1]=num
            else:
                return
    for i in range(9):
        if tic[i]==i+1:
            num=i+1
            tic[num-1]='O'
            if winner(num-1)==True:
                tic[num-1]='X'
                return
```

```
            else:
                tic[num-1]=num
            num=random.randint(1,9)
    while num  not in tic:
        num=random.randint(1,9)
    else:
        tic[num-1]='X'



def update_user():
    global tic,num
    num=int(input("enter a number on the board :"))
    while num not in tic:
        num=int(input("enter a number on the board :"))
    else:
        tic[num-1]='O'

def winner(num):
    if tic[0]==tic[4] and tic[4]==tic[8] or tic[2]==tic[4] and tic[4]==tic[6]:
        return True
    if tic[num]==tic[num-3] and tic[num-3]==tic[num-6]:
        return True
    if tic[num//3*3]==tic[num//3*3+1] and tic[num//3*3+1]==tic[num//3*3+2]:
        return True
    return False



try:
    for i in range(1,10):
        tic.append(i)
```

```
    count=0
    #print(tic)
    board(tic)
    while count!=9:
        if count%2==0:
            print("computer's turn :")
            update_comp()
            board(tic)
            count+=1
        else:
            print("Your turn :")
            update_user()
            board(tic)
            count+=1
        if count>=5:
            if winner(num-1):
                print("winner is ",tic[num-1])
                break
            else:
                continue
except:
    print("\nerror\n")
```

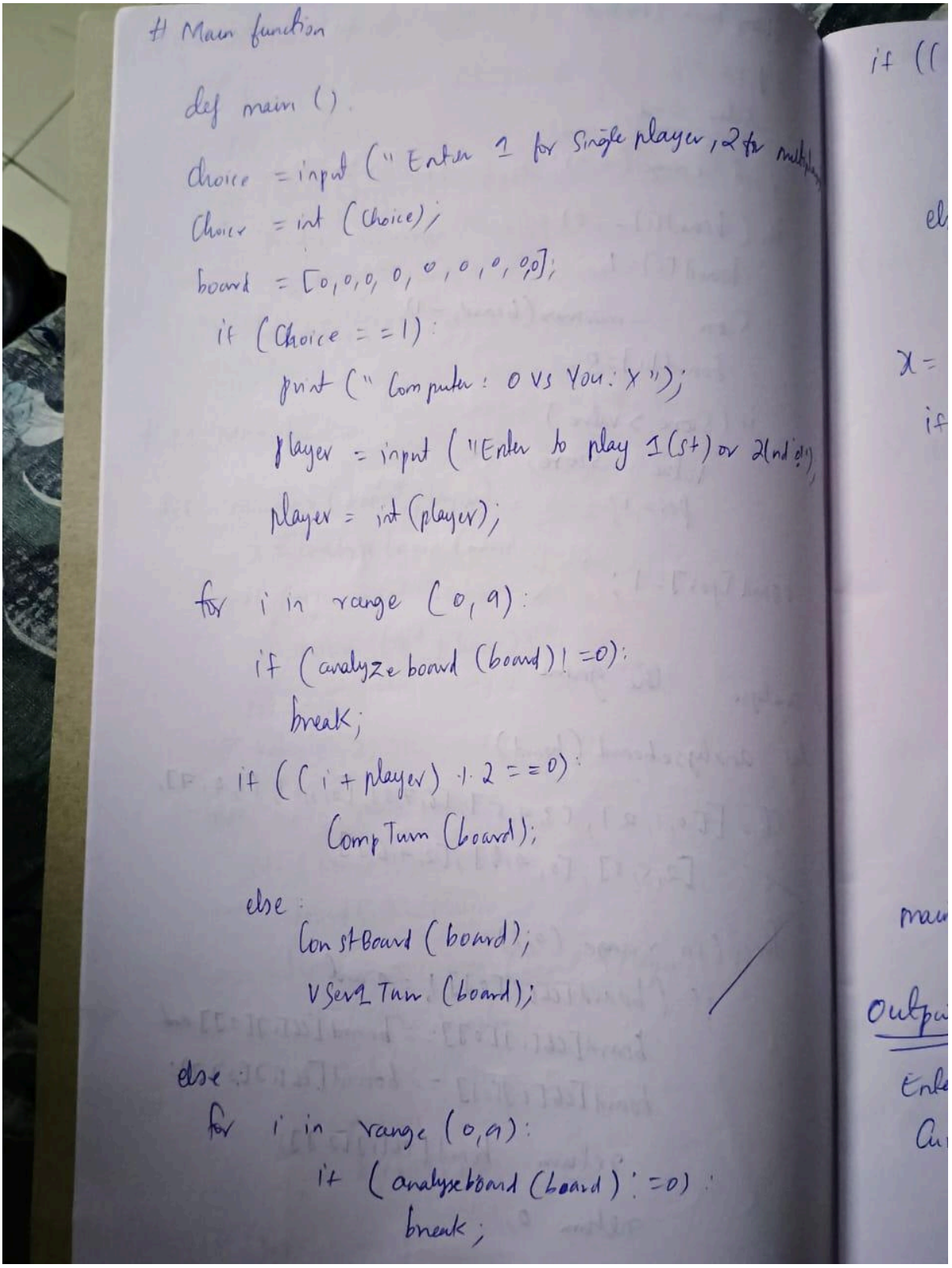
Screenshots:

2) Explore TICK TAC TOE using MinMAX

```
def ConstBoard (board):
    print ("Current State of Board : \n\n");
    for i in range (0,9):
        if ((i>0) and (i%3)==0):
            print("\n");
        if(board[i]==0):
            print(" -", end=" ");
        if(board[i]==1):
            print(" 0", end=" ");
        if(board[i]==-1):
            print(" X", end=" ");
    print("\n\n");

def User1Turn(board):
    pos=input("Enter X's position from [1...9]:");
    pos=int(pos);
    if(board[pos-1]!=0):
        print("Wrong Move !!!");
        exit(0);
    board[pos-1]=-1;
```

```
def User2Turn (board):
    pos = input("Enter O's position from [1..9]: ");
    pos = int(pos);
    if (board[pos-1] != 0):
        print("Wrong Move !!!");
        exit(0);
    board[pos-1] = 1;

# Min Max function

def minmax (board, player):
    x = analyze board (board);
    if (x != 0):
        return (x * player);
    pos = -1;
    value = -2;
    for i in range (0,9):
        if (board[i] == 0):
            board[i] = player;
            score = - minmax(board, (player * -1));
            if (score > value):
                value = score;
                pos = i;
                board[i] = 0;
```

```
def CompTurn (baard):
    pos = -1;
    Value = -2;
for i in range (0,9):
    if ( board[i] == 0)
        board [i] = 1;
        Score = - minmax (board, -1);
        board [i] = 0;
        if (Score > value ):
            value = Score;
            pos = i;

    board [pos] = 1;

# analyse the game
def analyseboard (board):
    cb = [[0,1,2], [3,4,5], [6,7,8], [0,3,6], [1,4,7],
          [2,5,8], [0,4,8], [2,4,6]];

    for i in range (0,8):
        if (board[cb[i][0]] != 0 and
            board[cb[i][0]] == board [cb[i][2]] and
            board[cb[i][0]] == board [cb[i][2]]):
            return board [cb[i][2]]
        return 0;
```



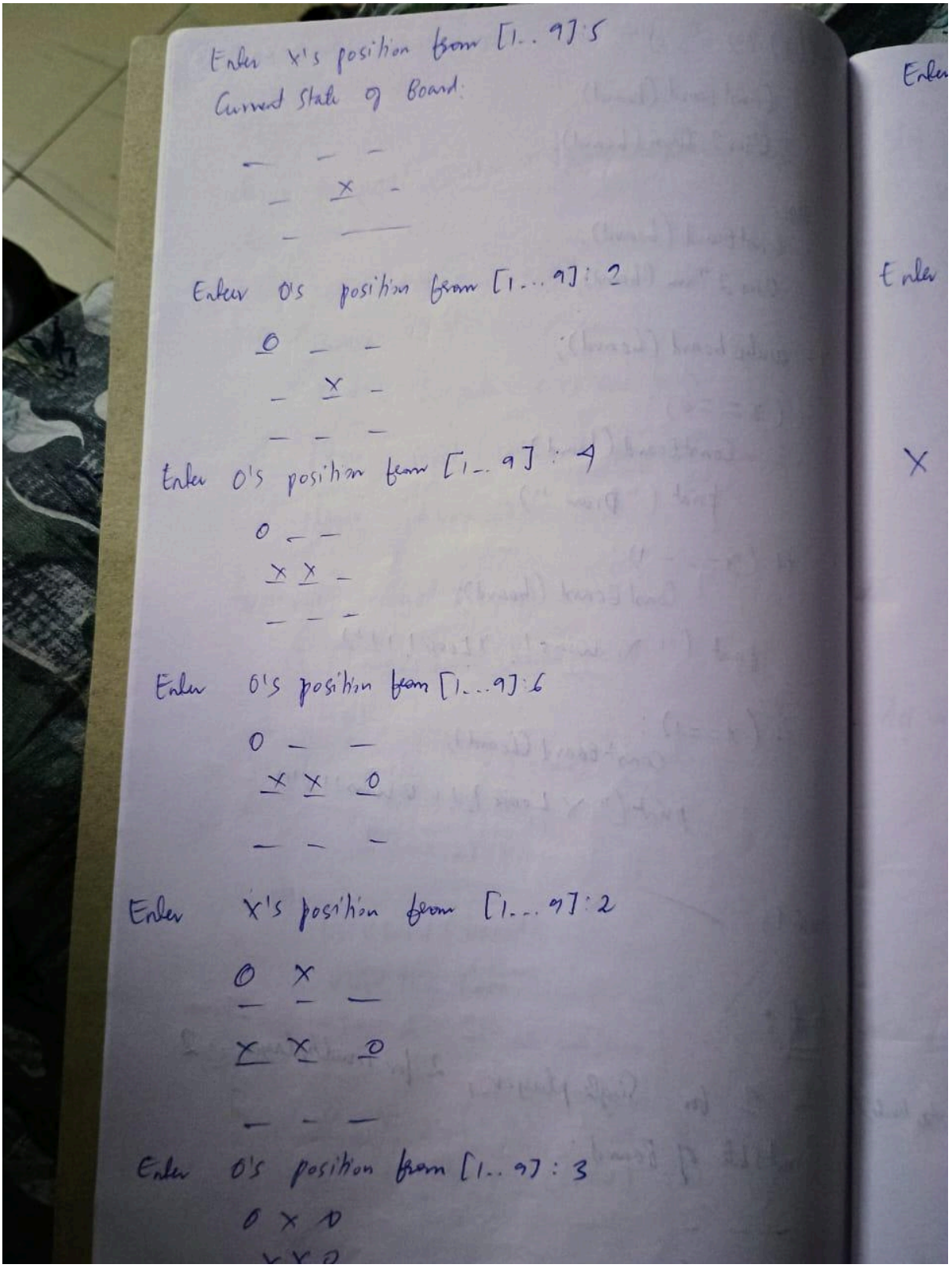
```
# Main function

def main():
    choice = input("Enter 1 for Single player, 2 for multi
    Choice = int(Choice);
    board = [0,0,0,0,0,0,0,0,0];
    if (Choice == 1):
        print("Computer: O vs You: X");
        player = input("Enter to play 1(st) or 2(nd)
        player = int(player);

    for i in range(0,9):
        if (analyze board(board)! =0):
            break;
        if ((i+player) % 2 == 0):
            CompTurn(board);

        else:
            ConstBoard(board);
            VSer2_Turn(board);

else:
    for i in range(0,9):
        if (analyseboard(board) == 0):
            break;
```

```
        ConstBoard(board);
        User1Turn(board);
    else
        ConstBoard(board);
        User2Turn(board);
x = analyzeboard(board);
if(x==0):
        ConstBoard(board);
        print("Draw")
if(x==-1):
        ConstBoard(board);
    print("X Wins!! Y Loose!!!")
if(x==1):
        ConstBoard(board);
        print("X Loose!!! O Wins!!!")

main()
```

Output:

Enter 1 for Single player, 2 for multiplayer : 2

Current state of Board:



Enter X's position from [1..9]: 5
Current State of Board:

_ _ _
_ X _
_ _ _

Enter O's position from [1...9]: 2

O _ _
_ X _
_ _ _

Enter O's position from [1..9]: 4

O _ _
X X _
_ _ _

Enter O's position from [1...9]: 6

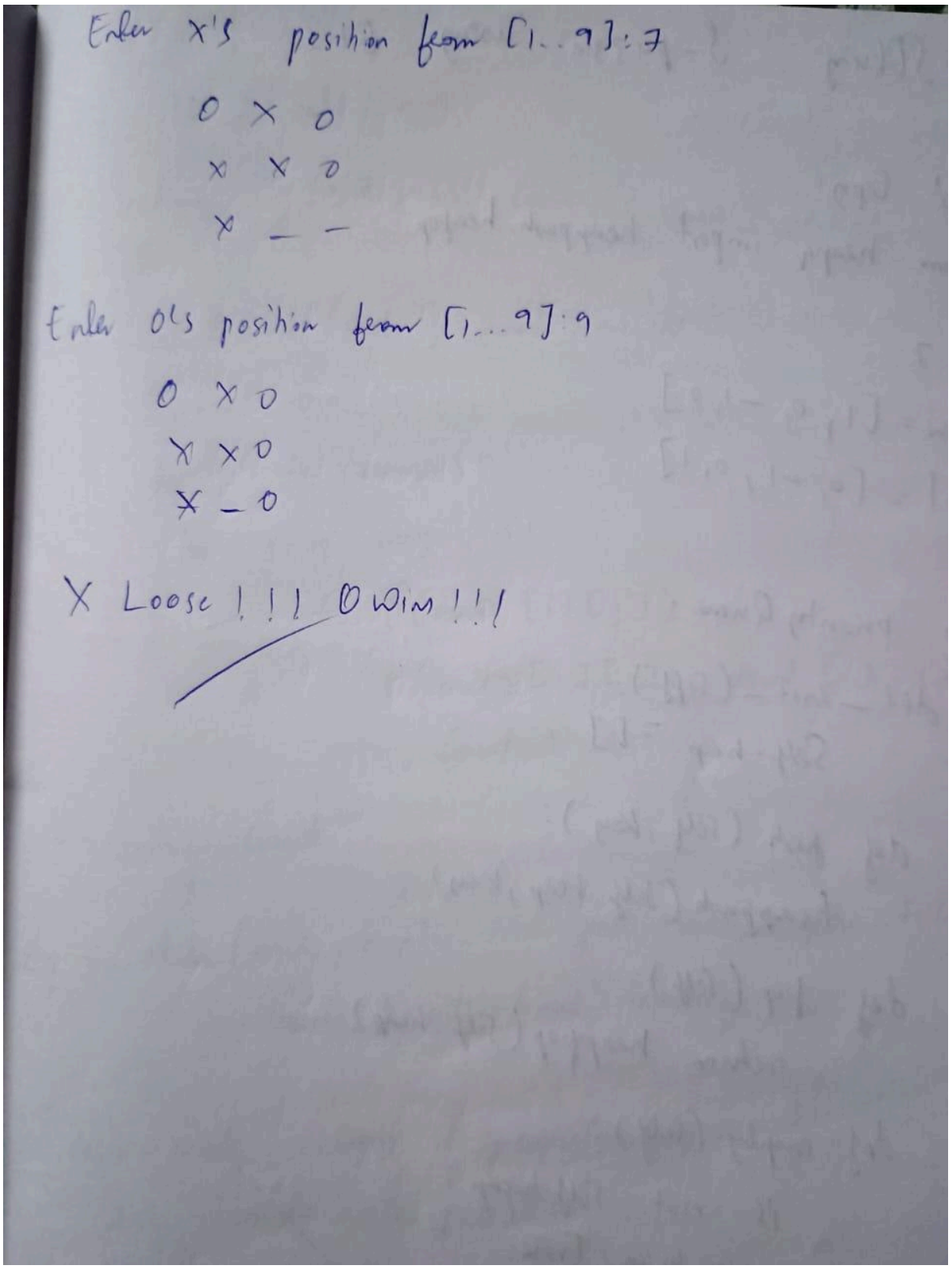
O _ _
X X O
_ _ _

Enter X's position from [1...9]: 2

O X _
_ _ _
X X O
_ _ _

Enter O's position from [1..9]: 3

O X O
X X O


Enter x's position from [1..9]: 7
O X O
X X O
X _ _
Enter O's position from [1...9]: 9
O X O
X X O
X _ O
X Loose !!! O Wins !!!

OUTPUT

```
[1, 2, 3, 4, 5, 6, 7, 8, 9]
+-------------------------------+
|         |         |         |
|    1    |    2    |    3    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    4    |    5    |    6    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-------------------------------+
computer's turn :
+-------------------------------+
|         |         |         |
|    1    |    X    |    3    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    4    |    5    |    6    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-------------------------------+
Your turn :
enter a number on the board :4
```

```
+-------------------------------+
Your turn :
enter a number on the board :4
+-------------------------------+
|         |         |         |
|    1    |    X    |    3    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    O    |    5    |    6    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-------------------------------+
computer's turn :
+-------------------------------+
|         |         |         |
|    X    |    X    |    3    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    O    |    5    |    6    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-------------------------------+
Your turn :
enter a number on the board :5
+-------------------------------+
```

```
+-----------------------------+
Your turn :
enter a number on the board :5
+-----------------------------+
|             |             |             |
|      X      |      X      |      3      |
|             |             |             |
+-----------------------------+
|             |             |             |
|      O      |      O      |      6      |
|             |             |             |
+-----------------------------+
|             |             |             |
|      7      |      8      |      9      |
|             |             |             |
+-----------------------------+
computer's turn :
+-----------------------------+
|             |             |             |
|      X      |      X      |      X      |
|             |             |             |
+-----------------------------+
|             |             |             |
|      O      |      O      |      6      |
|             |             |             |
+-----------------------------+
|             |             |             |
|      7      |      8      |      9      |
|             |             |             |
+-----------------------------+
winner is  X
```

2 .Solve 8 puzzle problems.

```
def bfs(src,target):
    queue=[]
    queue.append(src)
    exp=[]
    while len(queue)>0:
        source=queue.pop(0)
        #print("queue",queue)
        exp.append(source)

        print(source[0],'|',source[1],'|',source[2])
        print(source[3],'|',source[4],'|',source[5])
        print(source[6],'|',source[7],'|',source[8])
        print("-----------")
        if source==target:
            print("Success")
            return
        poss_moves_to_do=[]
        poss_moves_to_do=possible_moves(source,exp)
        #print("possible moves",poss_moves_to_do)
        for move in poss_moves_to_do:
            if move not in exp and move not in queue:
             #print("move",move)
             queue.append(move)

def possible_moves(state,visited_states):
    b=state.index(0)

    #direction array
```

```
    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-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


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

bfs(src,target)

OUTPUT

```
1 | 2 | 3
4 | 5 | 6
0 | 7 | 8
-----------
1 | 2 | 3
0 | 5 | 6
4 | 7 | 8
-----------
1 | 2 | 3
4 | 5 | 6
7 | 0 | 8
-----------
0 | 2 | 3
1 | 5 | 6
4 | 7 | 8
-----------
1 | 2 | 3
5 | 0 | 6
4 | 7 | 8
-----------
1 | 2 | 3
4 | 0 | 6
7 | 5 | 8
-----------
1 | 2 | 3
4 | 5 | 6
7 | 8 | 0
-----------
Success
```

3. Implement Iterative deepening search algorithm.

```
def id_dfs(puzzle, goal, get_moves):
    import itertools
#get_moves -> possible_moves
    def dfs(route, depth):
        if depth == 0:
            return
        if route[-1] == goal:
            return route
```

```
        for move in get_moves(route[-1]):
            if move not in route:
                next_route = dfs(route + [move], depth - 1)
                if next_route:
                    return next_route

    for depth in itertools.count():
        route = dfs([puzzle], depth)
        if route:
            return route



def possible_moves(state):
    b = state.index(0)  # ) indicates White space -> so b has index of it.
    d = []  # direction
    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 = []
    for i in d:
        pos_moves.append(generate(state, i, b))
    return pos_moves
```

```
def generate(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 - 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



# calling ID-DFS
initial = [1, 2, 3, 0, 4, 6, 7, 5, 8]
goal = [1, 2, 3, 4, 5, 6, 7, 8, 0]

route = id_dfs(initial, goal, possible_moves)

if route:
    print("Success!! It is possible to solve 8 Puzzle problem")
    print("Path:", route)
else:
    print("Failed to find a solution")
```

Screenshots:

1 Iterative deeping Search 18th

```
from collections import defaultdict

class Graph:
    def __init__(self):
        self.graph = defaultdict(list)

    def add_edge(self,u,v):
        self.graph[u].append(v)

    def iddfs(self, start, goal, max_depth):
        for depth in range(max_depth+1):
            visited = set()
        if self.dls(start, goal, depth, visited):
            return true
        return True
        return false.

def dls(self node, goal, depth, visited):
    if node == goal:
        return True
    if depth == 0:
        return false

    visited.add(node)
    for neighbour in self.graph[node]:
        if neighbour not in visited:
            if self.dls(neighbour, goal, depth-1, visited):
```

```
# input.
g = Graph()
g.add_edge (0,1)
g.add_edge (0, 2)
g.add_edge (1, 2)
g.add_edge (2,0)
g.add_edge (2, 3)
g.add_edge (3,3)
Start = 0
goal = 3
max_depth = 3
if g.iddfs (Start, goal, max_depth):
    print (" Path found ")
else.
print ("Path not found ")
```

Output: (Input is given in the Code.

Path Found.

OUTPUT

```
Harika N (1BM21CS071)
Success!! It is possible to solve 8 Puzzle problem
Path: [[1, 2, 3, 0, 4, 6, 7, 5, 8], [1, 2, 3, 4, 0, 6, 7, 5, 8], [1, 2, 3, 4, 5, 6, 7, 0, 8], [1, 2, 3, 4, 5, 6, 7, 8, 0]]
```

4. Implement A* search algorithm.

```
class Node:
    def __init__(self,data,level,fval):
        """ Initialize the node with the data, level of the node and the calculated fvalue """
        self.data = data
        self.level = level
        self.fval = fval

    def generate_child(self):
        """ Generate child nodes from the given node by moving the blank space
            either in the four directions {up,down,left,right} """
        x,y = self.find(self.data,'_')
        """ val_list contains position values for moving the blank space in either of
            the 4 directions [up,down,left,right] respectively. """
        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):
        """ Move the blank space in the given direction and if the position value are out
```

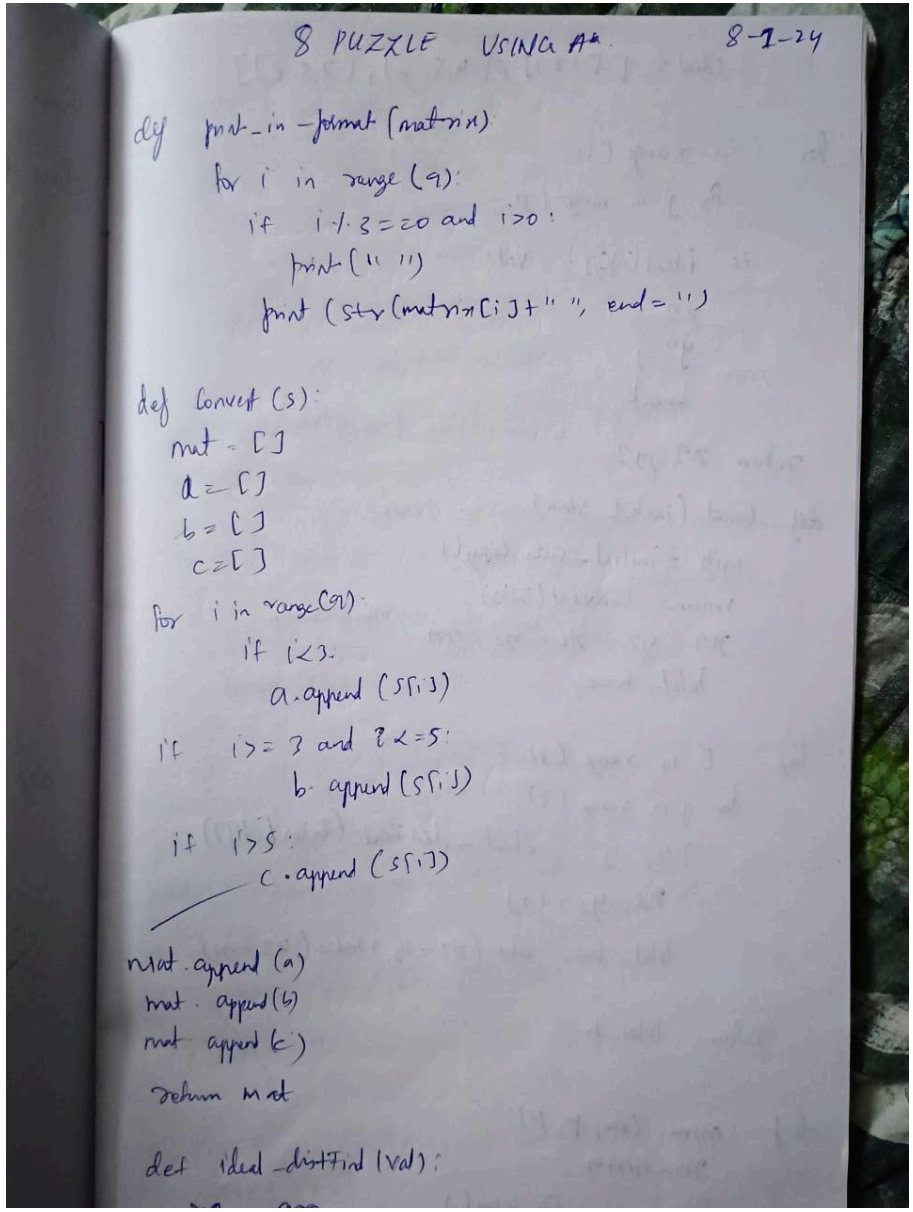
```
            of limits the return None """
        if x2 >= 0 and x2 < len(self.data) and y2 >= 0 and y2 < len(self.data):
            temp_puz = []
            temp_puz = self.copy(puz)
            temp = temp_puz[x2][y2]
            temp_puz[x2][y2] = temp_puz[x1][y1]
            temp_puz[x1][y1] = temp
            return temp_puz
        else:
            return None

def copy(self,root):
        """ Copy function to create a similar matrix of the given node"""
        temp = []
        for i in root:
            t = []
            for j in i:
                t.append(j)
            temp.append(t)
        return temp

    def find(self,puz,x):
        """ Specifically used to find the position of the blank space """
        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):
        """ Initialize the puzzle size by the specified size,open and closed lists to empty """
        self.n = size
        self.open = []
        self.closed = []

    def accept(self):
        """ Accepts the puzzle from the user """
        puz = []
        for i in range(0,self.n):
            temp = input().split(" ")
            puz.append(temp)
        return puz

def f(self,start,goal):
        """ Heuristic Function to calculate hueristic value f(x) = h(x) + g(x) """
        return self.h(start.data,goal)+start.level

    def h(self,start,goal):
        """ Calculates the different between the given puzzles """
        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):
        """ Accept Start and Goal Puzzle state"""
```

```
        print("Enter the start state matrix \n")
        start = self.accept()
        print("Enter the goal state matrix \n")
        goal = self.accept()

        start = Node(start,0,0)
        start.fval = self.f(start,goal)
        """ Put the start node in the open list"""
        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 the difference between current and goal node is 0 we have reached the goal node"""
            if(self.h(cur.data,goal) == 0):
                break
            for i in cur.generate_child():
                i.fval = self.f(i,goal)
                self.open.append(i)
            self.closed.append(cur)
            del self.open[0]

            """ sort the opne list based on f value """
```

```
        self.open.sort(key = lambda x:x.fval,reverse=False)


puz = Puzzle(3)
puz.processs
```

Screenshots:



8 PUZZLE USING A*. 8-1-24

```
def print_in_format(matrix):
    for i in range(9):
        if i%3==0 and i>0:
            print("")
        print(str(matrix[i])+" ", end="")

def convert(s):
    mat = []
    a=[]
    b=[]
    c=[]
    for i in range(9):
        if i<3:
            a.append(s[i])
        if i>=3 and i<=5:
            b.append(s[i])
        if i>5:
            c.append(s[i])
    mat.append(a)
    mat.append(b)
    mat.append(c)
    return mat

def ideal_distFind(val):
```

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

for i in range(3):
    for j in range(3):
        if ideal[i][j] == val:
            x1 = i
            y1 = j
            break
return x1, y1

def count(initial_state):
    init = initial_state.copy()
    inian = convert(init)
    x1 = y1 = x2 = y2 = 999
    total_h = 0;

for i in range(3):
    for j in range(3):
        x1, y1 = ideal_dist_find(inian[i][j])
        x2, y2 = i, j
        total_h += abs(x2 - x1) + abs(y2 - y1)

return total_h

def move(a, b, h):
    n = 9999
```

```
for i in range (len(av)):
    dupl_st = st.copy()
    tmp = dup2_st[i]
    dup_st[av[i]]=tmp

trh = count (dupl_st)
    if trh < rh:
        rh = trh
        store_st = dupl_st.copy()

return store_st, rh

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

h = count (State)
Level = 1.

print("\n--- Level "+str(Level)+" ---")
print_in format (State)
print ("\n Heuristic value (Manhattan Distance): "+str(h))

while (h>0):
    pos = int (State.index(0))

Level += 1

if pos=0:
```

Level 3

1 0 3
4 0 5
7 8 6

Heuristic value : 4

Level 4

1 2 3
4 5 0
7 8 6

Heuristic value : 2

1 2 3
4 5 6
7 8 0

Heuristic value : 0.

8/1/2024

OUTPUT

```
Enter the start state matrix

1 2 3
4 5 6
_ 7 8
Enter the goal state matrix

1 2 3
4 5 6
7 8 _




  |
  |
 \'/

1 2 3
4 5 6
_ 7 8

  |
  |
 \'/

1 2 3
4 5 6
7 _ 8

  |


   _

   |
   |
  \'/

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

5. Implement vaccum cleaner agent.

```
def vacuum_world():
    # 0 indicates Clean and 1 indicates Dirty
    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")

    if location_input == 'A':
        # Location A is Dirty.
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            # suck the dirt  and mark it as clean
            cost += 1                    #cost for suck
            print("Cost for CLEANING A " + str(cost))
            print("Location A has been Cleaned.")

            if status_input_complement == '1':
                # if B is Dirty
                print("Location B is Dirty.")
                print("Moving right to the Location B. ")
                cost += 1                    #cost for moving right
                print("COST for moving RIGHT" + str(cost))
                # suck the dirt and mark it as clean
                cost += 1                    #cost for suck
                print("COST for SUCK " + str(cost))
                print("Location B has been Cleaned. ")
            else:
```

```
            print("No action" + str(cost))
            # suck and mark clean
            print("Location B is already clean.")
        if status_input == '0':
        print("Location A is already clean ")
        if status_input_complement == '1':# if B is Dirty
            print("Location B is Dirty.")
            print("Moving RIGHT to the Location B. ")
            cost += 1                    #cost for moving right
            print("COST for moving RIGHT " + str(cost))
            # suck the dirt and mark it as clean
            cost += 1                    #cost for suck
            print("Cost for SUCK" + str(cost))
            print("Location B has been Cleaned. ")
        else:
            print("No action " + str(cost))
            print(cost)
            # suck and mark clean
            print("Location B is already clean.")

else:
    print("Vacuum is placed in location B")
    # Location B is Dirty.
    if status_input == '1':
        print("Location B is Dirty.")
        # suck the dirt  and mark it as clean
        cost += 1  # cost for suck
        print("COST for CLEANING " + str(cost))
        print("Location B has been Cleaned.")
```

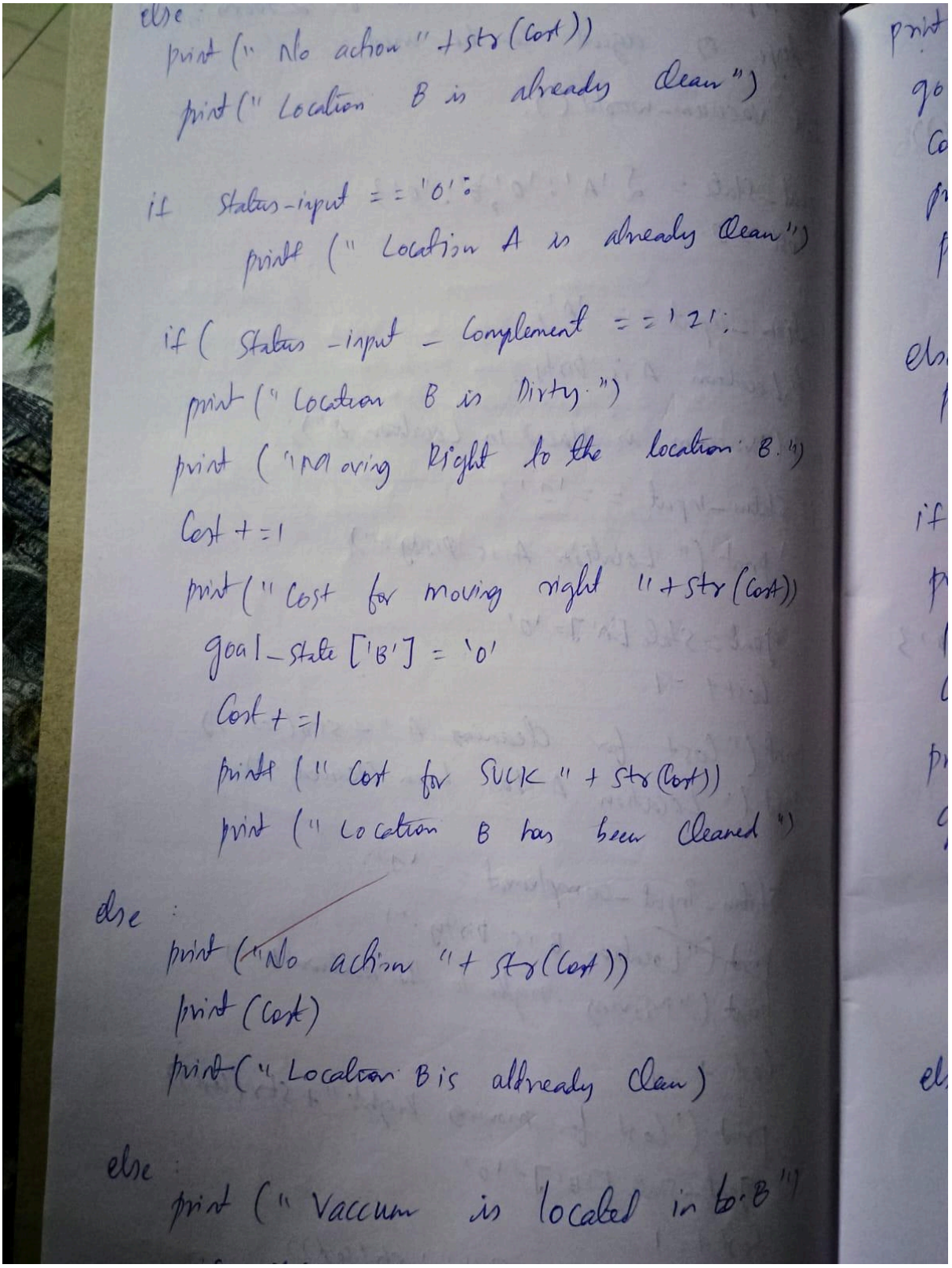
```
    if status_input_complement == '1':
        # if A is Dirty
        print("Location A is Dirty.")
        print("Moving LEFT to the Location A. ")
        cost += 1  # cost for moving right
        print("COST for moving LEFT" + str(cost))
        # suck the dirt and mark it as clean
        cost += 1  # cost for suck
        print("COST for SUCK " + str(cost))
        print("Location A has been Cleaned.")

else:
    print(cost)
    # suck and mark clean
    print("Location B is already clean.")

    if status_input_complement == '1':  # if A is Dirty
        print("Location A is Dirty.")
        print("Moving LEFT to the Location A. ")
        cost += 1  # cost for moving right
        print("COST for moving LEFT " + str(cost))
        # suck the dirt and mark it as clean
        cost += 1  # cost for suck
        print("Cost for SUCK " + str(cost))
        print("Location A has been Cleaned. ")
    else:
        print("No action " + str(cost))
        # suck and mark clean
        print("Location A is already clean.")
```

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

print("0 indicates clean and 1 indicates dirty")
vacuum_world()
```

Screenshots:

Q) Implement Vaccum Cleaner for 2 rooms, any type of agent can be used.

```
def vacuum-world():

goal_State = {'A':'0','B':'0'}
 Cost = 0.

location_input == 'A';
 # Location A is Dirty.
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 the location B.")
   Cost + =1
   print ("Cost for moving Right " + str(cost))
    goal_State['B'] = '0'
   Cost += 1
   print (" cost for SUCK " + str(cost))
```



```
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 == '2':
    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 allready clean")

else:
    print ("Vaccum is located in B")
```

```
print ("Location B is Dirty.")
goal_State['B'] = '0'
Cost += 1
print ("Cost of Cleaning " + str(Cost))
print ("Location B has been Cleaned")

else:
print(Cost)
print ("Location B is already ")

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))

Vaccum_world()
```

Output :

Enter Location of Vaccum : A
Enter Status of A : 1
Enter the Status of other Room : 1
Initial Location Condition {'A' : '0', 'B' : '0'}
Vacuum is placed in location A
Location A is Dirty
Cost for Cleaning A : 1
Location A has been Cleaned
Location B is Dirty
Moving Right to Location B.
Cost for moving Right : 2
Cost for Suck : 3
20/4/23
Location B has been cleaned.
Goal_State :

2)

def

def

OUTPUT:

```
0 indicates clean and 1 indicates dirty
Enter Location of Vacuumb
Enter status of b1
Enter status of other room1
Vacuum is placed in location B
Location B is Dirty.
COST for CLEANING 1
Location B has been Cleaned.
Location A is Dirty.
Moving LEFT to the Location A.
COST for moving LEFT2
COST for SUCK 3
Location A has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 3
```

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

```
from sympy import symbols, And, Not, Implies, satisfiable


def create_knowledge_base():
    # Define propositional symbols
    p = symbols('p')
    q = symbols('q')
    r = symbols('r')

    # Define knowledge base using logical statements
    knowledge_base = And(
        Implies(p, q),       # If p then q
        Implies(q, r),       # If q then r
        Not(r)               # Not r
    )

    return knowledge_base
```

```
def query_entails(knowledge_base, query):
    # Check if the knowledge base entails the query
    entailment = satisfiable(And(knowledge_base, Not(query)))

    # If there is no satisfying assignment, then the query is entailed
    return not entailment

if __name__ == "__main__":
    # Create the knowledge base
    kb = create_knowledge_base()

    # Define a query
    query = symbols('p')

    # Check if the query entails the knowledge base
    result = query_entails(kb, query)

    # Display the results
    print("Knowledge Base:", kb)
    print("Query:", query)
    print("Query entails Knowledge Base:", result)
```

Screenshots:

Create a knowledge base using propotional logic and show that the fine query entails the knowledge base or not.

Algorithm:

function TI_ENTAILS ?(KB, α) return true or false

input: KB, the knowledge base
α, the query, a sentence

Symbols: a list of the proposition Symbols in KB and α

function TI_CHECK_ALL (KB, α, Symbol, model)
return false or true

if EMPTY ?(Symbols) then
if PL_TRUE ? (KB, model) then return PL_TRUE (α, model)
else return true
else do
P = First(Symbols)
γ = REST (Symbols)

return TI_CHECK_ACL (KB, α, rest, Extend α, true model) and

Knowledge Base (truth table):

KB: $(p \vee q) \wedge (p \wedge \sim r)$

p	q	r	$p \vee q$	$\neg r$	$p \wedge \neg r$	$(p \vee q) \wedge (p \wedge \neg r)$
T	T	T	T	F	F	F
T	T	F	T	T	T	T
T	F	T	T	F	F	F
T	F	F	T	T	T	T
F	T	T	T	F	F	F
F	T	F	T	T	F	F
F	F	T	F	F	F	F
F	F	F	F	T	F	F

The knowledge both query.

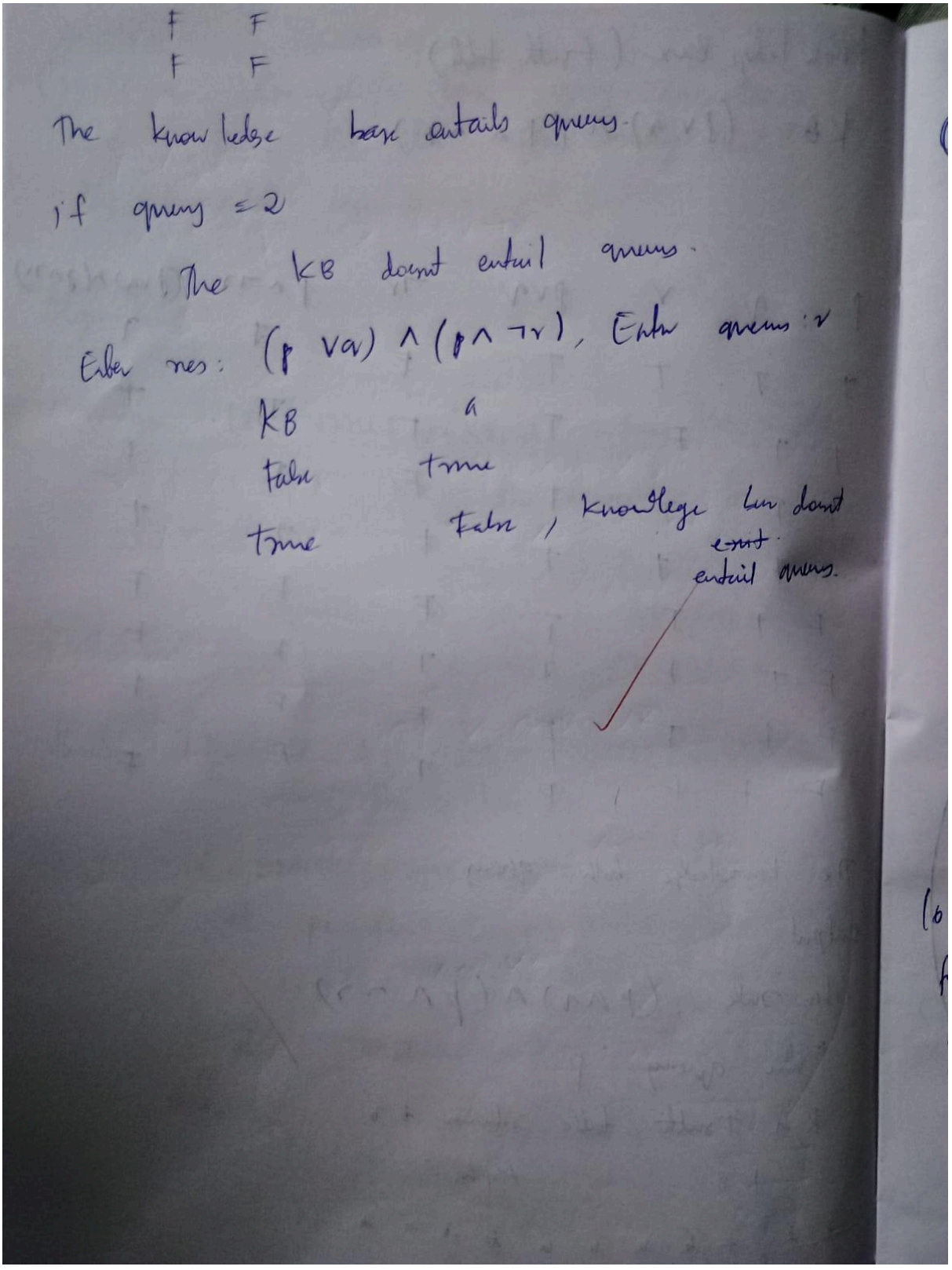
Output:

Enter rule $(p \wedge r) \wedge (p \wedge \sim r)$

Enter query: p

Truth table reference

KB	Alpha
False	True
True	T
F	T
T	T
F	F


F F
F F
The knowledge base entails query
if query = 2
The KB doesn't entail query.
Either res: (p ∨ q) ∧ (p ∧ ¬r), Enter query: r
KB q
False true
true False, knowledge can doesn't
entail query.

OUTPUT:

```
Knowledge Base: ~r & (Implies(p, q)) & (Implies(q, r))
Query: p
Query entails Knowledge Base: False
```

7. Create a knowledge base using prepositional logic and prove the given query using 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]}\t')
        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(rule):
    exp = '(~*[PQRS])'
```

```
    terms = re.findall(exp, rule)
    return terms

split_terms('~PvR')
```

Screenshots:

Create a knowledge base using propotional logic and show that the give query entails the knowledge base or not.

Algorithm:

function TI_ENTAILS ?(KB, α) return true or false

input: KB, the knowledge base
α, the query, a sentence

Symbols: a list of the proposition Symbols in KB and α

function TI_CHECK_ALL (KB, α, Symbol, model)
return false or true

if EMPTY ?(Symbols) then
if PL_TRUE ? (KB, model) then return PL_TRUE (α, model)
else return true
else do
P = First(Symbols)
γ = REST (Symbols)

return TI_CHECK_ACL (KB, α, rest, Extend α, true model) and

Knowledge Base (truth table):

KB: $(p \vee q) \wedge (p \wedge \sim r)$

p	q	r	$p \vee q$	$\neg r$	$p \wedge \neg r$	$(p \vee q) \wedge (p \wedge \neg r)$
T	T	T	T	F	F	F
T	T	F	T	T	T	T
T	F	T	T	F	F	F
T	F	F	T	T	T	T
F	T	T	T	F	F	F
F	T	F	T	T	F	F
F	F	T	F	F	F	F
F	F	F	F	T	F	F

The knowledge both query.

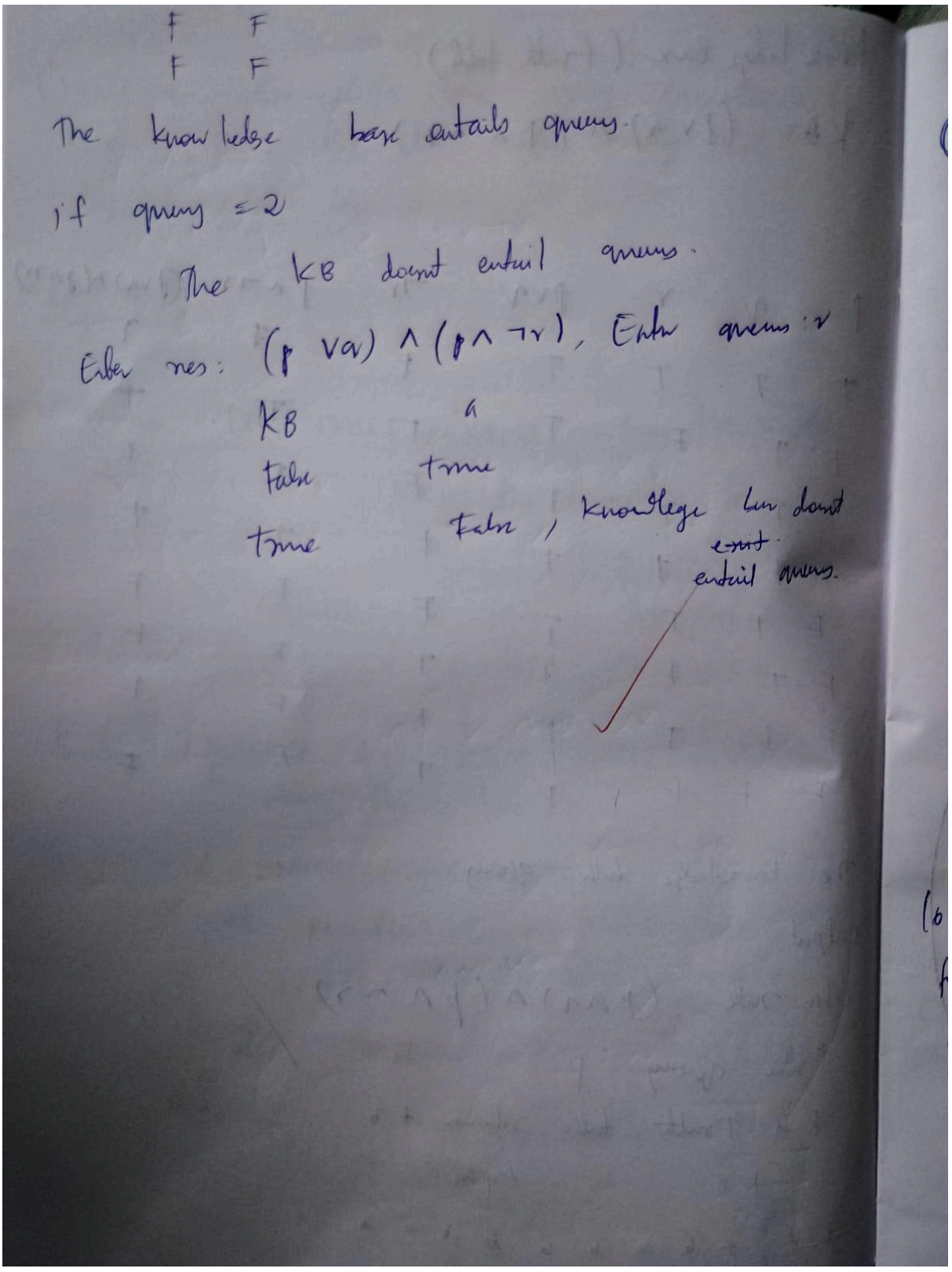
Output:

Enter rule $(p \wedge q) \wedge (p \wedge \sim r)$

Enter query: p

Truth table reference

KB	Alpha
False	True
True	T
F	T
T	T
F	F


F F
F F
The knowledge base entails query
if query = 2
The KB doesn't entail query.
Either res: (p ∨ q) ∧ (p ∧ ¬r), Enter query: r
KB q
False true
true False, knowledge can doesn't
entail query.

OUTPUT:

```
['~P', 'R']
```

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


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 terms1 if t != c]
                    t2 = [t for t in terms2 if t != negate(c)]
                    gen = t1 + t2
                    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 in turn null. \
                        \nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal} is true."
                        return steps
            elif len(gen) == 1:
                clauses += [f'{gen[0]}']
            else:
                if contradiction(goal,f'{terms1[0]}v{terms2[0]}'):
                    temp.append(f'{terms1[0]}v{terms2[0]}')
                    steps[''] = f'Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
                    \nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal} is true."
                    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 = 'Rv~P Rv~Q ~RvP ~RvQ' #(P^Q)<=>R : (Rv~P)v(Rv~Q)^(~RvP)^(~RvQ)
goal = 'R'
main(rules, goal)
```

Screenshots:

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

Algorithm

function PL-RESOLUTION (KB, α) return true or false

inputs: KB, the knowledge base, a sentence in propotional logic

α, the query sentence in propotional logic

Clauses, the set of CNF representation of KB $\wedge \neg \alpha$.

new $\leftarrow$ {}

loop do

for each pair of clause, C_i, C_j in clauses

resolve $\leftarrow$ PL. RESOLVE (C_i, C_j)

if resolve contains empty clause return true

new $\leftarrow$ new $\cup$ resolve

if new $\subseteq$ Clause then return false.

Clause $\leftarrow$ Clause $\cup$ new

KB Query

r ^

r ^ q → ^

S v t → q ⇒ KB v ¬α

(

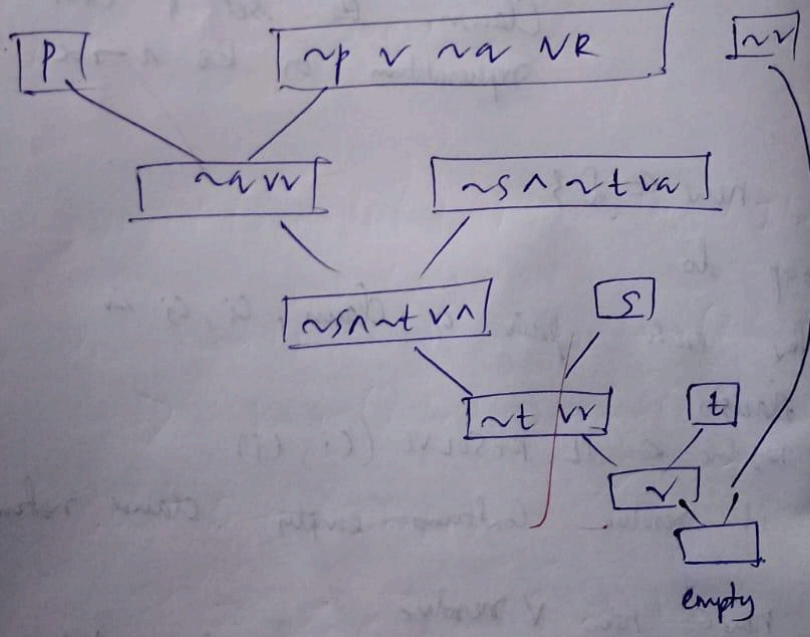
S

Convert to CNF

~(p ^ q) vr → ~p v ~q v r

~(S v t) v q → ~S ^ ~t vN

Resolution :



output : true

Implem

Step 1

Step 2

Step

Stp 4

```
Step    |Clause |Derivation
------------------------------
 1.     | Rv~P  | Given.
 2.     | Rv~Q  | Given.
 3.     | ~RvP  | Given.
 4.     | ~RvQ  | Given.
 5.     | ~R    | Negated conclusion.
 6.     |       | Resolved Rv~P and ~RvP to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.
```

rules = 'PvQ ~PvR ~QvR' #P=vQ, P=>Q : ~PvQ, Q=>R, ~QvR

goal = 'R'

main(rules, goal)

```
Step    |Clause |Derivation
------------------------------
 1.     | PvQ   | Given.
 2.     | ~PvR  | Given.
 3.     | ~QvR  | Given.
 4.     | ~R    | Negated conclusion.
 5.     | QvR   | Resolved from PvQ and ~PvR.
 6.     | PvR   | Resolved from PvQ and ~QvR.
 7.     | ~P    | Resolved from ~PvR and ~R.
 8.     | ~Q    | Resolved from ~QvR and ~R.
 9.     | Q     | Resolved from ~R and QvR.
 10.    | P     | Resolved from ~R and PvR.
 11.    | R     | Resolved from QvR and ~Q.
 12.    |       | Resolved R and ~R to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.
```

8. Implement unification in first order logic

```
import re


def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression[:-1]
```

```
    expression = re.split("(?

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)
    for index, val in enumerate(attributes):
        if val == old:
            attributes[index] = new
    predicate = getInitialPredicate(exp)
    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:
            return False

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

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

    if isVariable(exp1):
        if checkOccurs(exp1, exp2):
            return False
```

```
    else:
        return [(exp2, exp1)]

if isVariable(exp2):
    if checkOccurs(exp2, exp1):
        return False
    else:
        return [(exp1, exp2)]

if getInitialPredicate(exp1) != getInitialPredicate(exp2):
    print("Predicates do not match. Cannot be unified")
    return False

attributeCount1 = len(getAttributes(exp1))
attributeCount2 = len(getAttributes(exp2))
if attributeCount1 != attributeCount2:
    return False

head1 = getFirstPart(exp1)
head2 = getFirstPart(exp2)
initialSubstitution = unify(head1, head2)
if not initialSubstitution:
    return False
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 False

    initialSubstitution.extend(remainingSubstitution)
    return initialSubstitution



exp1 = "knows(X)"
exp2 = "knows(Richard)"
substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

Screenshots:

Implement unification in first order logic: 29/1/24

Step 1: If Ψ_1 and Ψ_2 is a variable or constant, then:

a) If Ψ_1 or Ψ_2 are identical, then return NIL.

b) Else if Ψ_1 is a variable,

a. then if Ψ_1 occurs in Ψ_2, then return FAILURE.

b. Else return $\{(\Psi_2 / \Psi_1)\}$

c) Else if Ψ_2 is a variable

a) If Ψ_2 occurs in Ψ_1 then return Failure,

b) Else return $\{(\Psi_1 / \Psi_2)\}$.

d) Else return FAILURE.

Step 2: If the initial predicate Symbol in Ψ_1 and Ψ_2 are not same, then return failure.

Step 3: If Ψ_1 and Ψ_2 have a different number of arguments, then return FAILURE

Step 4: Set Substitution Set (SUBST) to NIL.

Step 5: For i=1 to the number of elements in Ψ_1

a) Call unify function with ith element of Ψ_1 and Ψ_2, and put the result into S

b) If S = failure then return Failure

c) If S ≠ NIL then do

a) Apply S to the remainder of both L1 and L2.

b) SUBST = APPEND (S, SUBST)

Step 6: Return SUBST

Output : UNIFY (Knows (Richard, x), Knows (Richard, John))

Here Ψ_1 = Knows (Richard, x) and Ψ_2 = Knows (Richard, John)

S0 ⇒ { Knows (Richard, x); Knows (Richard, John)}

SUBST 0 = { John/x}

S1 ⇒ {Knows (Richard, John); Knows (Richard, John)

Successfully unified

Unifier : { John /x}.

OUTPUT

```
Substitutions:
[('X', 'Richard')]
```

```
exp1 = "knows(A,x)"
exp2 = "knows(y,mother(y))"
substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

```
Harika N (1BM21CS071)

Substitutions:
[('A', 'y'), ('mother(y)', 'x')]
```

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

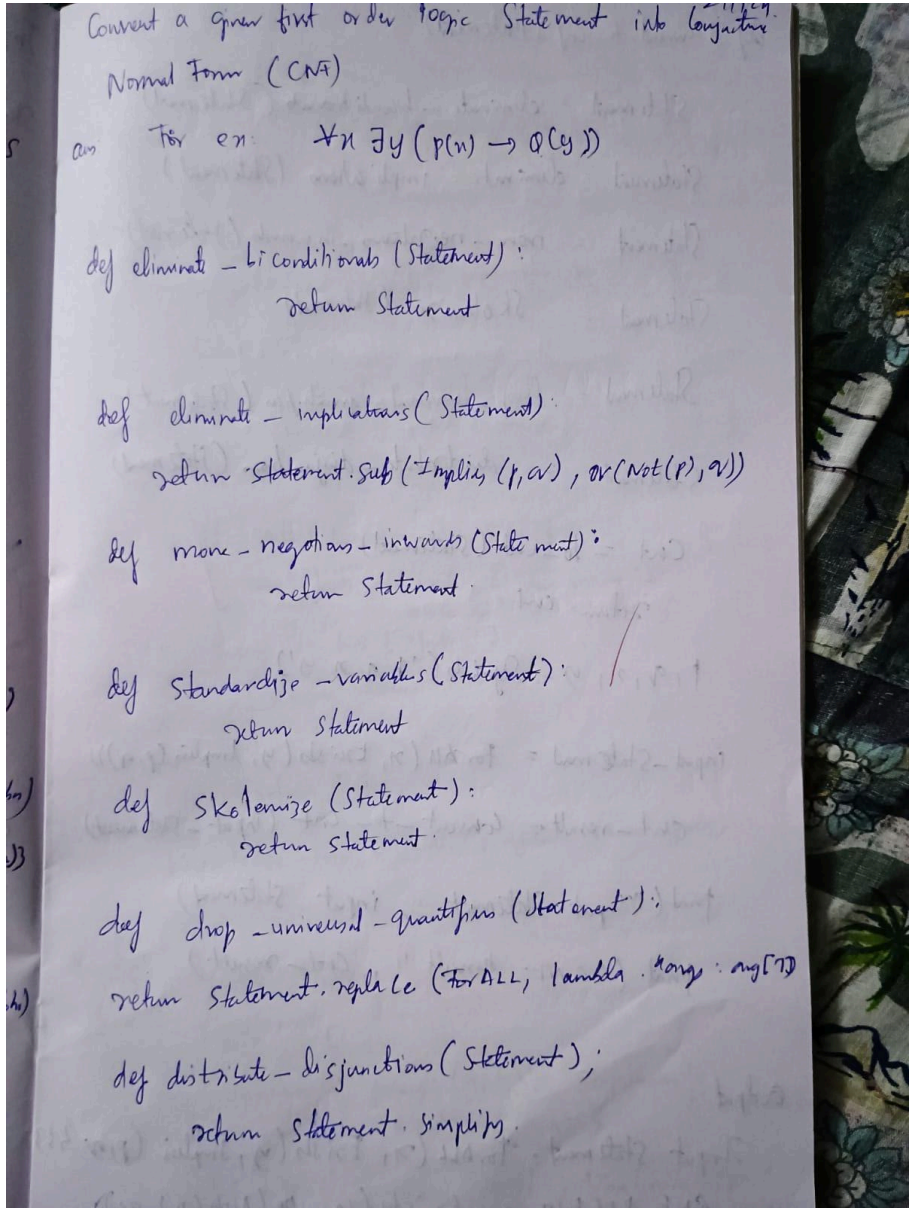
```
def getAttributes(string):
    expr = '
'
    matches = re.findall(expr, string)
    return [m for m in str(matches) if m.isalpha()]


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


def DeMorgan(sentence):
    string = ''.join(list(sentence).copy())
    string = string.replace('~~','')
    flag = '[' in string
    string = string.replace('~[','')
```

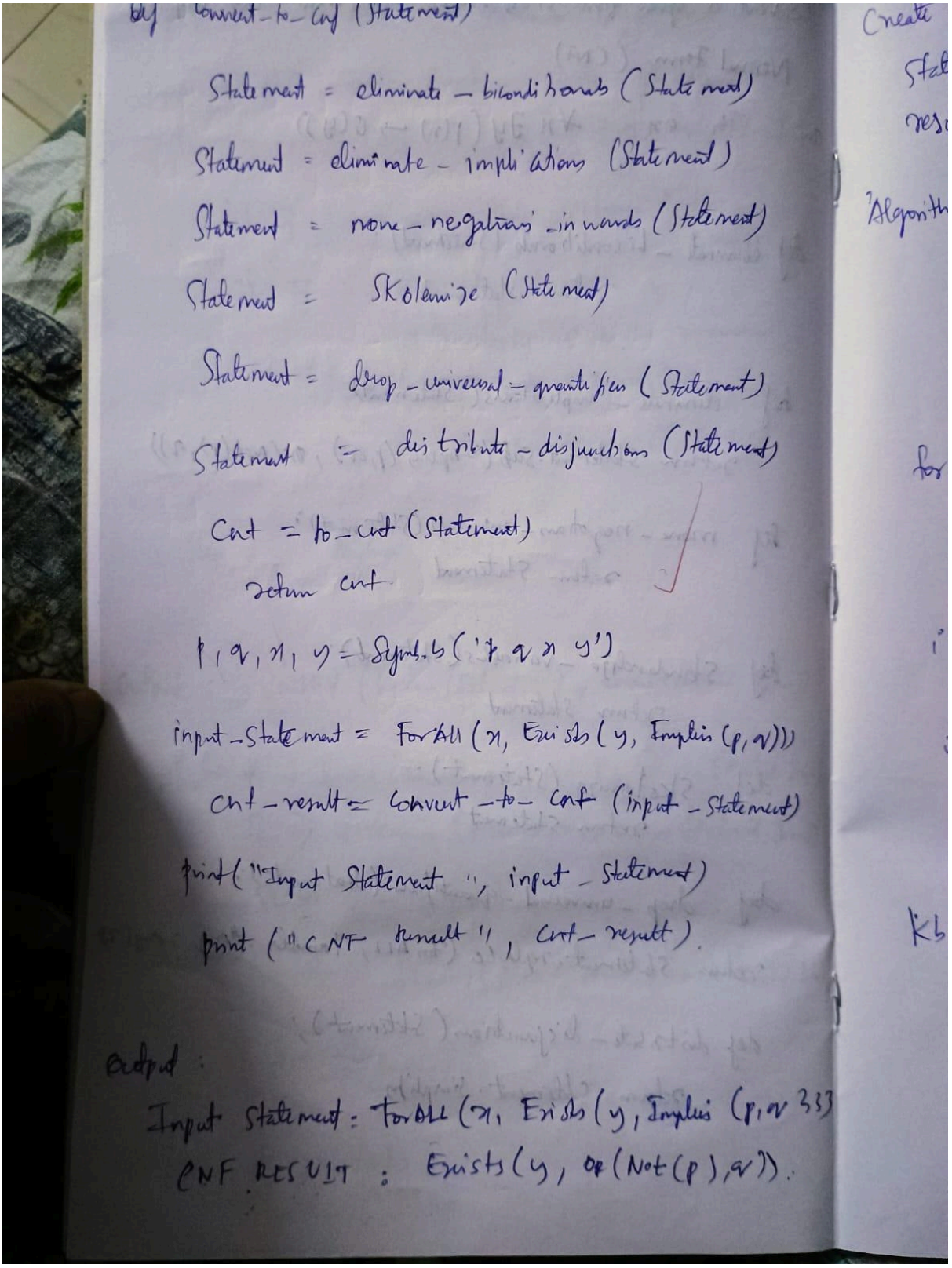
```
    string = string.strip(']')
    for predicate in getPredicates(string):
        string = string.replace(predicate, f'~{predicate}')
    s = list(string)
    for i, c in enumerate(string):
        if c == '|':
            s[i] = '&'
        elif c == '&':
            s[i] = '|'
    string = ''.join(s)
    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




import re

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] + '|' + 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 = '(~[∀|∃].)'
    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


print(Skolemization(fol_to_cnf("animal(y)<=>loves(x,y)")))
print(Skolemization(fol_to_cnf("∀x[∀y[animal(y)=>loves(x,y)]]=>[∃z[loves(z,x)]]")))
print(fol_to_cnf("[american(x)&weapon(y)&sells(x,y,z)&hostile(z)]=>criminal(x)"))
```

Screenshots:


Convert a given first order logic Statement into Conjunctive
Normal Form (CNF)
ex: For ex: ∀x ∃y (P(x) → Q(y))
def eliminate_biconditionals(Statement):
return Statement
def eliminate_implications(Statement):
return Statement.subs(Implies(P,Q), Or(Not(P),Q))
def move_negations_inwards(Statement):
return Statement
def Standardize_variables(Statement):
return Statement
def Skolemize(Statement):
return Statement
def drop_universal_quantifiers(Statement):
return Statement.replace(ForALL, lambda x: x[1])
def distribute_disjunctions(Statement):
return Statement.simplify



```
by  convert_to_cnf (Statement)

    Statement = eliminate_biconditionals (Statement)
    Statement = eliminate_implications (Statement)
    Statement = move_negations_inwards (Statement)
    Statement = Skolemize (Statement)
    Statement = drop_universal_quantifiers (Statement)
    Statement = distribute_disjunctions (Statement)
    Cnf = to_cnf (Statement)
    return cnf

P, Q, x, y = Symbols('P Q x y')

input_Statement = ForAll (x, Exists (y, Implies (P, Q)))
cnf_result = convert_to_cnf (input_Statement)

print("Input Statement :", input_Statement)
print ("CNF Result :", cnf_result)
```

Output :

Input Statement : ForALL (x, Exists (y, Implies (P, Q)))

CNF RESULT : Exists (y, Or (Not (P), Q)).

OUTPUT

```
[~animal(y)|loves(x,y)]&[~loves(x,y)|animal(y)]
[animal(G(x))&~loves(x,G(x))]|[loves(F(x),x)]
[~american(x)|~weapon(y)|~sells(x,y,z)|~hostile(z)]|criminal(x)
```

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

```
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 query(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}')


kb = KB()
kb.tell('missile(x)=>weapon(x)')
kb.tell('missile(M1)')
kb.tell('enemy(x,America)=>hostile(x)')
kb.tell('american(West)')
kb.tell('enemy(Nono,America)')
kb.tell('owns(Nono,M1)')
kb.tell('missile(x)&owns(Nono,x)=>sells(West,x,Nono)')
kb.tell('american(x)&weapon(y)&sells(x,y,z)&hostile(z)=>criminal(x)')
kb.query('criminal(x)')
kb.display()
```

Screenshots:

Create a Knowledge base Consisting of first order logic statement and prove the given query using forward reasoning algo.

Algorithm:

```
def forward_reasoning(query, KB):
    while True:
        new_facts = set()

    for rule in KB['rules']:
        if rule['Condition'] in KB['facts']:
            new_facts.add(rule['Conclusion'])

    if query in KB['facts']:
        return True.

    if not new_facts:
        return False

    Knowledge_base['facts'].update(new_facts)

kb = {
    'facts': set(),
    'rules': [
{'Condition': 'parent(a,b)' = 'Conclusion':
        grandparent(a,b)'},

{'Condition': father(x,y)', 'Conclusion': 'parent
                                    (x,y)'}
```

```
}
}

kb['facts'].add('father(a,b)')

kb['facts'].add('mother(b,c)')

query = 'grandparents(a,c)'

result = forward_reasoning(query, kb)

print("Is {query} true? {result}")
```

Output:

Is grandparent(a,c) true? True.

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OUTPUT

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