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
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Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled **"ARTIFICIAL INTELLIGENCE"** carried out by **JAGADEESH A LATTI (1BM21CS079)**, 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.

```
if(xstate[choice]!=1 and zstate[choice]!=1):
    zstate[choice]=1
    Count+=1
else:
    print("Already this space is occupied,
          Try again")
    continue
Cwin=Checkwin(xstate,zstate)

if((cwin!=-1):
    print("Match over")
    Printboard(xstate,z_state)
    over=False
    break
if((count==9"):
    print("Match over")
    print("No space left")
    over=False
    break
turn=1-turn
```

Algorithm:

1) sum(a,b,c):
   ↳ This function takes 3 inputs & returns their sum

2) printboard(xstate,zstate):
   i) It prints tic-tac-toe board based on current states of x & z.
   ii) It converts the state of each cell to 'x' if x has marked it, 'O' if z has marked

it or else cell number.

3) checkwin(xstate, zstate) {
   a) It checks who won the game.
   b) It checks all possible winning combinations.
   c) If X wins, it prints & returns 1
   d) if Z wins, it prints & returns 0
   e) if there is no winner, it returns -1.

4.
   a. The game runs in a loop until it is explicitly terminated.
   b) The game alternates turns between X & Z until there is a winner or a draw.
   c) Printboard function is called to print current state of board.
   d) The checkwin function is called after each move to check if there's winner.
   e) Game ends when there is a winner or all spaces are filled.

Output:
```
0 | 1 | 2
3 | 4 | 5
6 | 7 | 8

X's turn, Enter a number: 0
X | 1 | 2
3 | 4 | 5
6 | 7 | 8
```

```
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")
```

OUTPUT:

OUTPUT SCREENSHOT

```
[1, 2, 3, 4, 5, 6, 7, 8, 9]
+-----+-----+-----+
|  1  |  2  |  3  |
+-----+-----+-----+
|  4  |  5  |  6  |
+-----+-----+-----+
|  7  |  8  |  9  |
+-----+-----+-----+
Computer's turn:
+-----+-----+-----+
|  1  |  2  |  3  |
+-----+-----+-----+
|  4  |  X  |  6  |
+-----+-----+-----+
|  7  |  8  |  9  |
+-----+-----+-----+
```

```
Your turn:
Enter a number on the board: 3
+-----+-----+-----+
|  1  |  2  |  O  |
+-----+-----+-----+
|  4  |  X  |  6  |
+-----+-----+-----+
|  7  |  8  |  9  |
+-----+-----+-----+
Computer's turn:
+-----+-----+-----+
|  1  |  2  |  O  |
+-----+-----+-----+
|  X  |  X  |  6  |
+-----+-----+-----+
|  7  |  8  |  9  |
+-----+-----+-----+
```

```
Your turn:
Enter a number on the board: 6
+-----+-----+-----+
|  1  |  2  |  O  |
+-----+-----+-----+
|  X  |  X  |  O  |
+-----+-----+-----+
|  7  |  8  |  9  |
+-----+-----+-----+
Computer's turn:
+-----+-----+-----+
|  1  |  2  |  O  |
+-----+-----+-----+
|  X  |  X  |  O  |
+-----+-----+-----+
|  7  |  8  |  X  |
+-----+-----+-----+
```

```
Your turn:
Enter a number on the board: 1
+-------------------------------+
|       |       |       |
|   O   |   2   |   O   |
|       |       |       |
+-------------------------------+
|       |       |       |
|   X   |   X   |   O   |
|       |       |       |
+-------------------------------+
|       |       |       |
|   7   |   8   |   X   |
|       |       |       |
+-------------------------------+
Computer's turn:
+-------------------------------+
|       |       |       |
|   O   |   2   |   O   |
|       |       |       |
+-------------------------------+
|       |       |       |
|   X   |   X   |   O   |
|       |       |       |
+-------------------------------+
|       |       |       |
|   7   |   X   |   X   |
|       |       |       |
+-------------------------------+
```

```
Your turn:
Enter a number on the board: 2
+-------------------------------+
|       |       |       |
|   O   |   O   |   O   |
|       |       |       |
+-------------------------------+
|       |       |       |
|   X   |   X   |   O   |
|       |       |       |
+-------------------------------+
|       |       |       |
|   7   |   X   |   X   |
|       |       |       |
+-------------------------------+
Computer's turn:
+-------------------------------+
|       |       |       |
|   O   |   O   |   O   |
|       |       |       |
+-------------------------------+
|       |       |       |
|   X   |   X   |   O   |
|       |       |       |
+-------------------------------+
|       |       |       |
|   X   |   X   |   X   |
|       |       |       |
+-------------------------------+
Winner is X
```

2 .Solve 8 puzzle problems.

3. 8-puzzle:

Initialize the puzzle:

1) Create a Puzzle8 class with the initial state, goal state, & possible moves

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

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

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

2) Define methods to print the current state, check if the puzzle is solved, get the index of blank tile & apply move.

Print current state:

for i in range(0, 9, 3):

print(state[i : i + 3])

Check if Puzzle is solved:

state == self.goal

Get index of the blank tile (represented by '0')

Apply move function:

Implement a method to apply a move to the current state, swapping the blank tile with adjacent tile.

BFS Algorithm

Initialize visited set to keep track of puzzle state to avoid revisiting.
visited = set()

Create an empty queue. It stores tuples where each tuple consists of puzzle state & corresponding path taken to reach state.
queue = deque()
queue.put((self.initial_state, []))

Until queue is empty run the loop:
i) Deque a state & its path.
ii) Check if the state is the goal state.
if yes print solution path & break out of loop.

iii) if state is not visited
mark it as visited
iv) Get index of blank tile
v) Apply all moves & enqueue the resulting states & paths.

eg: ~~Initial State: [1, 2, 3, 4, 5, 6, 0, 7~~
Queue: [(new state 1, [move 1]), (new state 2, [move 2])]

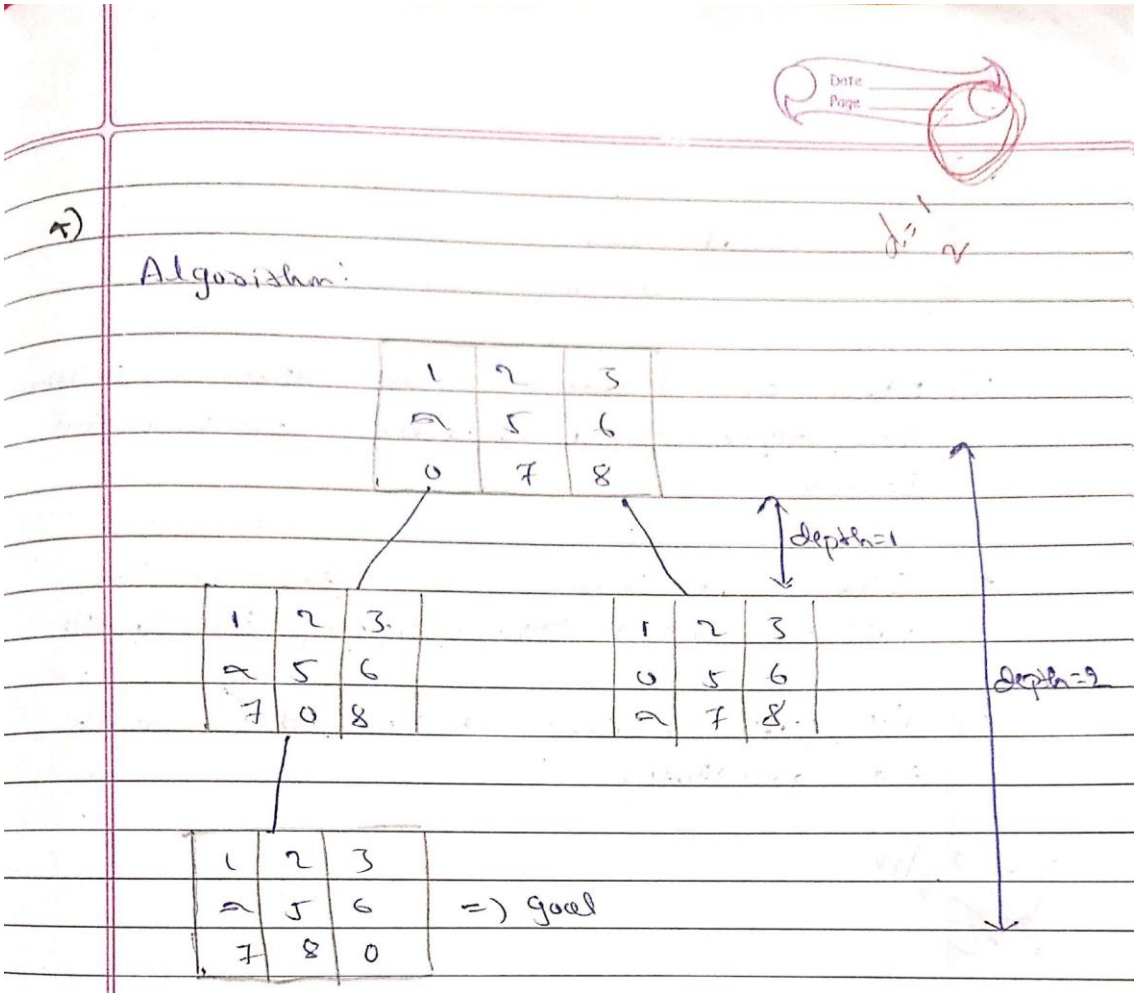
```
def bfs(src,target):
    queue=[]
    queue.append(src)
    exp=[]
    while len(queue)>0:
        source=queue.pop(0)
        #print("queue",queue)
        exp.append(source)

        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.



Algorithm:

1) Initialize the initial state = [ ] & goal state for the 8-puzzle.
goal state = [1, 2, 3, 4, 5, 7, 8, 0]

2) Set the depth=1 & expand the initial state
The depth-limited-search(depth) is performed
if node.state = goal
return node
else
for neighbour in get-neighbours(node.state)
child = puzzlenode(neighbour, node)
result = depth_limited-search(depth-1)

if result != Tuse:
return result

3) After one iteration where depth > 1, increase the depth by 1 & perform depth limited search.

4) Then get_neighbours will generate the possible moves by swapping the '0' tile

5) The path traversed is printed to reach the goal state.

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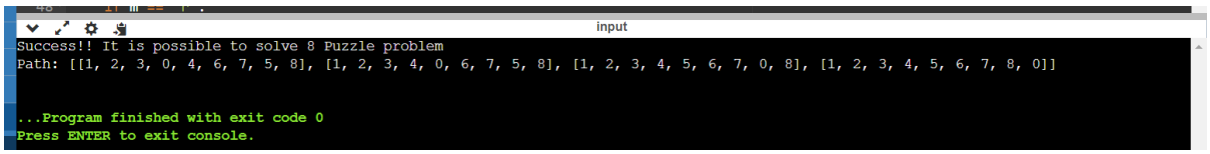
```
def id_dfs(puzzle, goal, get_moves):
    import itertools
#get_moves -> possible_moves
    def dfs(route, depth):
        if depth == 0:
            return
        if route[-1] == goal:
            return route
        for move in get_moves(route[-1]):
            if move not in route:
                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]:
```

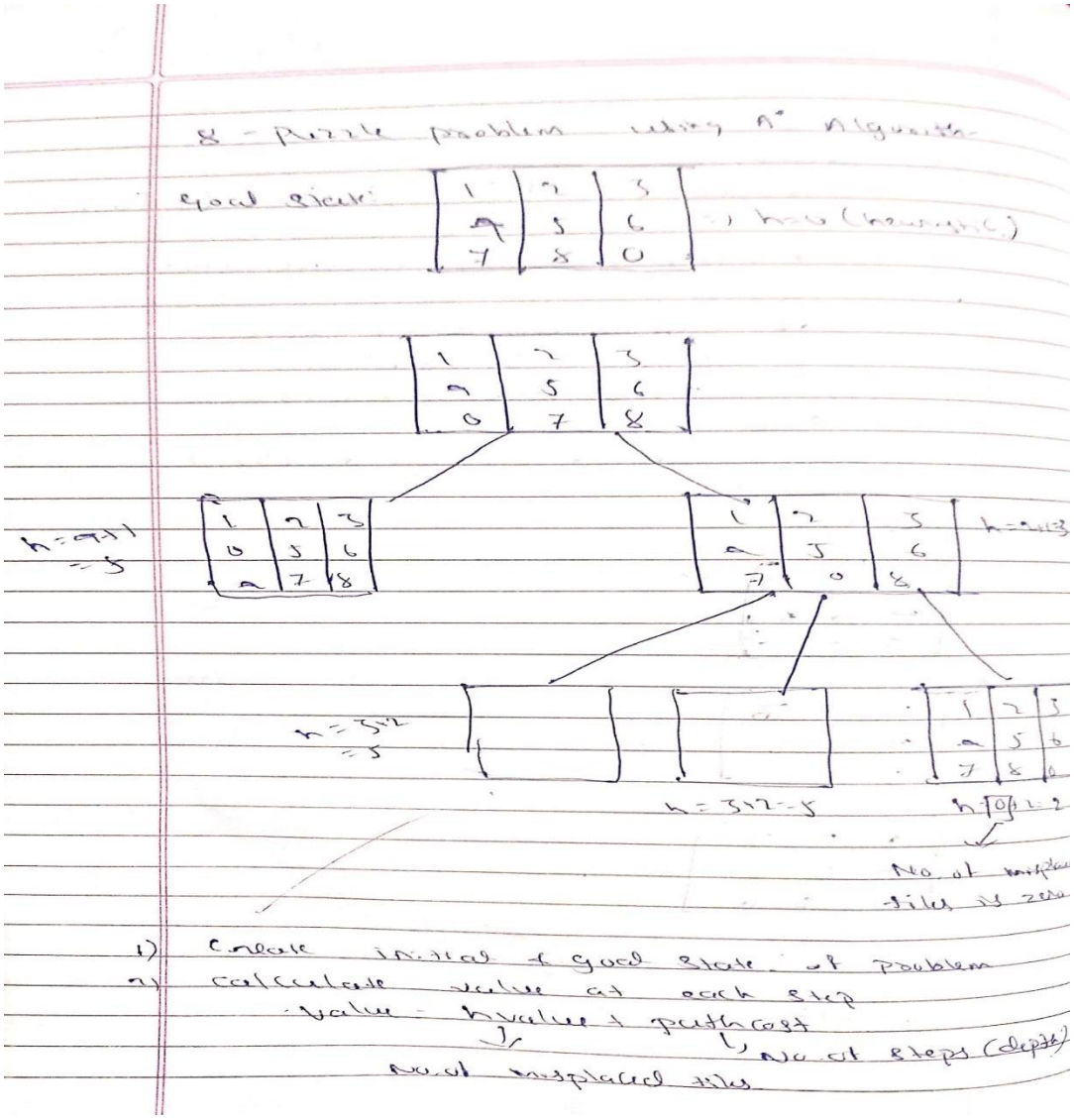
```
        d.append('r')

    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")
```

OUTPUT



4. Implement A* search algorithm.



3. Go to direction where h value is less.

4) All nodes stored in open list (keep track of all nodes).

5) Explored nodes stored in closed list.

6) Goal is when h value is 0, implies that we have reached final state.

```
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]
```

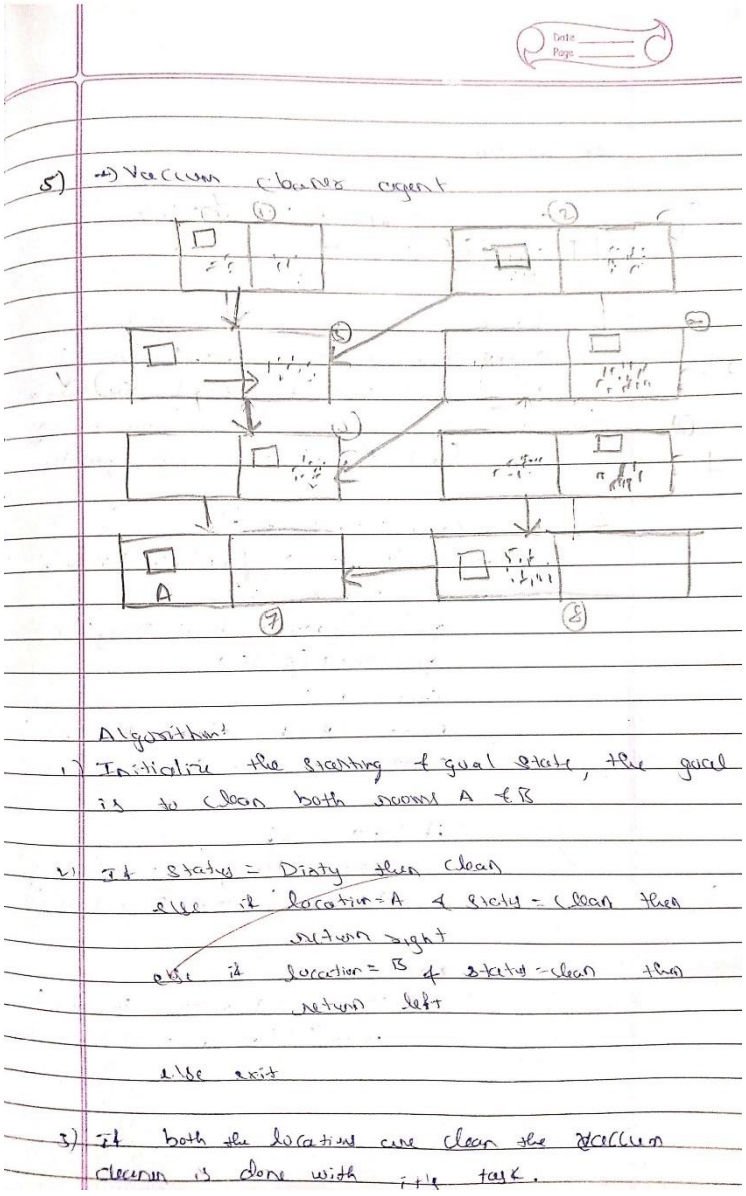
```
            temp_puz[x1][y1] = temp
            return temp_puz
        else:
            return None

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
OUTPUT
```

```
Success! 8 puzzle problem solved
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]]
```

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
```

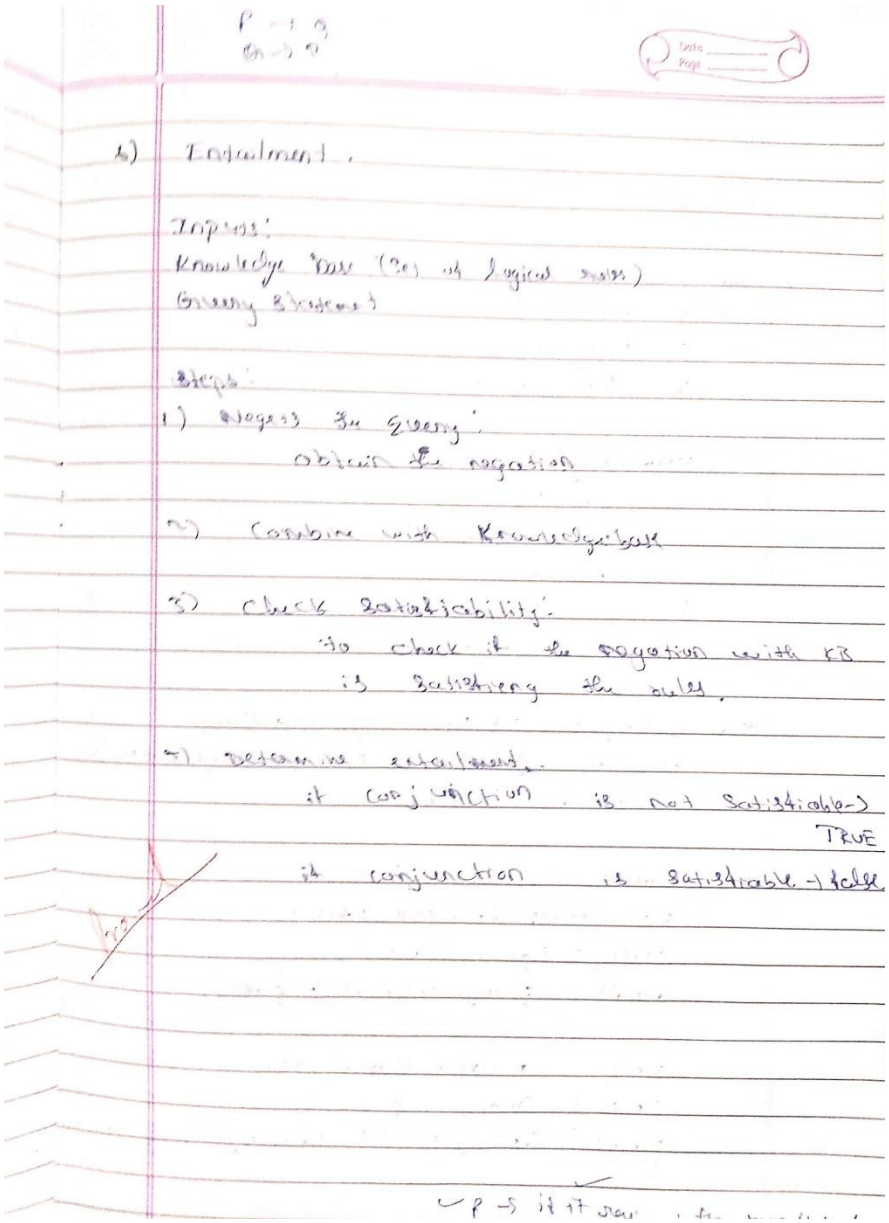
```
            print("Location A is Dirty.")
            print("Moving LEFT to the Location A. ")
            cost += 1  # cost for moving right
            print("COST for moving LEFT" + str(cost))
            # suck the dirt and mark it as clean
            cost += 1  # cost for suck
            print("COST 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()
```

OUTPUT:

```
Enter Location of Vacuumb
Enter status of b1
Enter status of other room1
Initial Location Condition{'A': '0', 'B': '0'}
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)
```

OUTPUT:

```
Enter the knowledge base: (p^q)v(~pvq)
Enter the query: pvq
[True, True, True] :kb= True :q= True
[True, True, False] :kb= True :q= True
[True, False, True] :kb= False :q= True
[True, False, False] :kb= False :q= True
[False, True, True] :kb= True :q= True
[False, True, False] :kb= True :q= True
[False, False, True] :kb= True :q= False
Doesn't entail!!
```

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

```
7)
def negate_literal(literal):
    if literal[0] == '~':
        return literal[1:]
    else:
        return '~' + literal

def resolve(C1, C2):
    resolved_clause = set(C1) | set(C2)

    for literal in C1:
        if negate_literal(literal) in C2:
            resolved_clause.remove(literal)
            resolved_clause.remove(negate_litera
            return tuple(resolved_clause)

def resolution(knowledge_base):

    while True:
        new_clauses = set()
        for i, C1 in enumerate(knowledge_base
            for j, C2 in enumerate(knowledge
                if i != j:
                    new_clause = resolve(C1, C2
```

```
        if len(new_clause)>0 & new_clause not
                                    knowledge_base
            new_clause.add(new_clause)

        if not new_clause
            break

    knowledge_base1 = new_clause
    return knowledge_base

if __name__ == "__main__":
    kb = set([('p','q'), ('~p','r'), ('~q','~r')])
    result = resolution(kb)
    print("original kb", kb)
    print("resolved KB", result)
```

Output:

Enter statement = Negation

The statement not entailed by knowledge-based

```
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')
```

OUTPUT:

```
Enter the clauses separated by a space: p v ~q ~r v p ~q
Enter the query: ~p
Trying to prove (p)^(v)^(~q)^(~r)^(v)^(p)^(~q)^(~p) by contradiction....
Knowledge Base entails the query, proved by resolution
```

```
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
```

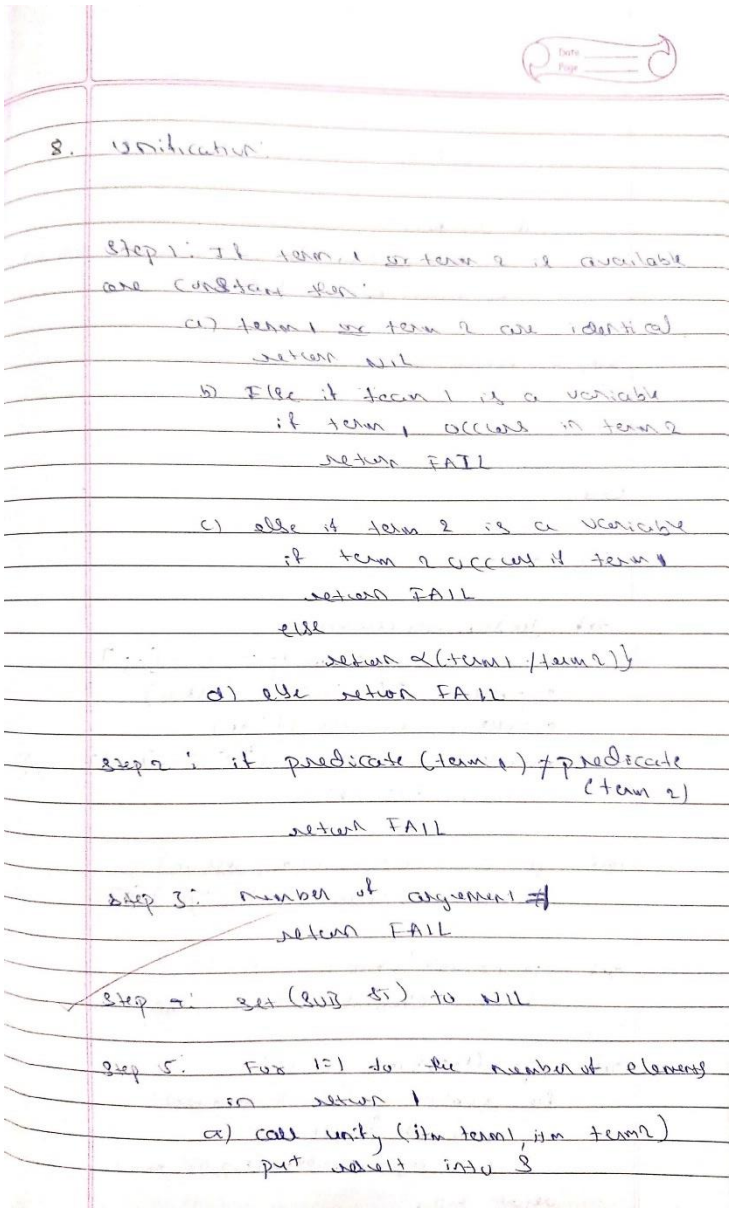
```
rules = 'Rv~P Rv~Q ~RvP ~RvQ' #(P^Q)<=>R : (Rv~P)v(Rv~Q)^(~RvP)^(~RvQ)
goal = 'R'
main(rules, goal)
```

```
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 :



8. Unification

Step 1: If term 1 or term 2 is variable one substitution for:

a) term 1 or term 2 are identical return NIL

b) Else if term 1 is a variable
if term 1 occurs in term 2
return FAIL

c) else if term 2 is a variable
if term 2 occurs in term 1
return FAIL
else
return {(term 1 / term 2)}

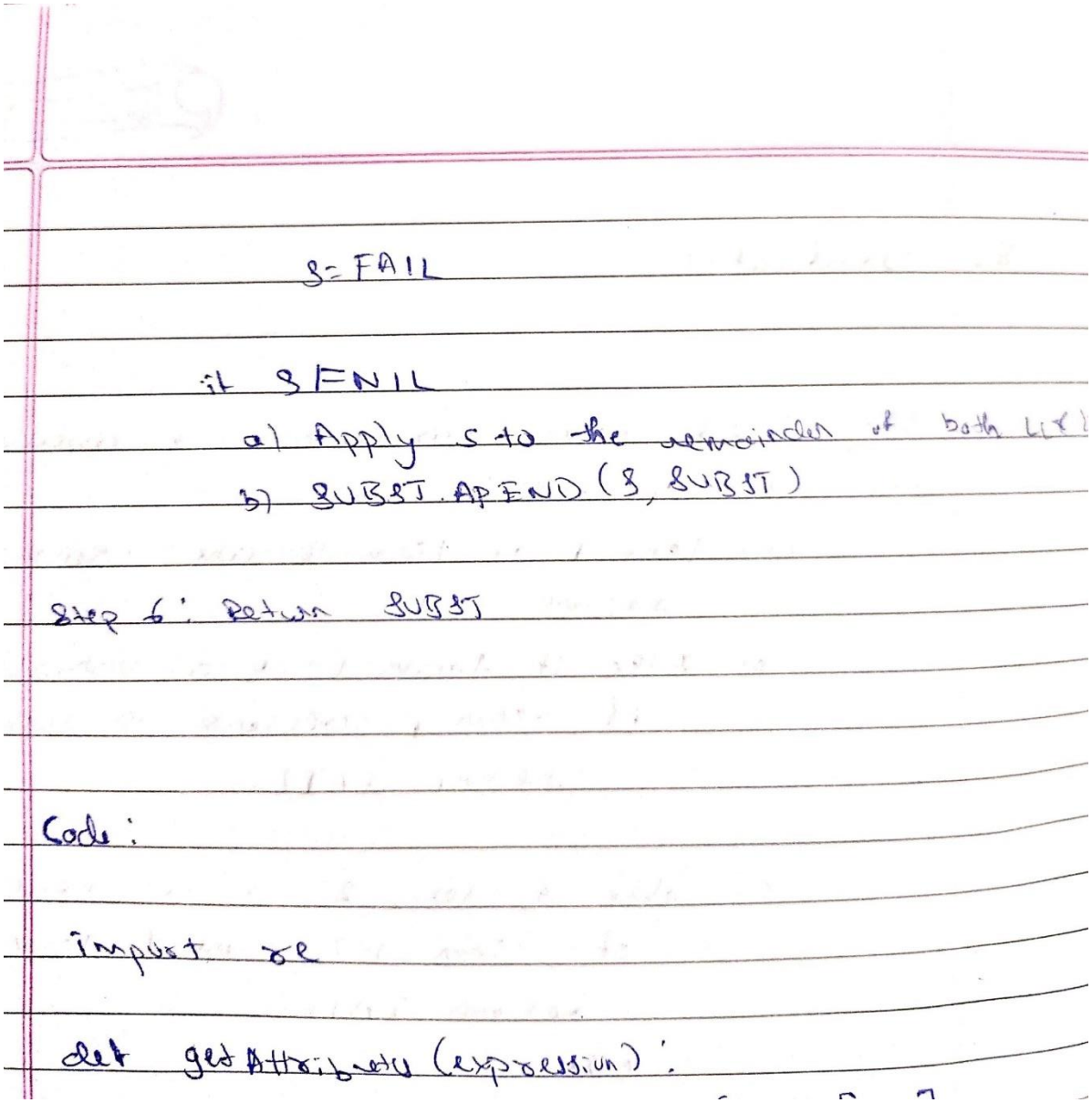
d) else return FAIL

Step 2: if predicate (term 1) ≠ predicate (term 2)
return FAIL

Step 3: number of arguments ≠
return FAIL

Step 4: set (SUB ST) to NIL

Step 5: For I=1 to the number of elements in return 1
a) call unify (ith term1, ith term2)
put result into S




```
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)
```

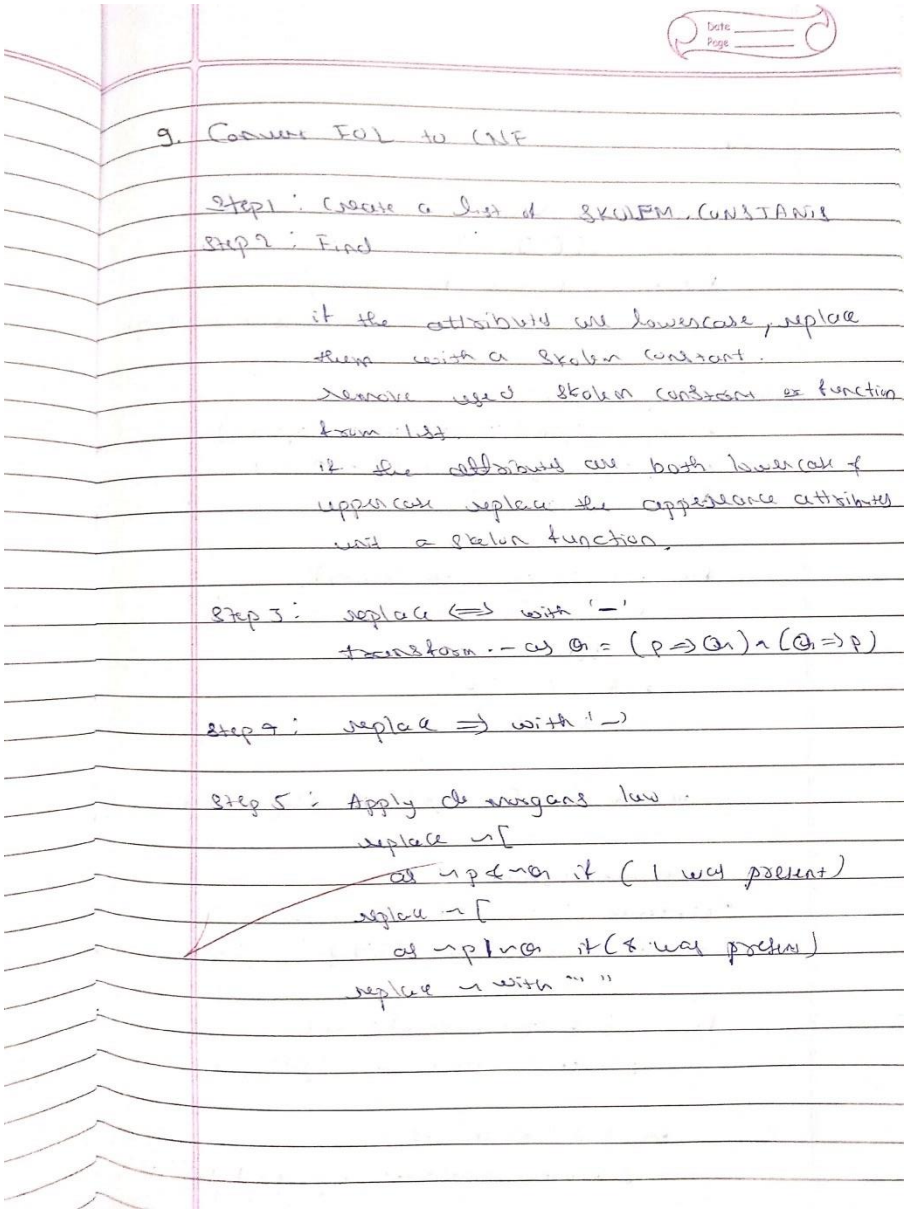
OUTPUT

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

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

```
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)")))
```

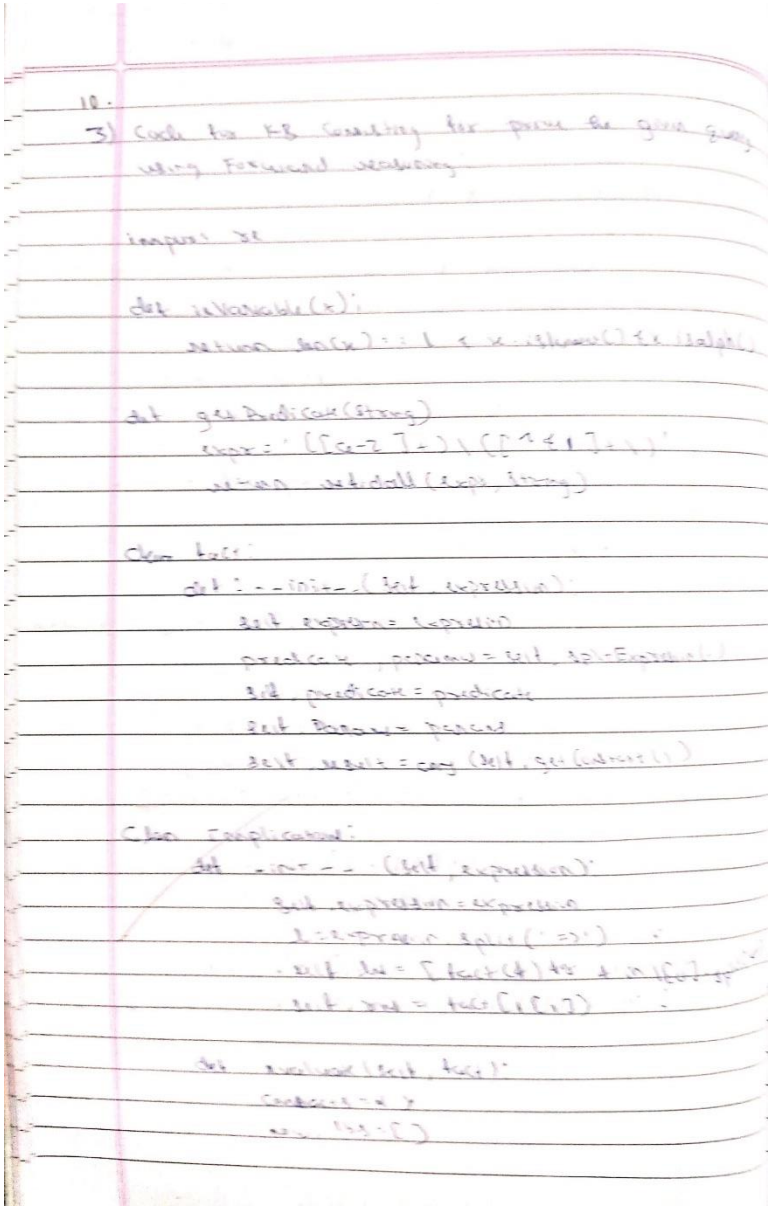
print(Skolemization(fol_to_cnf("∀x[∀y[animal(y)=>loves(x,y)]]=>[∃z[loves(z,x)]]")))

print(fol_to_cnf("[american(x)&weapon(y)&sells(x,y,z)&hostile(z)]=>criminal(x)"))

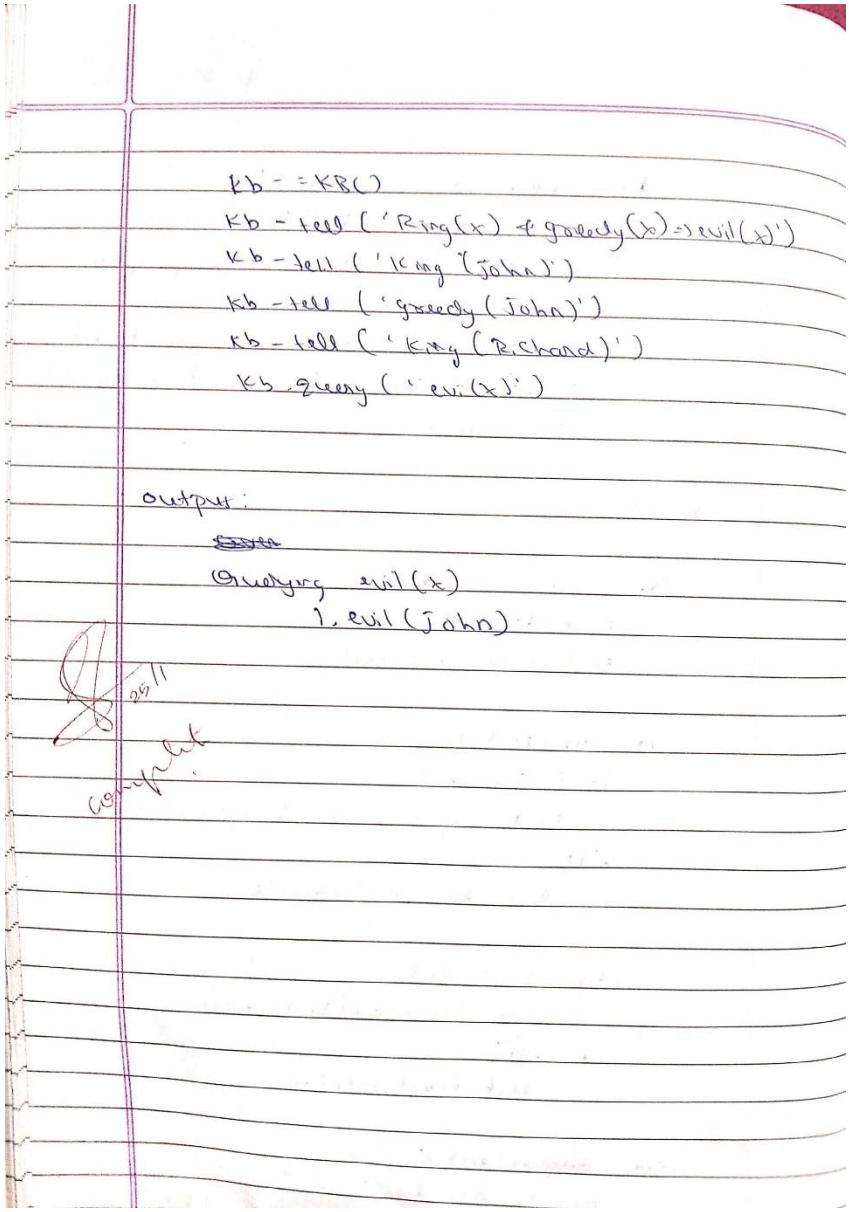
OUTPUT

```
Enter FOL statement: x+y_z*s
FOL converted to CNF: [~x+y|z*s]&[~z*s|x+y]
```

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



```
for key in conditions:
    if conditions[key]:
        attributes = attributes.replace

return Fact(expr) if len(new_lhs) and all
    ([f.getResult() for f in new])
    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 display(self):
        print("All facts: ")
        for i, f in enumerate(set([f.expression
                          for f in self.facts])):
            print(f'\t{i+1}. {f}')
```




```
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()
```

OUTPUT

```
Enter number of statements in Knowledge Base: 4
Elephant(x) => Mammal(x)
Lion(Mufasa)
Mammal(x) => Animal(x)
Animal(Simba)
Enter Query:
Mammal(x)
Querying Mammal(x):
All facts:
        1. Lion(Mufasa)
        2. Animal(Simba)
```