VISVESVARAYA TECHNOLOGICAL UNIVERSITY

“JnanaSangama”, Belgaum -590014, Karnataka.

LAB REPORT
On

ARTIFICIAL INTELLIGENCE

Submitted by

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

B.M.S. COLLEGE OF ENGINEERING
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CERTIFICATE

This is to certify that the Lab work entitled **“ARTIFICIAL INTELLIGENCE”** carried out by **Manoj Patil (1BM21CS104)**, who is bonafide student of **B. M. S. College of Engineering**. It is in partial fulfilment 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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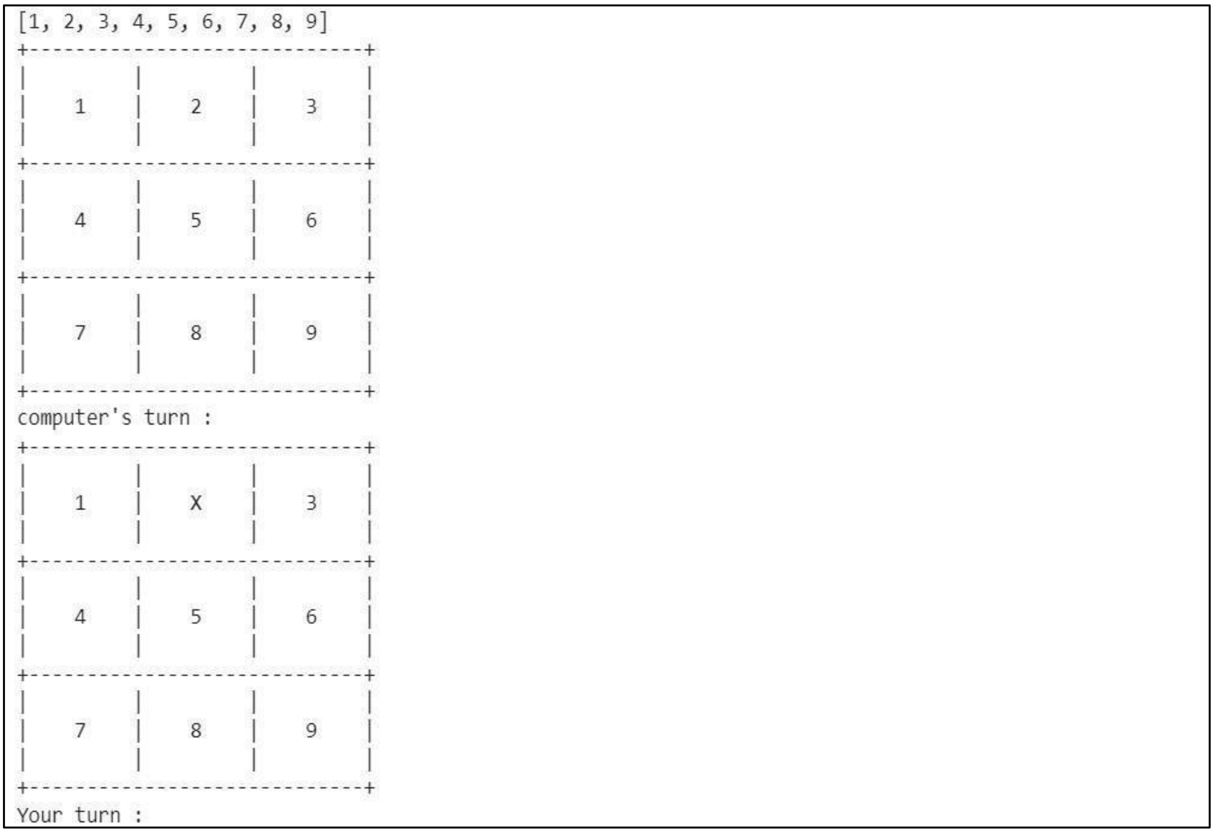
1.Implement Tic –Tac –Toe Game.

```
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'
```

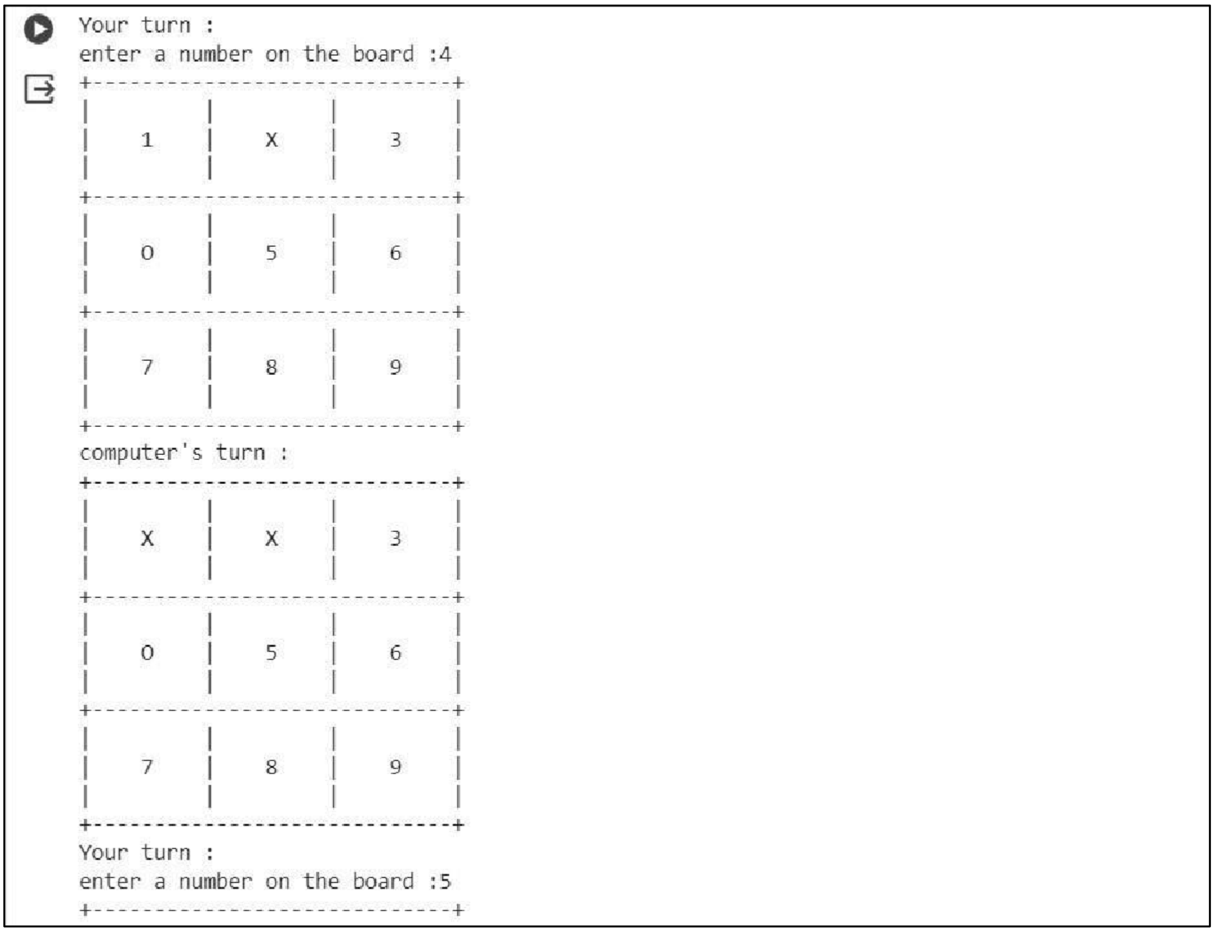
```
def update_user():     global tic,num

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")
```

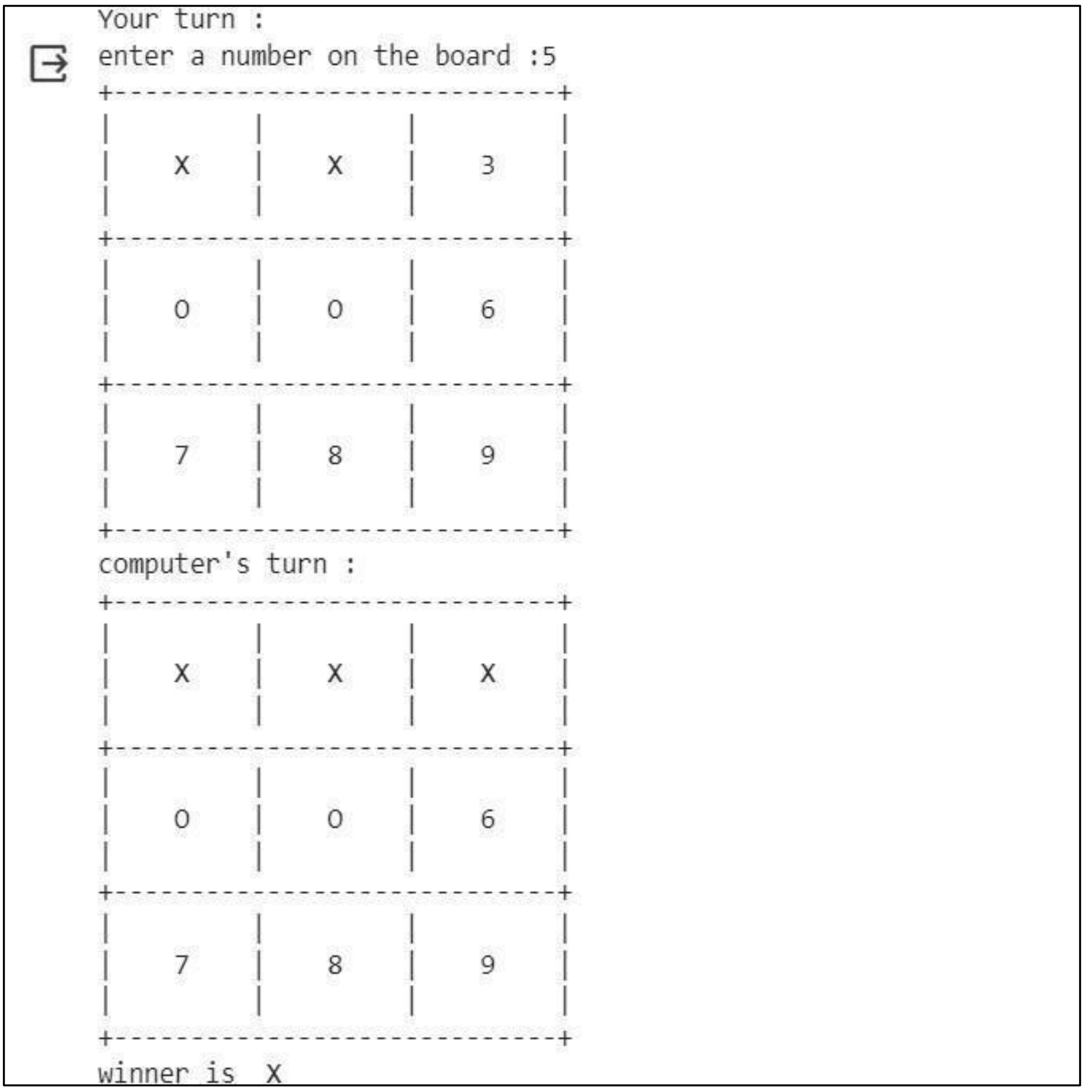
OUTPUT:



```
[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 :
```



```
Your turn :
enter a number on the board :4
+-----------------------------+
|         |         |         |
|    1    |    X    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    0    |    5    |    6    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
computer's turn :
+-----------------------------+
|         |         |         |
|    X    |    X    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    0    |    5    |    6    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
Your turn :
enter a number on the board :5
+-----------------------------+
```

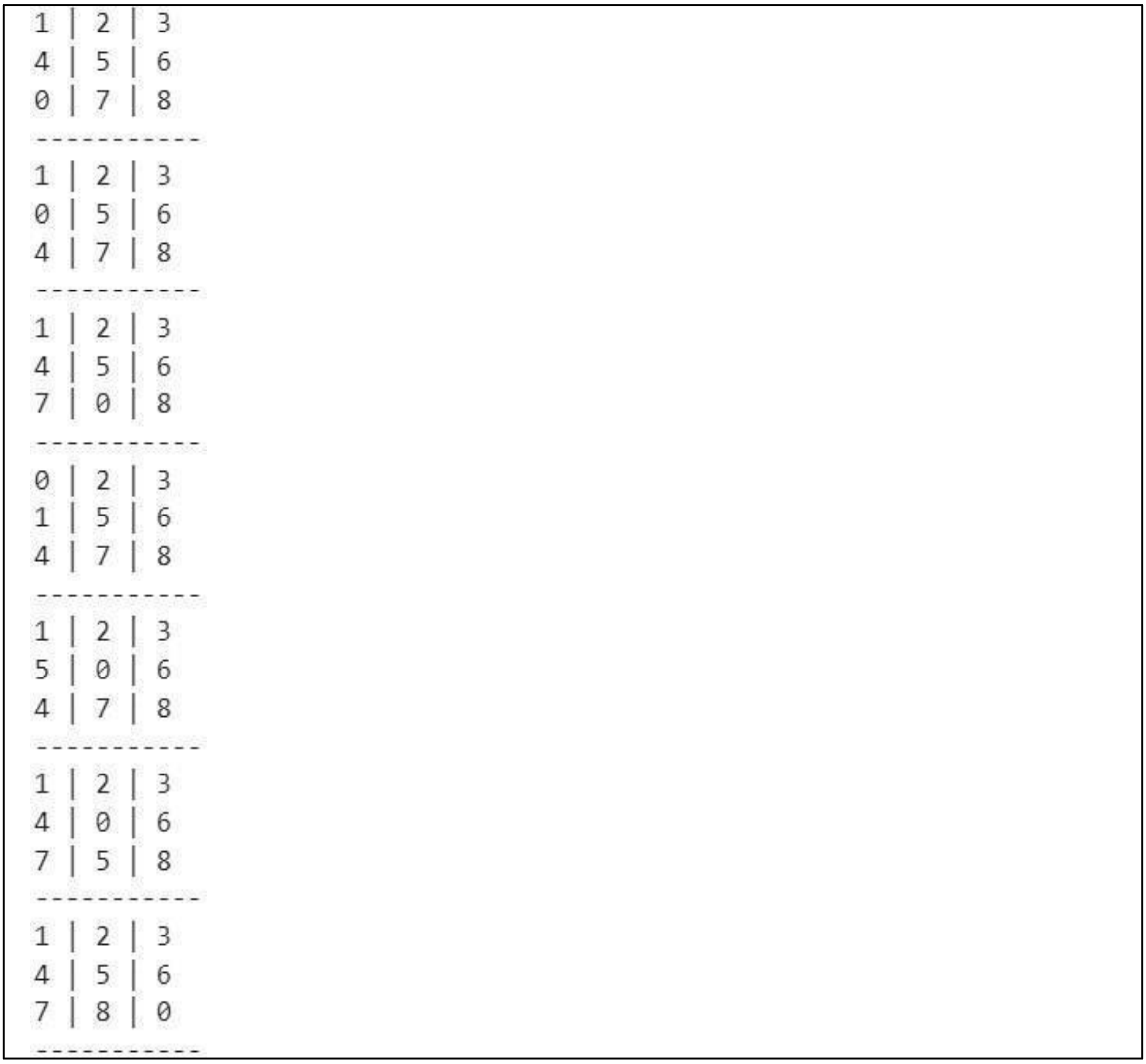


```
Your turn :
enter a number on the board :5
+-----------------------------+
|         |         |         |
|    X    |    X    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    O    |    O    |    6    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    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:



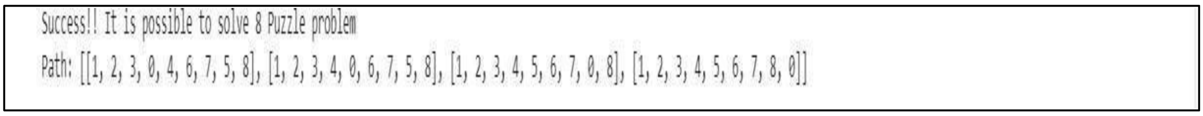
```
1 | 2 | 3
4 | 5 | 6
0 | 7 | 8
-----------
1 | 2 | 3
0 | 5 | 6
4 | 7 | 8
-----------
1 | 2 | 3
4 | 5 | 6
7 | 0 | 8
-----------
0 | 2 | 3
1 | 5 | 6
4 | 7 | 8
-----------
1 | 2 | 3
5 | 0 | 6
4 | 7 | 8
-----------
1 | 2 | 3
4 | 0 | 6
7 | 5 | 8
-----------
1 | 2 | 3
4 | 5 | 6
7 | 8 | 0
-----------
```

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")
```

OUTPUT:



```
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]]
```

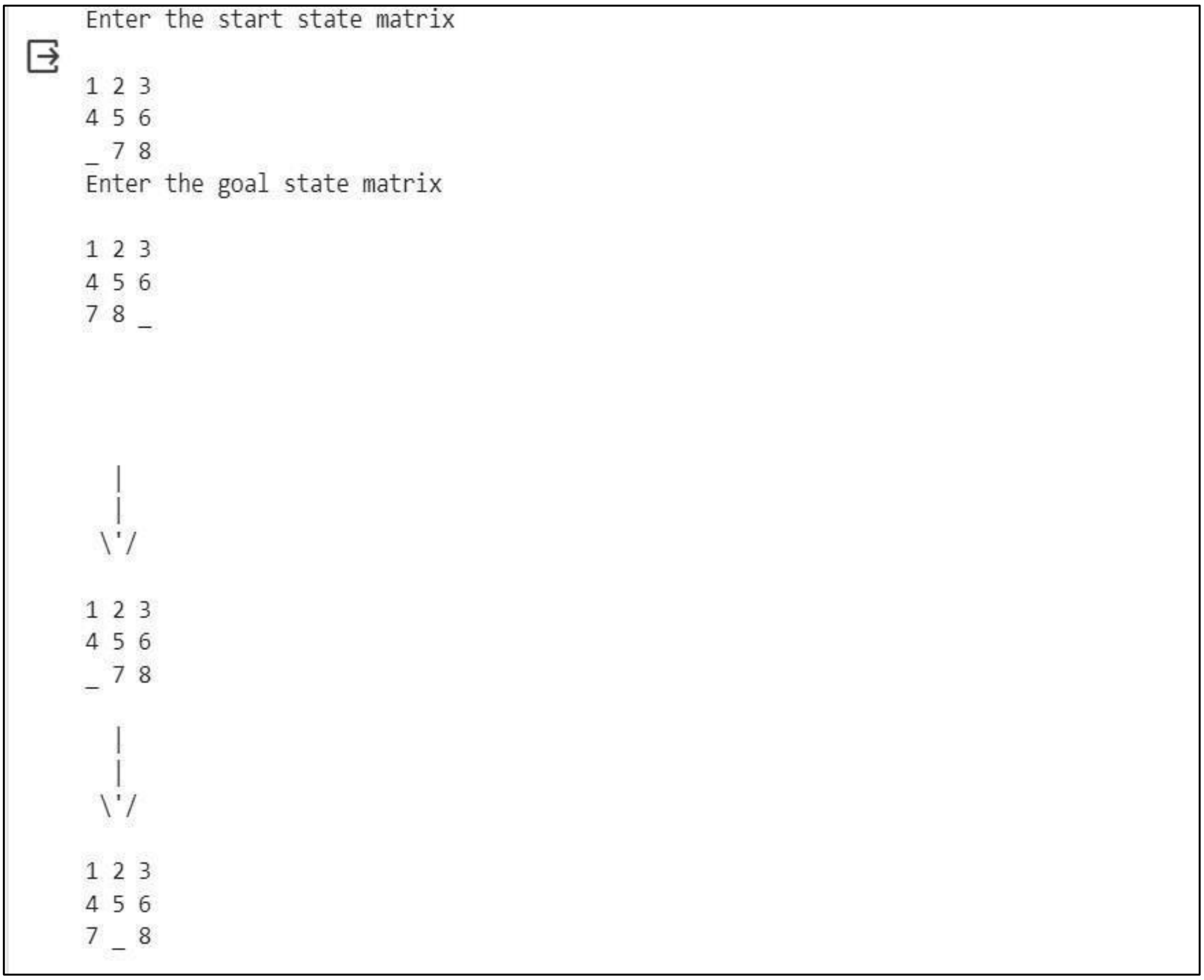
4. Implement A* search algorithm.

```
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
```

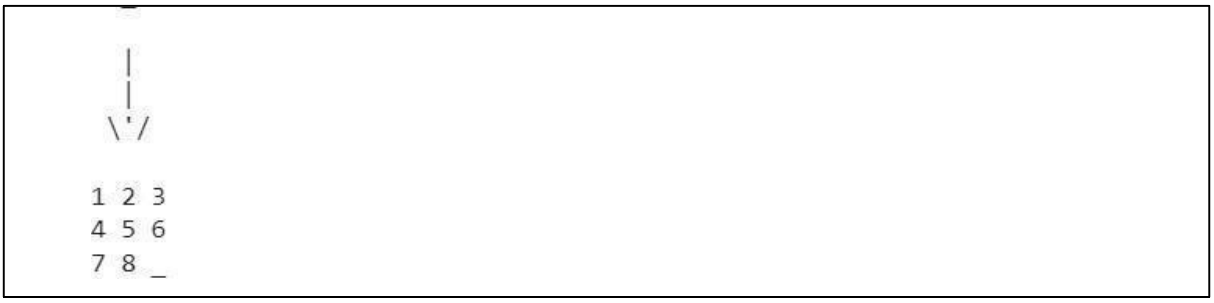
```
return temp_puz          else:
return None


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
```

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():

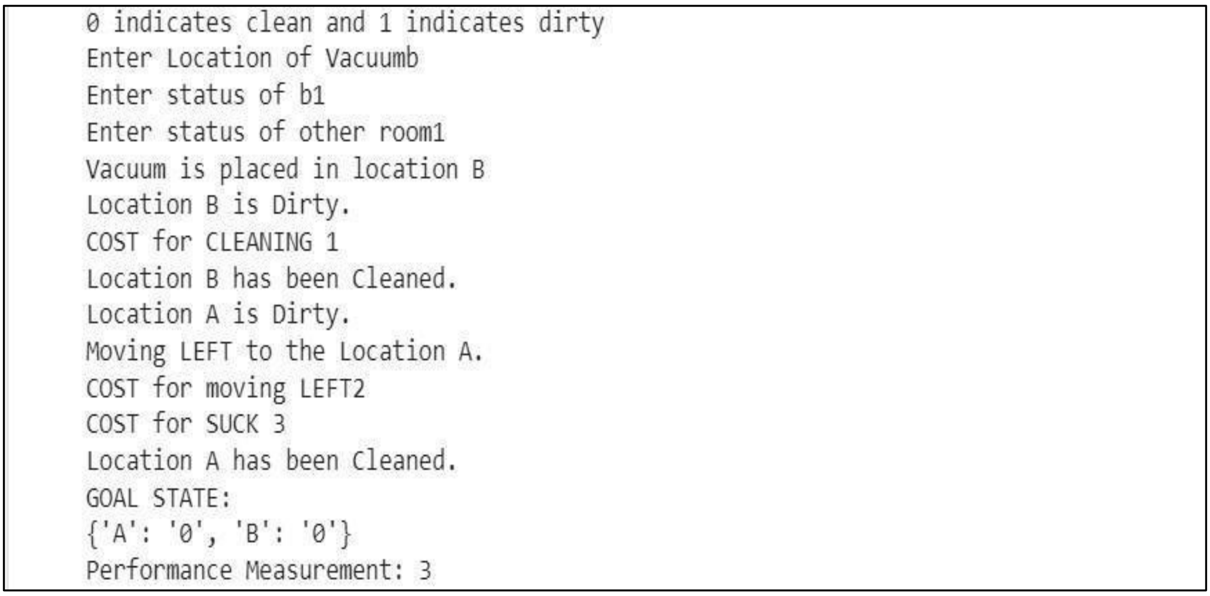
```
# 0 indicates Clean and 1 indicates Dirty  goal_state = {'A':
'0', 'B': '0'}  cost = 0


   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()
```

OUTPUT:



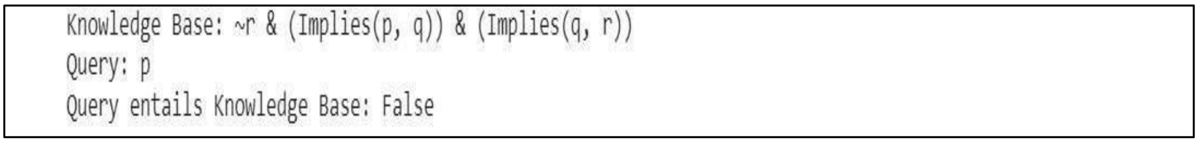
```
0 indicates clean and 1 indicates dirty
Enter Location of Vacuumb
Enter status of b1
Enter status of other room1
Vacuum is placed in location B
Location B is Dirty.
COST for CLEANING 1
Location B has been Cleaned.
Location A is Dirty.
Moving LEFT to the Location A.
COST for moving LEFT2
COST for 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)
```

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 ''

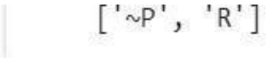
def split_terms(rule): exp =

'(~*[PQRS])' terms =

re.findall(exp, rule) return terms

split_terms('~PvR')

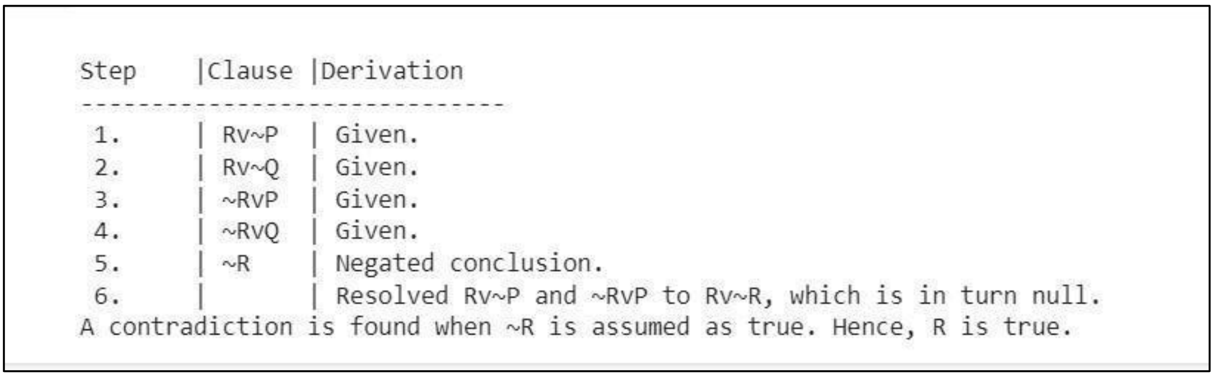
OUTPUT:



```
['~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]}'):
```

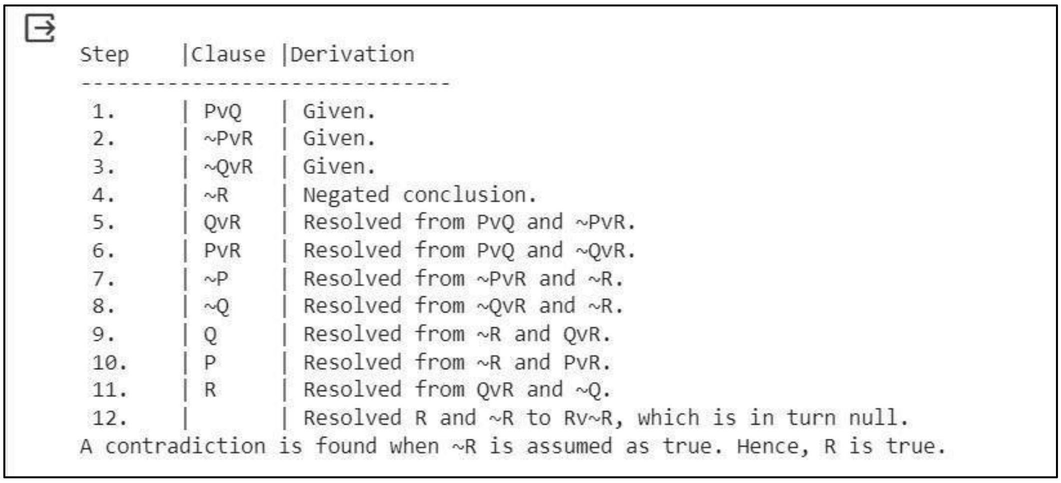
```
                temp.append(f'{gen[0]}v{gen[1]}')                        steps[''] =
f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \

                \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)
```



```
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) + ")"
```

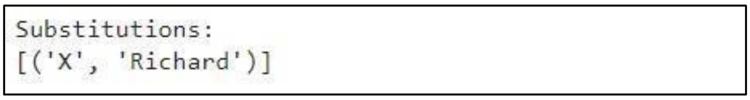
```
def apply(exp, substitutions):     for
substitution in substitutions:         new, old =
substitution exp = replaceAttributes(exp,
old, new)     return exp


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)
```

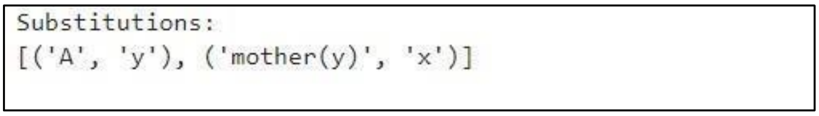
```
print("Substitutions:")

print(substitutions)
```

OUTPUT:



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

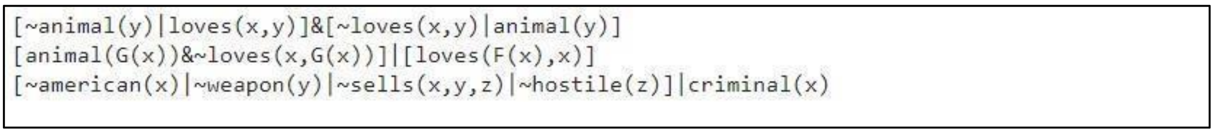
```
exp1 = "knows(A,x)" exp2 =

"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
```



```
[~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)
```

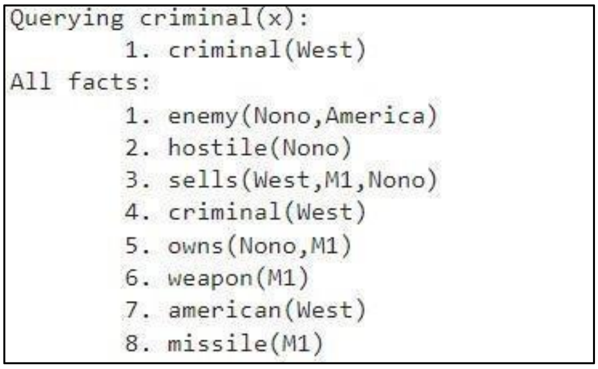
10. Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning import re

```
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()
```

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)
```