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LAB REPORT
On

ARTIFICIAL INTELLIGENCE

Submitted by
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(1BM22CS411)

in partial fulfilment for the award of the degree of
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CERTIFICATE

This is to certify that the Lab work entitled **"ARTIFICIAL INTELLIGENCE"** carried out by **NAVEEN (1BM22CS411)**, 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 :
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 ind:

        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")
```

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. A 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.A 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 get redicates(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)
```