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 **KEERTHI P REDDY (1BM21CS090)**, who is bonafide student of **B. M. S. College of Engineering**. It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2022-23. The Lab report has been approved as it satisfies the academic requirements in respect of Artificial Intelligence Lab - **(22CS5PCAIN)** work prescribed for the said degree.

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1.Implement Tic –Tac –Toe Game.

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



def update_comp():     global
tic,num     for i in range(9):
if tic[i]==i+1:             num=i+1
tic[num-1]='X'             if
winner(num-1)==False:
#reverse the change
tic[num-1]=num
            else:
                return     for i in
range(9):         if tic[i]==i+1:
num=i+1             tic[num-1]='O'
if winner(num-1)==True:
                tic[num-1]='X'
return
            else:
                tic[num-1]=num
            num=random.randint(1,9)
    while num  not in tic:
        num=random.randint(1,9)
```

```
    else:
        tic[num-1]='X'



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


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



try:     for i in
range(1,10):
        tic.append(i)
    count=0
    #print(tic)     board(tic)
while count!=9:          if
count%2==0:
```

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

OUTPUT :

Output:

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```
[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    |    5    |    X    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
Your turn :
enter a number on the board :1
```

```
+-----------------------------+
|         |         |         |
|    0    |    2    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    4    |    5    |    X    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
computer's turn :
+-----------------------------+
|         |         |         |
|    0    |    2    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    4    |    X    |    X    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
Your turn :
enter a number on the board :4
```

```
+-----------------------------+
|         |         |         |
|    O    |    2    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    O    |    X    |    X    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-----------------------------+
computer's turn :
+-----------------------------+
|         |         |         |
|    O    |    2    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    O    |    X    |    X    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    X    |    8    |    9    |
|         |         |         |
+-----------------------------+
Your turn :
enter a number on the board :2
```

```
+-----------------------------+
|         |         |         |
|    O    |    O    |    3    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    O    |    X    |    X    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    X    |    8    |    9    |
|         |         |         |
+-----------------------------+
computer's turn :
+-----------------------------+
|         |         |         |
|    O    |    O    |    X    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    O    |    X    |    X    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    X    |    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 :

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```
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")

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```
Success!! It is possible to solve 8 Puzzle problem
Path: [[1, 2, 3, 4, 5, 6, 0, 7, 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
```

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```
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()

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```
0 indicates clean and 1 indicates dirty
Enter Location of Vacuum        a
Enter status of a1
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)

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```
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')

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```
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.
```

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)

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.     | ~PvR  | Given.
 4.     | RvS   | Given.
 5.     | Rv~Q  | Given.
 6.     | ~Sv~Q | Given.
 7.     | ~R    | Negated conclusion.
 8.     | QvR   | Resolved from PvQ and ~PvR.
 9.     | Pv~S  | Resolved from PvQ and ~Sv~Q.
 10.    | P     | Resolved from PvR and ~R.
 11.    | ~P    | Resolved from ~PvR and ~R.
 12.    | Rv~S  | Resolved from ~PvR and Pv~S.
 13.    | R     | Resolved from ~PvR and P.
 14.    | S     | Resolved from RvS and ~R.
 15.    | ~Q    | Resolved from Rv~Q and ~R.
 16.    | Q     | Resolved from ~R and QvR.
 17.    | ~S    | Resolved from ~R and Rv~S.
 18.    |       | Resolved ~R and R to ~RvR, 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)
```

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```
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)"))
```

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```
[~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()

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```
Querying evil(x):
        1. evil(Richard)
        2. evil(John)

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