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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 **Harshavardhan HC (1BM22CS407)** 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
0	0	6
7	8	9

computer's turn :

x	x	x
0	0	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 route 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 Vacuum b
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 LEFT 2
COST for SUCK 3
Location A has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 3
```


6. Create a knowledge base using propositional 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 propositional 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.	$R \vee \sim P$	Given.
2.	$R \vee \sim Q$	Given.
3.	$\sim R \vee P$	Given.
4.	$\sim R \vee Q$	Given.
5.	$\sim R$	Negated conclusion.
6.		Resolved $R \vee \sim P$ and $\sim R \vee P$ to $R \vee \sim R$, which is in turn null. A contradiction is found when $\sim R$ 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.	$P \vee Q$	Given.
2.	$\sim P \vee R$	Given.
3.	$\sim Q \vee R$	Given.
4.	$\sim R$	Negated conclusion.
5.	$Q \vee R$	Resolved from $P \vee Q$ and $\sim P \vee R$.
6.	$P \vee R$	Resolved from $P \vee Q$ and $\sim Q \vee R$.
7.	$\sim P$	Resolved from $\sim P \vee R$ and $\sim R$.
8.	$\sim Q$	Resolved from $\sim Q \vee R$ and $\sim R$.
9.	Q	Resolved from $\sim R$ and $Q \vee R$.
10.	P	Resolved from $\sim R$ and $P \vee R$.
11.	R	Resolved from $Q \vee R$ and $\sim Q$.
12.		Resolved R and $\sim R$ to $R \vee \sim R$, which is in turn null. A contradiction is found when $\sim R$ 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('[\forall\exists].',
```

```

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)

```