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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CERTIFICATE

This is to certify that the Lab work entitled **"ARTIFICIAL INTELLIGENCE"** carried out by **Ashish Seru (1BM21CS035)**, 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)
```

```
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    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    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 in d:
 pos_moves_it_can.append(gen(state,i,b))
 return [move_it_can for move_it_can in pos_moves_it_can if move_it_can not in
visited_states]


def gen(state,m,b):
 temp=state.copy()
 if m=='d':
 temp[b+3],temp[b]=temp[b],temp[b+3]
 if m=='u':
 temp[b-3],temp[b]=temp[b],temp[b-3]
 if m=='l':
 temp[b-1],temp[b]=temp[b],temp[b-1]
 if m=='r':
 temp[b+1],temp[b]=temp[b],temp[b+1]
 return temp


src=[1,2,3,4,5,6,0,7,8]
target=[1,2,3,4,5,6,7,8,0]
bfs(src,target)
```

OUTPUT

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

3. Implement Iterative deepening search algorithm.

```
def id_dfs(puzzle, goal, get_moves):

import itertools

#get_moves -> possible_moves

def dfs(route, depth):

if depth == 0:

return

if route[-1] == goal:

return route

for move in get_moves(route[-1]):

if move not in route:

next_route = dfs(route + [move], depth - 1) if
next_route:

return next_route


for depth in itertools.count():

route = dfs([puzzle], depth)

if route:

return route



def possible_moves(state):

b = state.index(0) # ) indicates White space -> so b has index of it.

d = [] # direction

if b not in [0, 1, 2]:

d.append('u')

if b not in [6, 7, 8]:

d.append('d')

if b not in [0, 3, 6]:

d.append('l')
```

```
if b not in [2, 5, 8]:
d.append('r')

pos_moves = []
for i in d:
pos_moves.append(generate(state, i, b))
return pos_moves


def generate(state, m, b):
temp = state.copy()
if m == 'd':
temp[b + 3], temp[b] = temp[b], temp[b + 3] if
m == 'u':
temp[b - 3], temp[b] = temp[b], temp[b - 3] if
m == 'l':
temp[b - 1], temp[b] = temp[b], temp[b - 1] if
m == 'r':
temp[b + 1], temp[b] = temp[b], temp[b + 1]

return temp


# calling ID-DFS
initial = [1, 2, 3, 0, 4, 6, 7, 5, 8]
goal = [1, 2, 3, 4, 5, 6, 7, 8, 0]

route = id_dfs(initial, goal, possible_moves)
```

`

```
if route:
 print("Success!! It is possible to solve 8 Puzzle problem")
 print("Path:", route)
else:
 print("Failed to find a solution")
```

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

`

4. Implement A* search algorithm.

```
class Node:
def __init__(self,data,level,fval):
""" Initialize the node with the data, level of the node and the calculated fvalue """
self.data = data
self.level = level
self.fval = fval

def generate_child(self):
""" Generate child nodes from the given node by moving the blank space
either in the four directions {up,down,left,right} """
x,y = self.find(self.data,'_')
""" val_list contains position values for moving the blank space in either of the
4 directions [up,down,left,right] respectively. """
val_list = [[x,y-1],[x,y+1],[x-1,y],[x+1,y]]
children = []
for i in val_list:
child = self.shuffle(self.data,x,y,i[0],i[1])
if child is not None:
child_node = Node(child,self.level+1,0)
children.append(child_node)
return children

def shuffle(self,puz,x1,y1,x2,y2):
""" Move the blank space in the given direction and if the position value are out of
limits the return None """
if x2 >= 0 and x2 < len(self.data) and y2 >= 0 and y2 < len(self.data):
temp_puz = []
temp_puz = self.copy(puz)
temp = temp_puz[x2][y2]
```

```
temp_puz[x2][y2] = temp_puz[x1][y1]
temp_puz[x1][y1] = temp
return temp_puz
else:
return None

def copy(self,root):
""" Copy function to create a similar matrix of the given node"""
temp = []
for i in root:
t = []
for j in i:
t.append(j)
temp.append(t)
return temp

def find(self,puz,x):
""" Specifically used to find the position of the blank space """ for
i in range(0,len(self.data)):
for j in range(0,len(self.data)):
if puz[i][j] == x:
return i,j


class Puzzle:
def __init__(self,size):
""" Initialize the puzzle size by the specified size,open and closed lists to empty """
self.n = size
self.open = []
self.closed = []
```

```
def accept(self):
""" Accepts the puzzle from the user """
puz = []
for i in range(0,self.n):
temp = input().split(" ")
puz.append(temp)
return puz

def f(self,start,goal):
""" Heuristic Function to calculate hueristic value f(x) = h(x) + g(x)
""" return self.h(start.data,goal)+start.level

def h(self,start,goal):
""" Calculates the different between the given puzzles """
temp = 0
for i in range(0,self.n):
for j in range(0,self.n):
if start[i][j] != goal[i][j] and start[i][j] != '_':
temp += 1
return temp

def process(self):
""" Accept Start and Goal Puzzle state"""
print("Enter the start state matrix \n")
start = self.accept()
print("Enter the goal state matrix \n")
goal = self.accept()
```

```
start = Node(start,0,0)
start.fval = self.f(start,goal)
""" Put the start node in the open list"""
self.open.append(start)
print("\n\n")
while True:
cur = self.open[0]
print("")
print(" | ")
print(" | ")
print(" \\'/ \n")
for i in cur.data:
for j in i:
                print(j,end=" ")
print("")
""" If the difference between current and goal node is 0 we have reached the
goal node"""
if(self.h(cur.data,goal) == 0):
break
for i in cur.generate_child():
i.fval = self.f(i,goal)
self.open.append(i)
self.closed.append(cur)
del self.open[0]


""" sort the opne list based on f value """
self.open.sort(key = lambda x:x.fval,reverse=False)



puz = Puzzle(3)
puz.processs
```

OUTPUT

```
Enter the start state matrix

1 2 3
4 5 6
_ 7 8
Enter the goal state matrix

1 2 3
4 5 6
7 8 _



  |
  |
 \'/

1 2 3
4 5 6
_ 7 8

  |
  |
 \'/

1 2 3
4 5 6
7 _ 8

  |
  |
 \'/

1 2 3
4 5 6
7 8 _
```

5. Implement vaccum cleaner agent.

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


location_input = input("Enter Location of Vacuum")
status_input = input("Enter status of " + location_input)
status_input_complement = input("Enter status of other
room")


if location_input == 'A':
# Location A is Dirty.
print("Vacuum is placed in Location A")
if status_input == '1':
print("Location A is Dirty.")
# suck the dirt and mark it as clean
cost += 1 #cost for suck
print("Cost for CLEANING A " + str(cost))
print("Location A has been Cleaned.")


if status_input_complement == '1':
# if B is Dirty
print("Location B is Dirty.")
print("Moving right to the Location B. ") cost += 1
#cost for moving right print("COST for moving
RIGHT" + str(cost)) # suck the dirt and mark it as
clean
cost += 1 #cost for suck
print("COST for SUCK " + str(cost))
print("Location B has been Cleaned. ")
```

```
else:
print("No action" + str(cost))
# suck and mark clean
      print("Location B is already clean.") if
                  status_input == '0':
print("Location A is already clean ") if
status_input_complement == '1':# if B is Dirty
print("Location B is Dirty.")
print("Moving RIGHT to the Location B. ") cost += 1
#cost for moving right print("COST for moving
RIGHT " + str(cost)) # suck the dirt and mark it as
clean cost += 1 #cost for suck print("Cost for SUCK"
+ str(cost)) print("Location B has been Cleaned. ")
else:
print("No action " + str(cost))
print(cost)
# suck and mark clean
print("Location B is already clean.")


else:
print("Vacuum is placed in location B") #
Location B is Dirty.
if status_input == '1':
print("Location B is Dirty.")
# suck the dirt and mark it as clean cost
+= 1 # cost for suck
print("COST for CLEANING " + str(cost))
print("Location B has been Cleaned.")
```

```
if status_input_complement == '1':
# if A is Dirty
print("Location A is Dirty.")
print("Moving LEFT to the Location A. ") cost += 1
# cost for moving right print("COST for moving
LEFT" + str(cost)) # suck the dirt and mark it as
clean cost += 1 # cost for suck
print("COST for SUCK " + str(cost))
        print("Location A has been Cleaned.")


else:
print(cost)
# suck and mark clean
print("Location B is already clean.")


if status_input_complement == '1': # if A is Dirty
print("Location A is Dirty.")
print("Moving LEFT to the Location A. ") cost += 1
# cost for moving right print("COST for moving
LEFT " + str(cost)) # suck the dirt and mark it as
clean cost += 1 # cost for suck
print("Cost for SUCK " + str(cost))
print("Location A has been Cleaned. ") else:
print("No action " + str(cost))
# suck and mark clean
print("Location A is already clean.")
```

```
 # done cleaning
 print("GOAL STATE: ")
 print(goal_state)
 print("Performance Measurement: " + str(cost))

print("0 indicates clean and 1 indicates dirty")

vacuum_world()
```

OUTPUT:

```
0 indicates clean and 1 indicates dirty
Enter Location of Vacuumb
Enter status of b1
Enter status of other room1
Vacuum is placed in location B
Location B is Dirty.
COST for CLEANING 1
Location B has been Cleaned.
Location A is Dirty.
Moving LEFT to the Location A.
COST for moving LEFT2
COST for SUCK 3
Location A has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 3
```

6. Create a knowledge base using prepositional logic and show that the given query entails the knowledge base or not .

```
from sympy import symbols, And, Not, Implies, satisfiable


def create_knowledge_base():
# Define propositional symbols
p = symbols('p')
q = symbols('q')
r = symbols('r')


# Define knowledge base using logical statements
knowledge_base = And(
Implies(p, q), # If p then q
Implies(q, r), # If q then r
Not(r) # Not r
)
return knowledge_base


def query_entails(knowledge_base, query):
# Check if the knowledge base entails the query entailment
= satisfiable(And(knowledge_base, Not(query)))


# If there is no satisfying assignment, then the query is entailed
return not entailment


if __name__ == "__main__":
# Create the knowledge base
kb = create_knowledge_base()


# Define a query
```

```
query = symbols('p')

# Check if the query entails the knowledge base
result = query_entails(kb, query)

# Display the results
print("Knowledge Base:", kb)
print("Query:", query)
print("Query entails Knowledge Base:", result)
```

OUTPUT:

```
Knowledge Base: ~r & (Implies(p, q)) & (Implies(q, r))
Query: p
Query entails Knowledge Base: False
```


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

```
import re

def main(rules, goal):
rules = rules.split(' ')
steps = resolve(rules, goal)
print('\nStep\t|Clause\t|Derivation\t')
print('-' * 30)
i = 1
for step in steps:
print(f' {i}.\t| {step}\t| {steps[step]}\t')
```

```
i += 1



def negate(term):
return f'~{term}' if term[0] != '~' else term[1]


def reverse(clause):
if len(clause) > 2:
t = split_terms(clause)
return f'{t[1]}v{t[0]}'
return ''



def split_terms(rule):
exp = '(~*[PQRS])'
terms = re.findall(exp, rule)
return terms


split_terms('~PvR')
```


OUTPUT:

```
['~P', 'R']
```

```
def contradiction(goal, clause):
contradictions = [ f'{goal}v{negate(goal)}',
f'{negate(goal)}v{goal}'] return clause in contradictions or
reverse(clause) in contradictions


def resolve(rules, goal):
temp = rules.copy()
temp += [negate(goal)]
steps = dict()
for rule in temp:
steps[rule] = 'Given.'
```

```
steps[negate(goal)] = 'Negated conclusion.'
i = 0
while i < len(temp):
n = len(temp)
j = (i + 1) % n
clauses = []
while j != i:
terms1 = split_terms(temp[i])
terms2 = split_terms(temp[j])
for c in terms1:
if negate(c) in terms2:
t1 = [t for t in terms1 if t != c]
t2 = [t for t in terms2 if t != negate(c)]
gen = t1 + t2
if len(gen) == 2:
```



```
if gen[0] != negate(gen[1]):
clauses += [f'{gen[0]}v{gen[1]}']
else:
if contradiction(goal,f'{gen[0]}v{gen[1]}'):
temp.append(f'{gen[0]}v{gen[1]}')
steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
\nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal} is
true."
return steps
        elif len(gen) == 1:
clauses += [f'{gen[0]}']
else:
if contradiction(goal,f'{terms1[0]}v{terms2[0]}'):
temp.append(f'{terms1[0]}v{terms2[0]}')
steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \ \nA
contradiction is found when {negate(goal)} is assumed as true. Hence, {goal} is true."
return steps
for clause in clauses:
```

if clause not in temp and clause != reverse(clause) and reverse(clause) not in temp:
temp.append(clause)

steps[clause] = f'Resolved from {temp[i]} and {temp[j]}.' j = (j + 1)

% n

i += 1

return steps

rules = 'Rv~P Rv~Q ~RvP ~RvQ' #(P^Q)<=>R :

(Rv~P)v(Rv~Q)^(~RvP)^(~RvQ) goal = 'R'

main(rules, goal)


```
Step    |Clause |Derivation
-----------------------------
 1.     | Rv~P  | Given.
 2.     | Rv~Q  | Given.
 3.     | ~RvP  | Given.
 4.     | ~RvQ  | Given.
 5.     | ~R    | Negated conclusion.
 6.     |       | Resolved Rv~P and ~RvP to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.
```

rules = 'PvQ ~PvR ~QvR' #P=vQ, P=>Q : ~PvQ, Q=>R, ~QvR

goal = 'R'

main(rules, goal)

```
Step    |Clause |Derivation
-----------------------------
 1.     | PvQ   | Given.
 2.     | ~PvR  | Given.
 3.     | ~QvR  | Given.
 4.     | ~R    | Negated conclusion.
 5.     | QvR   | Resolved from PvQ and ~PvR.
 6.     | PvR   | Resolved from PvQ and ~QvR.
 7.     | ~P    | Resolved from ~PvR and ~R.
 8.     | ~Q    | Resolved from ~QvR and ~R.
 9.     | Q     | Resolved from ~R and QvR.
 10.    | P     | Resolved from ~R and PvR.
 11.    | R     | Resolved from QvR and ~Q.
 12.    |       | Resolved R and ~R to Rv~R, which is in turn null.
A contradiction is found when ~R is assumed as true. Hence, R is true.
```

 8. Implement unification in first order logic

import re

def getAttributes(expression):

```
expression = expression.split("(")[1:]
expression = "(".join(expression)
expression = expression[:-1]
expression = re.split("(?

def getInitialPredicate(expression):
return expression.split("(")[0]

def isConstant(char):
return char.isupper() and len(char) == 1

def isVariable(char):
return char.islower() and len(char) == 1

def replaceAttributes(exp, old, new):
attributes = getAttributes(exp)
for index, val in enumerate(attributes):
if val == old:
attributes[index] = new
predicate = getInitialPredicate(exp) return
predicate + "(" + ",".join(attributes) + ")"

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



```
return exp

def checkOccurs(var, exp):
if exp.find(var) == -1:
return False
return True
```

```
def getFirstPart(expression):
 attributes = getAttributes(expression)
 return attributes[0]


def getRemainingPart(expression):
 predicate = getInitialPredicate(expression)
 attributes = getAttributes(expression)
 newExpression = predicate + "(" + ",".join(attributes[1:]) + ")"
return newExpression
def unify(exp1, exp2):
 if exp1 == exp2:
 return []

 if isConstant(exp1) and isConstant(exp2):
 if exp1 != exp2:
 return False

 if isConstant(exp1):
 return [(exp1, exp2)]
```



```
 if isConstant(exp2):
 return [(exp2, exp1)]

 if isVariable(exp1):
 if checkOccurs(exp1, exp2):
 return False
 else:
 return [(exp2, exp1)]

 if isVariable(exp2):
 if checkOccurs(exp2, exp1):
 return False
```

```
 else:
 return [(exp1, exp2)]

 if getInitialPredicate(exp1) != getInitialPredicate(exp2):
print("Predicates do not match. Cannot be unified")
return False
  attributeCount1 = len(getAttributes(exp1))
attributeCount2 = len(getAttributes(exp2)) if
attributeCount1 != attributeCount2: return
False

 head1 = getFirstPart(exp1)
 head2 = getFirstPart(exp2)
 initialSubstitution = unify(head1, head2)
 if not initialSubstitution:
 return False
```



```
 if attributeCount1 == 1:
 return initialSubstitution

 tail1 = getRemainingPart(exp1)
 tail2 = getRemainingPart(exp2)

 if initialSubstitution != []:
 tail1 = apply(tail1, initialSubstitution)
tail2 = apply(tail2, initialSubstitution)
remainingSubstitution = unify(tail1, tail2)
if not remainingSubstitution:
 return False

 initialSubstitution.extend(remainingSubstitution)
return initialSubstitution
```

```
exp1 = "knows(X)"
exp2 = "knows(Richard)"

substitutions = unify(exp1, exp2)

print("Substitutions:")

print(substitutions)
```

OUTPUT

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

exp2 = "knows(y,mother(y))"

substitutions = unify(exp1, exp2)
```



```
print("Substitutions:")

print(substitutions)
```


9.Convert a given first order logic statement into Conjunctive Normal Form (CNF). def getAttributes(string):

```
 expr = '
'

 matches = re.findall(expr, string)
 return [m for m in str(matches) if m.isalpha()]
```

```
def getPredicates(string):
 expr = '[a-z~]+
'
 return re.findall(expr, string)


def DeMorgan(sentence):
 string = ''.join(list(sentence).copy())
 string = string.replace('~~','')
 flag = '[' in string
 string = string.replace('~[','')
 string = string.strip(']')
 for predicate in getPredicates(string):
 string = string.replace(predicate, f'~{predicate}')
 s = list(string)
 for i, c in enumerate(string):
 if c == '|':
 s[i] = '&'
 elif c == '&':
 s[i] = '|'
 string = ''.join(s)
 string = string.replace('~~','')
 return f'[{string}]' if flag else string
```



```
def Skolemization(sentence):
 SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'),
ord('Z')+1)] statement = ''.join(list(sentence).copy())
 matches = re.findall('[∀∃].', statement)
 for match in matches[::-1]:
 statement = statement.replace(match, '')
 statements = re.findall('
]', statement)
 for s in statements:
```

```
statement = statement.replace(s, s[1:-1])
for predicate in getPredicates(statement):
attributes = getAttributes(predicate)
if ''.join(attributes).islower():
statement = statement.replace(match[1],SKOLEM_CONSTANTS.pop(0)) else:
aL = [a for a in attributes if a.islower()]
aU = [a for a in attributes if not a.islower()][0]
statement = statement.replace(aU, f'{SKOLEM_CONSTANTS.pop(0)}({aL[0] if len(aL)
else match[1]})')
return statement
```

```
import re

def fol_to_cnf(fol):

statement = fol.replace("<=>", "_")
while '_' in statement:
i = statement.index('_')
```



```
new_statement = '[' + statement[:i] + '=>' + statement[i+1:] + ']&['+ statement[i+1:] + '=>'
+ statement[:i] + ']'
statement = new_statement
statement = statement.replace("=>", "-")
expr = '
'
statements = re.findall(expr, statement)
for i, s in enumerate(statements):
if '[' in s and ']' not in s:
statements[i] += ']'
for s in statements:
statement = statement.replace(s, fol_to_cnf(s))
while '-' in statement:
```

```
i = statement.index('-')
br = statement.index('[') if '[' in statement else 0
new_statement = '~' + statement[br:i] + '|' + statement[i+1:] statement =
statement[:br] + new_statement if br > 0 else new_statement while '~∀'
in statement:
i = statement.index('~∀')
statement = list(statement)
statement[i], statement[i+1], statement[i+2] = '∃', statement[i+2],
'~' statement = ''.join(statement)
while '~∃' in statement:
i = statement.index('~∃')
s = list(statement)
s[i], s[i+1], s[i+2] = '∀', s[i+2], '~'
statement = ''.join(s)
statement = statement.replace('~[∀','[~∀')
statement = statement.replace('~[∃','[~∃')
expr = '(~[∀|∃].)'
statements = re.findall(expr, statement)
```



```
for s in statements:
statement = statement.replace(s, fol_to_cnf(s))
expr = '~
'
statements = re.findall(expr, statement)
for s in statements:
statement = statement.replace(s, DeMorgan(s))
return statement



print(Skolemization(fol_to_cnf("animal(y)<=>loves(x,y)")))
print(Skolemization(fol_to_cnf("∀x[∀y[animal(y)=>loves(x,y)]]=>[∃z[loves(z,x)]]")))
print(fol_to_cnf("[american(x)&weapon(y)&sells(x,y,z)&hostile(z)]=>criminal(x)"))
```

OUTPUT

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