VISVESVARAYA TECHNOLOGICAL UNIVERSITY

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LAB REPORT
on

ARTIFICIAL INTELLIGENCE

Submitted by

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in partial fulfillment for the award of the degree of

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in

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CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence" carried out by **Advithi D (1BM21CS009),** 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 2023. The Lab report has been approved as it satisfies the academic requirements in respect of a **Artificial Intelligence** course **(22CS5PCAIN)** work prescribed for the said degree.

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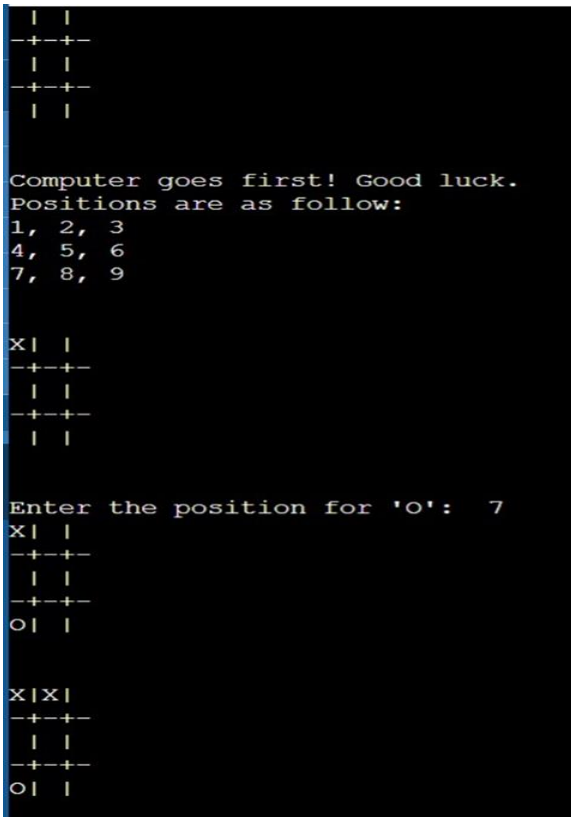
1) Implement Tic –Tac –Toe Game.

```
import numpy as np
import random
from time import sleep
def create_board():
	return(np.array([[0, 0, 0], [0, 0, 0], [0, 0, 0]]))
def possibilities(board):
	l = []
	for i in range(len(board)):
		for j in range(len(board)):
			if board[i][j] == 0:
				l.append((i, j))
	return(l)
def random_place(board, player):
	selection = possibilities(board)
	current_loc = random.choice(selection)
	board[current_loc] = player
	return(board)
def row_win(board, player):
	for x in range(len(board)):
		win = True
		for y in range(len(board)):
			if board[x, y] != player:
				win = False
				continue
		if win == True:
			return(win)
	return(win)
def col_win(board, player):
for x in range(len(board)):
		win = True
```

```
for y in range(len(board)):
                    if board[y][x] != player:
                        win = False
                        continue
                if win == True:
                    return(win)
        return(win)
def diag_win(board, player):
        win = True
        y = 0
        for x in range(len(board)):
                if board[x, x] != player:
                    win = False
        if win:
                return win
        win = True
        if win:
                for x in range(len(board)):
                    y = len(board) - 1 - x
                    if board[x, y] != player:
            win = False
        return win
def evaluate(board):
        winner = 0
        for player in [1, 2]:
                if (row_win(board, player) or
                        col_win(board, player) or
                        diag_win(board, player)):
                    winner = player
        if np.all(board != 0) and winner == 0:
                winner = -1
        return winner
```

```
def play_game():
    board, winner, counter = create_board(), 0, 1
    print(board)
    sleep(2)
    while winner == 0:
        for player in [1, 2]:
            board = random_place(board, player)
            print("Board after " + str(counter) + " move")
            print(board)
            sleep(2)
            counter += 1
            winner = evaluate(board)
            if winner != 0:
                break
    return(winner)
print("Winner is: " + str(play_game()))
```

OUTPUT



2) Solve 8 puzzle problems.

```
import copy

from heapq import heappush, heappop
n = 3
rows = [ 1, 0, -1, 0 ]
cols = [ 0, -1, 0, 1 ]
class priorityQueue:
    def __init__(self):
        self.heap = []
    def push(self, key):
        heappush(self.heap, key)
    def pop(self):
        return heappop(self.heap)
    def empty(self):
        if not self.heap:
            return True
        else:
            return False
class nodes:
    def __init__(self, parent, mats, empty_tile_posi,
                costs, levels):
        self.parent = parent
        self.mats = mats
          self.empty_tile_posi = empty_tile_posi
        self.costs = costs
        self.levels = levels
    def __lt__(self, nxt):
        return self.costs < nxt.costs
def calculateCosts(mats, final) -> int:
    count = 0
    for i in range(n):
        for j in range(n):
            if ((mats[i][j]) and
                (mats[i][j] != final[i][j])):
                count += 1
    return count
```

```
def newNodes(mats, empty_tile_posi, new_empty_tile_posi,
          levels, parent, final) -> nodes:
    new_mats = copy.deepcopy(mats)
    x1 = empty_tile_posi[0]
    y1 = empty_tile_posi[1]
    x2 = new_empty_tile_posi[0]
    y2 = new_empty_tile_posi[1]
    new_mats[x1][y1], new_mats[x2][y2] = new_mats[x2][y2], new_mats[x1][y1]
    costs = calculateCosts(new_mats, final)
      new_nodes = nodes(parent, new_mats, new_empty_tile_posi,
                    costs, levels)
    return new_nodes
def printMatsrix(mats):
    for i in range(n):
        for j in range(n):
            print("%d " % (mats[i][j]), end = " ")
        print()
def isSafe(x, y):
          return x >= 0 and x < n and y >= 0 and y < n
      def printPath(root):
          if root == None:
            return
          printPath(root.parent)
          printMatsrix(root.mats)
          print()
      def solve(initial, empty_tile_posi, final):
          pq = priorityQueue()
          costs = calculateCosts(initial, final)
          root = nodes(None, initial,
                      empty_tile_posi, costs, 0)
          pq.push(root)
          while not pq.empty():
            minimum = pq.pop()
              if minimum.costs == 0:
                  printPath(minimum)
                  return
              for i in range(n):
```

```
            new_tile_posi = [
                minimum.empty_tile_posi[0] + rows[i],
                minimum.empty_tile_posi[1] + cols[i], ]
                              if isSafe(new_tile_posi[0], new_tile_posi[1]):
                child = newNodes(minimum.mats,
                                minimum.empty_tile_posi,
                                new_tile_posi,
                                minimum.levels + 1,
        minimum, final,)
      pq.push(child)
initial = [ [ 1, 2, 3 ],
            [ 5, 6, 0 ],
            [ 7, 8, 4 ] ]
final = [ [ 1, 2, 3 ],
        [ 5, 8, 6 ],
        [ 0, 7, 4 ] ]
empty_tile_posi = [ 1, 2 ]
solve(initial, empty_tile_posi, final)
```

OUTPUT

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

```
[1, 2, 3, -1, 4, 5, 6, 7, 8]
[-1, 2, 3, 1, 4, 5, 6, 7, 8]
[1, 2, 3, 6, 4, 5, -1, 7, 8]
[1, 2, 3, 4, -1, 5, 6, 7, 8]
[6, 2, 3, 1, 4, 5, -1, 7, 8]
[8, 2, 3, 1, 4, 5, 6, 7, -1]
[2, -1, 3, 1, 4, 5, 6, 7, 8]
[1, 2, 3, 6, 4, 5, 7, -1, 8]
[1, -1, 3, 4, 2, 5, 6, 7, 8]
[1, 2, 3, 4, 7, 5, 6, -1, 8]
[1, 2, 3, 4, 5, -1, 6, 7, 8]
success
```

3) Implement Iterative deepening search algorithm.

```
from collections import defaultdict
class Graph:
    def __init__(self,vertices):
        self.V = vertices
        self.graph = defaultdict(list)
    def addEdge(self,u,v):
        self.graph[u].append(v)
    def DLS(self,src,target,maxDepth):
        if src == target : return True
        if maxDepth <= 0 : return False
        for i in self.graph[src]:
            if(self.DLS(i,target,maxDepth-1)):
                return True
        return False
    def IDDFS(self,src, target, maxDepth):
        for i in range(maxDepth):
            if (self.DLS(src, target, i)):
                return True
        return False
g = Graph (7);
g.addEdge(0, 1)
g.addEdge(0, 2)
g.addEdge(1, 3)
g.addEdge(1, 4)
g.addEdge(2, 5)
g.addEdge(2, 6)
target = 6; maxDepth = 3; src = 0
if g.IDDFS(src, target, maxDepth) == True:
    print ("Target is reachable from source within max depth")
else :
    print ("Target is NOT reachable from source within max depth")
```

OUTPUT

```
Enter number of elements : 9
Enter source elements
1
2
3
-1
4
5
6
7
8
Enter target elements
1
2
3
4
5
-1
6
7
8
True
```

4) Implement A* search algorithm.

```
from collections import deque
class Graph:
    def __init__(self, adjac_lis):
        self.adjac_lis = adjac_lis
    def get_neighbors(self, v):
        return self.adjac_lis[v]
    def h(self, n):
        H = {
            'A': 1,
            'B': 1,
            'C': 1,
            'D': 1
        }
        return H[n]
    def a_star_algorithm(self, start, stop):
        open_lst = set([start])
        closed_lst = set([])
        poo = {}
        poo[start] = 0
        par = {}
        par[start] = start
        while len(open_lst) > 0:
            n = None
            for v in open_lst:
                if n == None or poo[v] + self.h(v) < poo[n] + self.h(n):
                    n = v;
            if n == None:
                print('Path does not exist!')
                return None
            if n == stop:
                reconst_path = []
```

```
                while par[n] != n:
                    reconst_path.append(n)
                    n = par[n]
                reconst_path.append(start)
                reconst_path.reverse()
                print('Path found: {}'.format(reconst_path))
                return reconst_path
            for (m, weight) in self.get_neighbors(n):
                if m not in open_lst and m not in closed_lst:
                    open_lst.add(m)
                    par[m] = n
                    poo[m] = poo[n] + weight
                else:
                    if poo[m] > poo[n] + weight:
                        poo[m] = poo[n] + weight
                        par[m] = n
                        if m in closed_lst:
                            closed_lst.remove(m)
                            open_lst.add(m)
            open_lst.remove(n)
            closed_lst.add(n)
        print('Path does not exist!')
    return None
```

OUTPUT

```
enter the start state matrix

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

1 2 3
4 5 6
7 8 _



==================================================

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

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

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

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

5) Write a program to implement Simulated Annealing Algorithm

```
import math
import random
def objective_function(x):
    return math.sin(x) * (1 + 0.1 * x)
def simulated_annealing(initial_solution, temperature, cooling_rate, max_iterations):
    current_solution = initial_solution
    current_energy = objective_function(current_solution)
    for iteration in range(max_iterations):
        temperature *= cooling_rate
        neighbor_solution = current_solution + random.uniform(-1, 1)
        neighbor_energy = objective_function(neighbor_solution)
        energy_difference = neighbor_energy - current_energy
        if energy_difference < 0 or random.uniform(0, 1) < math.exp(-energy_difference / temperature):
            current_solution = neighbor_solution
            current_energy = neighbor_energy
    return current_solution, current_energy
initial_solution = 2.0
initial_temperature = 1.0
cooling_rate = 0.95
max_iterations = 1000
final_solution, final_energy = simulated_annealing(initial_solution, initial_temperature, cooling_rate, max_iterations)
print(f"Final Solution: {final_solution}")
print(f"Final Energy: {final_energy}")
```

OUTPUT:

```
Final Solution: -1.454347370686816
Final Energy: -0.848777701446893
```

6)Implement vaccum cleaner agent.

```
import random
def display(room):
    print(room)
room = [
    [1, 1, 1, 1],
    [1, 1, 1, 1],
    [1, 1, 1, 1],
    [1, 1, 1, 1],
]
print("All the rooom are dirty")
display(room)
x =0
y= 0
while x < 4:
    while y < 4:
        room[x][y] = random.choice([0,1])
        y+=1
    x+=1
    y=0
print("Before cleaning the room I detect all of these random dirts")
display(room)
x =0
y= 0
z=0
while x < 4:
    while y < 4:
        if room[x][y] == 1:
            print("Vaccum in this location now,",x, y)
            room[x][y] = 0
            print("cleaned", x, y)
```

```
            z+=1
        y+=1
    x+=1
    y=0
pro= (100-((z/16)*100))
print("Room is clean now, Thanks for using : 3710933")
display(room)
print('performance=',pro,'%')
```

OUTPUT

```
Enter Location of VacuumA
Enter status of A1
Enter status of other room1
Initial Location Condition{'A': '0', 'B': '0'}
Vacuum is placed in Location A
Location A is Dirty.
Cost for CLEANING A 1
Location A has been Cleaned.
Location B is Dirty.
Moving right to the Location B.
COST for moving RIGHT2
COST for SUCK 3
Location B has been Cleaned.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 3
```

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

```
def tell(kb, rule):
    kb.append(rule)
combinations = [(True, True, True), (True, True, False),
                (True, False, True), (True, False, False),
                (False, True, True), (False, True, False),
                (False, False, True), (False, False, False)]
def ask(kb, q):
    for c in combinations:
        s = all(rule(c) for rule in kb)
        f = q(c)
        print(s, f)
        if s != f and s != False:
            return 'Does not entail'
    return 'Entails'
kb = []
# Get user input for Rule 1
rule_str = input("Enter Rule 1 as a lambda function (e.g., lambda x: x[0] or x[1] and (x[0] and x[1]): ")
r1 = eval(rule_str)
tell(kb, r1)


# Get user input for Rule 2
#rule_str = input("Enter Rule 2 as a lambda function (e.g., lambda x: (x[0] or x[1]) and x[2]): ")
#r2 = eval(rule_str)
#tell(kb, r2)


# Get user input for Query
query_str = input("Enter Query as a lambda function (e.g., lambda x: x[0] and x[1] and (x[0] or x[1]): ")
```

```
q = eval(query_str)

# Ask KB Query
result = ask(kb, q)
print(result)
```

OUTPUT:

```
Shell                                                              Clear
Enter Rule 1 as a lambda function (e.g., lambda x: x[0] or x[1] and (x[0] and x[1]):
    lambda x: (x[0] or x[1]) and ( not x[2] or x[0])
Enter Query as a lambda function (e.g., lambda x: x[0] and x[1] and (x[0] or x[1]): lambda
    x: (x[0] and x[2])
True True
True False
Does not entail
>
```

8) 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

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)
```

OUTPUT:

Shell Clear

```
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.
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.
```

9) Implement unification in first order logic.

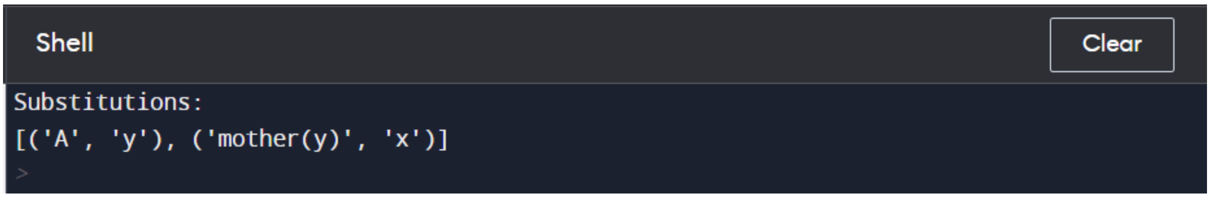
```
import re
def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression[:-1]
    expression = re.split("(?<!\(.),(?!.\))", expression)
    return expression

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(A,x)"
exp2 = "knows(y,mother(y))"
substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

OUTPUT:



10) Convert a given first order logic statement into Conjunctive Normal Form (CNF).

```
import re
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~]+\([A-Za-z,]+\)'
    return re.findall(expr, string)

def Skolemization(statement):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    matches = re.findall('[∃].', statement)
    for match in matches[::-1]:
        statement = statement.replace(match, '')
        for predicate in getPredicates(statement):
            attributes = getAttributes(predicate)
            if ''.join(attributes).islower():
                statement = statement.replace(match[1],SKOLEM_CONSTANTS.pop(0))
    return statement

def fol_to_cnf(fol):
    statement = fol.replace("=>", "-")
    expr = '\[([^]]+)\]'
    statements = re.findall(expr, statement)
    print(statements)
    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
    return Skolemization(statement)

print(fol_to_cnf("bird(x)=>~fly(x)"))
print(fol_to_cnf("∃x[bird(x)=>~fly(x)]"))
```

OUTPUT:

```
Shell                                                     Clear
[]
~bird(x)|~fly(x)
['bird(x)-~fly(x)']
[]
[~bird(A)|~fly(A)]
```

11) 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('king(x)&greedy(x)=>evil(x)')
kb_.tell('king(John)')
kb_.tell('greedy(John)')
kb_.tell('king(Richard)')
kb_.query('evil(x)')
```

OUTPUT:

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