VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT on

Artificial Intelligence LAB

Submitted by

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in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

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(Autonomous Institution under VTU)

B. M. S. College of Engineering,

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(Affiliated To Visvesvaraya Technological University, Belgaum)

Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled "Artificial Intelligence lab" carried out by **Rahul Raj (1BM21CS158),** who is a bonafide student of **B. M. S. College of Engineering.** It is inpartial 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 an **Artificial Intelligence lab (22CS5PCAIN)** work prescribed for the said degree.

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Program 1:

Implement the vacuum cleaner program(20/11/23)

```
 def vacuum_world():
 # initializing goal_state
 # 0 indicates Clean and 1 indicates Dirty
goal_state = {'A': '0', 'B': '0'}      cost = 0
   location_input = input("Enter Location of Vacuum") #user_input of location vacuum is placed
status_input = input("Enter status of " + location_input) #user_input if location is dirty or clean
status_input_complement = input("Enter status of other room")
   print("Initial Location Condition" + str(goal_state))
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
          goal_state['A'] = '0'             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
             goal_state['B'] = '0'                 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               goal_state['B'] = '0'
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
           goal_state['B'] = '0'             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
            goal_state['A'] = '0'                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
           goal_state['A'] = '0'             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))

vacuum_world()
```

Date 20/11/23
Page

Program - 1

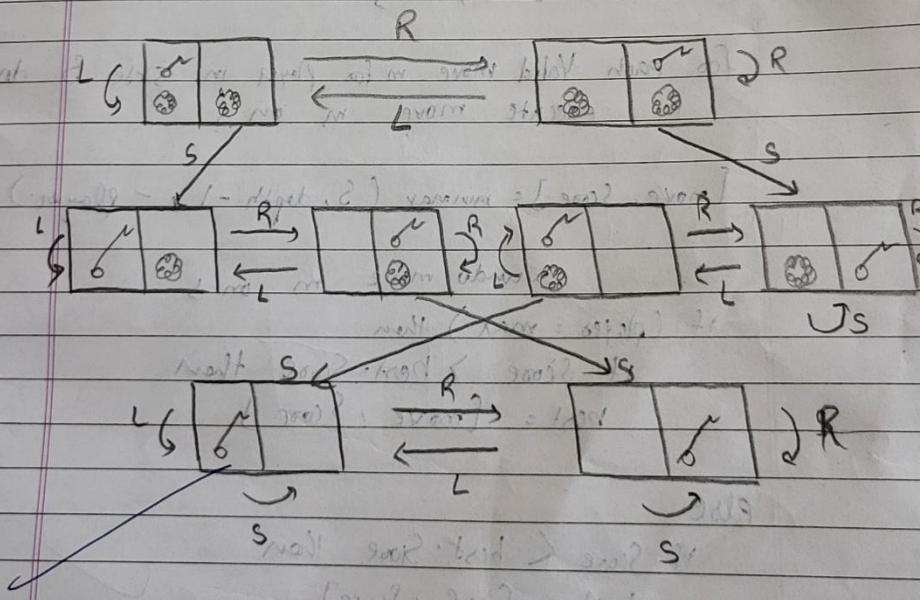
Vaccum Cleaner Agent

Algorithm :-

function REFLEX-VACCUM-AGENT ([location, status])
returns an action

if status = Dirty then return Suck
elseif location = A then return Right
else if location = B then return Left.

State Space Tree :-



Output at the Back : 03

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.
```

Program 2:

Implement the 8 Puzzle Bíeadth Ïiíst Seaích Algoíithm.(11/12/23)

```
import numpy as np import
pandas as pd
import os

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

   return temp  # Return the modified state

def possible_moves(state, visited_states):
   b = state.index(0)
   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 bfs(src, target):
   queue = []
queue.append(src)     cost=0

   exp = []
```

```
   while len(queue) > 0:
source = queue.pop(0)
exp.append(source)
print("queue")         for q in
queue:
          print(q)
          print("-----------***-----------")

        print(source[0],'|',source[1],'|',source[2])
print(source[3],'|',source[4],'|', source[5])          print(source[6],'|',
source[7],'|',source[8])
        print()
        cost=cost+1

        if source == target:
print("success")             print("path
cost",cost)
            return

        poss_moves_to_do = possible_moves(source, exp)

        for move in poss_moves_to_do:              if
move not in exp and move not in queue:
queue.append(move)

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

27/11/25

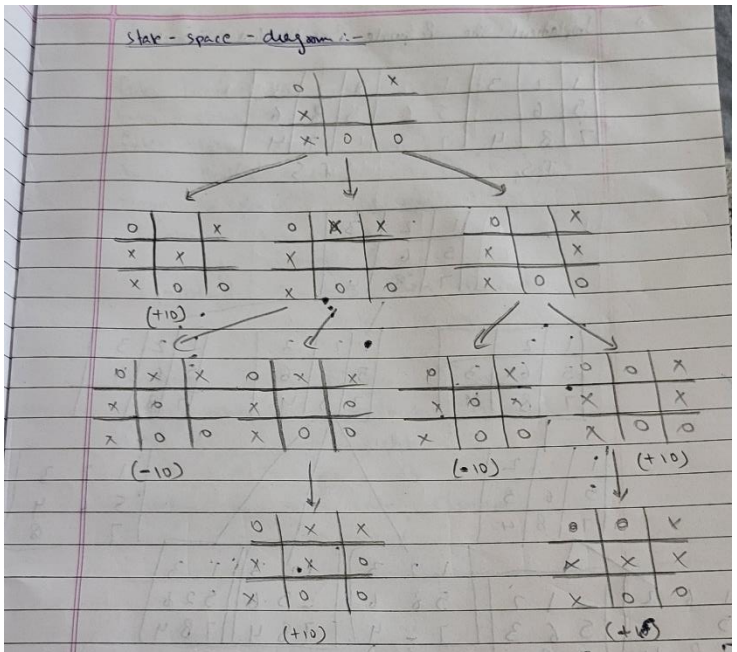
Program - 02

Implement Tic-Tak-Toe game :-

Algorithm :-

```
MinMax (state, depth, player)
  if (player = max),
  then
      best = [null, -infinity]
  else
      best = [null, +infinity]
  if [depth = 0 or gameover] then
  Score = evaluate this state for player
      return [null, score]

  for each valid move m for player in state S do
        execute move m on s
  [move, score] = minmax (S, depth-1, -player)
        undo move m on s
  if (player = max) then
      if score > best.score then
        best = [move, score]
  else
      if score < best.score then
        best = [move, score]
  return best
```

State - space - diagram :-



Output : Enter row : 1
Enter column : 2
- | - | - 0 -
- | - | - X
||

Enter row : 2
Enter column : 0

Enter row : 0
Enter column : 0
X - | - | - | - 0 - 0
- 0 - | - | - X
||

Output

```
queue
[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]
----------***------------
0 | 2 | 3
1 | 5 | 6
4 | 7 | 8

queue
[1, 2, 3, 4, 0, 6, 7, 5, 8]
----------***------------
[1, 2, 3, 4, 5, 6, 7, 8, 0]
----------***------------
[2, 0, 3, 1, 5, 6, 4, 7, 8]
----------***------------
1 | 2 | 3
5 | 0 | 6
4 | 7 | 8

queue
[1, 2, 3, 4, 5, 6, 7, 8, 0]
----------***------------
[2, 0, 3, 1, 5, 6, 4, 7, 8]
----------***------------
[1, 0, 3, 5, 2, 6, 4, 7, 8]
----------***------------
[1, 2, 3, 5, 7, 6, 4, 0, 8]
----------***------------
[1, 2, 3, 5, 6, 0, 4, 7, 8]
----------***------------
1 | 2 | 3
4 | 0 | 6
7 | 5 | 8

queue
[2, 0, 3, 1, 5, 6, 4, 7, 8]
----------***------------
[1, 0, 3, 5, 2, 6, 4, 7, 8]
----------***------------
[1, 2, 3, 5, 7, 6, 4, 0, 8]
----------***------------
[1, 2, 3, 5, 6, 0, 4, 7, 8]
----------***------------
[1, 0, 3, 4, 2, 6, 7, 5, 8]
----------***------------
[1, 2, 3, 0, 4, 6, 7, 5, 8]
----------***------------
[1, 2, 3, 4, 6, 0, 7, 5, 8]
----------***------------
1 | 2 | 3
4 | 5 | 6
7 | 8 | 0

success
path cost 7
```

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

queue
[1, 2, 3, 4, 5, 6, 7, 0, 8]
----------***------------
1 | 2 | 3
0 | 5 | 6
4 | 7 | 8

queue
[0, 2, 3, 1, 5, 6, 4, 7, 8]
----------***------------
[1, 2, 3, 5, 0, 6, 4, 7, 8]
----------***------------
1 | 2 | 3
4 | 5 | 6
7 | 0 | 8
```

Program 3:
Exploíe the woíking of I'ic I'ac I'oe using Min max stíategy. (11/12/23)

```
board = [[" ", " ", " "], [" ", " ", " "], [" ", " ", " "]]
print("0,0|0,1|0,2")
print("1,0|1,1|1,2")
print("2,0|,2,1|2,2 \n\n")
def print_board(): for
row in board:
print("|".join(row))
    print("-" * 5)

def check_winner(player):   for i in range(3):      if all([board[i][j] == player for j in
range(3)]) or all([board[j][i] == player for j in range(3)]):        return True

  if all([board[i][i] == player for i in range(3)]) or all([board[i][2 - i] == player for i in range(3)]):
return True
  return False

def is_full(): return all([cell != " " for row in board
for cell in row])

def minimax(depth, is_maximizing):
if check_winner("X"):
    return -1 if
check_winner("O"):
    return 1 if
is_full():     return
0 if
is_maximizing:
    max_eval = float("-inf")
for i in range(3):       for j
in range(3):         if
board[i][j] == " ":
board[i][j] = "O"
          eval = minimax(depth + 1, False)
board[i][j] = " "
          max_eval = max(max_eval, eval)
return max_eval  else:
    min_eval = float("inf")
    for i in range(3):
for j in range(3):         if
```

```
board[i][j] == " ":
board[i][j] = "X"
            eval = minimax(depth + 1, True)
board[i][j] = " "
            min_eval = min(min_eval, eval)

    return min_eval

def ai_move():
best_move = None
  best_eval = float("-inf") for i
in range(3):     for j in
range(3):       if board[i][j] == "
":          board[i][j] = "O"
eval = minimax(0, False)
board[i][j] = " "          if eval >
best_eval:            best_eval =
eval
          best_move = (i, j)

  return best_move

while not is_full() and not check_winner("X") and not check_winner("O"):
print_board() row = int(input("Enter row (0, 1, or 2): ")) col =
int(input("Enter column (0, 1, or 2): ")) if board[row][col] == " ":
board[row][col] = "X"     if check_winner("X"):       print_board()
print("You win!")       break     if is_full():       print_board()       print("It's a
draw!")       break
    ai_row, ai_col = ai_move()
board[ai_row][ai_col] = "O"
if check_winner("O"):
print_board()       print("AI
wins!")
      break

  else:
    print("Cell is already occupied. Try again.")
```

27/11/22

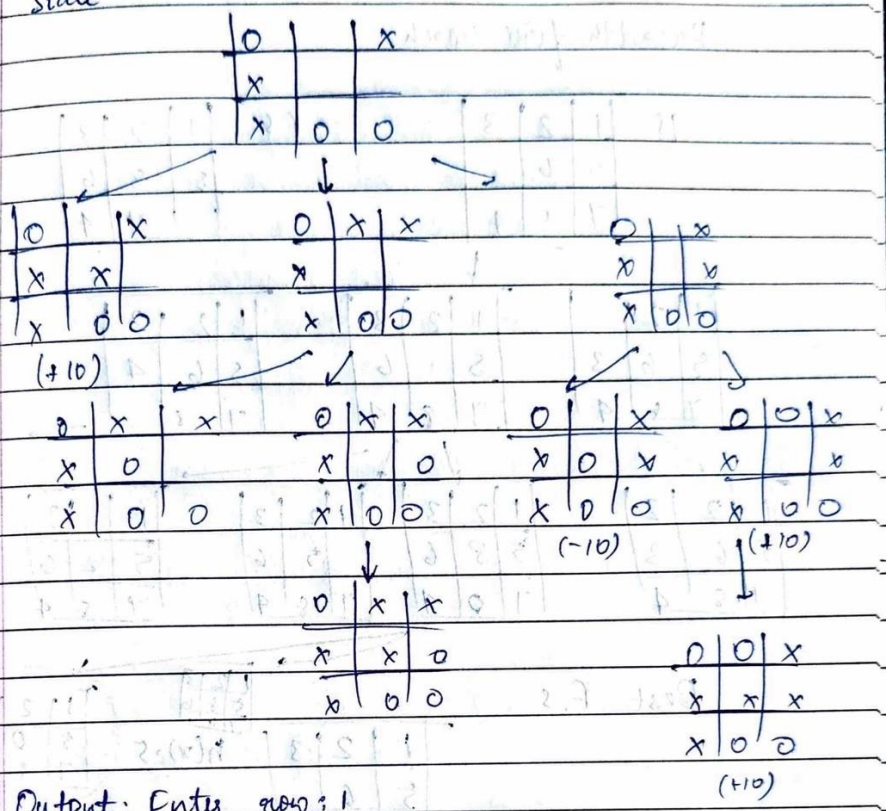
program 02

Implement Tic-Tac-Toe game

Algorithm:

```
MinMax( state , depth , player)
    if ( player = max ) then
        best = [null, -infinity]
    else
        best = [null, +infinity]
    if ( depth = 0 . or gameover ) then
        score = evaluate this state for player
        return [null, score]
    for each valid move m for player in state s
    do execute move m on s
    [move, score] = minmax (s, depth-1, -player)
    Undo move mv on s
    if ( player = max ) then
        if score > best, score then
        best = [move, score]
    else
        if score < best.score then
            best = [move, score]
    return best.
```

State



Output: Enter row: 1
Enter column: 2
_1_1_0_
_1_1_X
11

Enter row: 0
Enter column: 0
X_1_1_0_
_0_1_1_X
11

Enter row: 2
Enter column: 0
_0_1_1_0_
_X_1_0_1_X
X 1 0 1 X

Enter row: 0
Enter column: 1
_0_1_X_1_0
_0_1_0_1_X
X 1 0 1 X
ets a draw.

output

```
 0,0|0,1|0,2
 1,0|1,1|1,2
 2,0|,2,1|2,2


  | |
-----
  | |
-----
  | |
-----
Enter row (0, 1, or 2): 1
Enter column (0, 1, or 2): 1
O| |
-----
 |X|
-----
  | |
-----
Enter row (0, 1, or 2): 0
Enter column (0, 1, or 2): 2
O| |X
-----
 |X|
-----
O| |
-----
Enter row (0, 1, or 2): 1
Enter column (0, 1, or 2): 0
O| |X
-----
X|X|O
-----
O| |
-----
Enter row (0, 1, or 2): 2
Enter column (0, 1, or 2): 1
O|O|X
-----
X|X|O
-----
O|X|
-----
Enter row (0, 1, or 2): 2
Enter column (0, 1, or 2): 2
O|O|X
-----
X|X|O
-----
O|X|X
-----
It's a draw!
```

Program 4:

Implement Iteíative deepening seaích algoíithm.(18/12/23) from collections import defaultdict

```
# This class represents a directed graph using adjacency
# list representation class
Graph:

    def__init_(self,vertices):

        # No. of vertices
        self.V = vertices

        # default dictionary to store graph
self.graph = defaultdict(list)
        self.ans = list()

    # function to add an edge to graph
def                    addEdge(self,u,v):
self.graph[u].append(v)

    # A function to perform a Depth-Limited search
    # from given source 'src'     def
DLS(self,src,target,maxDepth,l):
        if src == target :
#  print(self.ans)
            return True

        # If reached the maximum depth, stop recursing.
        if maxDepth <= 0 : return False

        # Recur for all the vertices adjacent to this vertex
for i in self.graph[src]:
if(self.DLS(i,target,maxDepth-1,l)):
l.append(i)                    return True
        return False

    # IDDFS to search if target is reachable from v.
# It uses recursive DLS()
    def IDDFS(self,src, target, maxDepth):

        # Repeatedly depth-limit search till the
        # maximum depth
for i in range(maxDepth):
```

```
            l = []              if
(self.DLS(src, target, i,l)):
l.append(src)
                l.reverse()
return l          return l

# Create a graph given in the above diagram n,e = map(int
,input("Enter no.of vertices and edges").split()) g = Graph
(n); for i in range(e):      a,b = map(int , input().split())
g.addEdge(a,b)

# 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 = int(input("Enter the target vertex")) maxDepth
= int(input("Enter the max depth"))
src = 0 l = g.IDDFS(src, target,
maxDepth)  if len(l)!=0:      print(l)
    print ("Target is reachable from source " +
        "within max depth") else
:
    print ("Target is NOT reachable from source " +
        "within max depth")
```

18/12/23

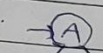
Program - 03.

Implement Iterative deepening A* algorithm

Algorithm :

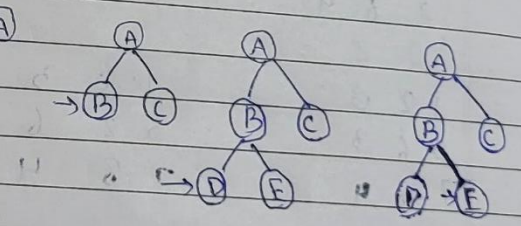
function Iterative_Deepening_search (problem)
return a solution or failure
for depth = 0 to ∞
result ← Depth-Limited-Search (problem, depth)
if result ≠ Cutoff then return result.

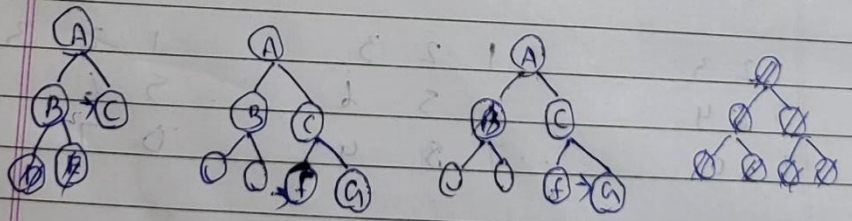
limit = 0



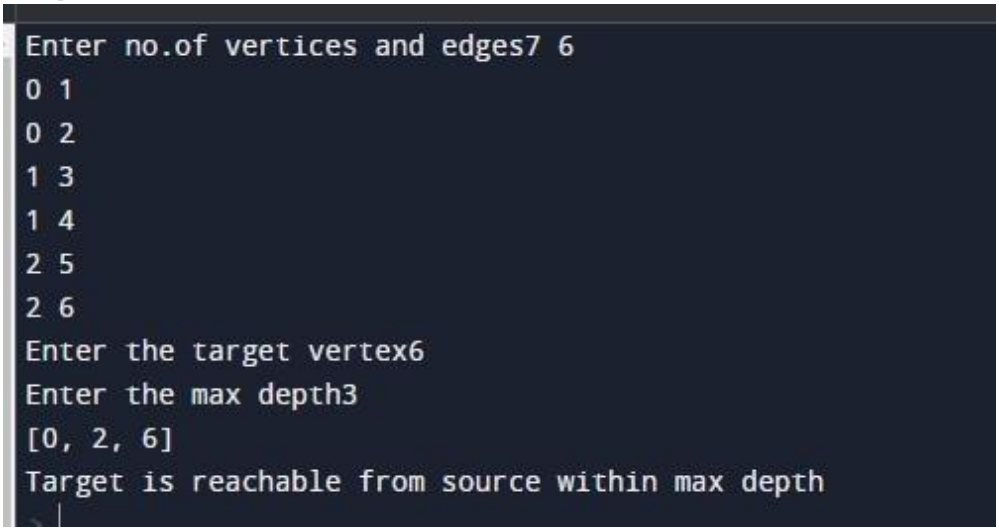
limit = 1

limit = 2





output


Enter no.of vertices and edges7 6
0 1
0 2
1 3
1 4
2 5
2 6
Enter the target vertex6
Enter the max depth3
[0, 2, 6]
Target is reachable from source within max depth

Program 5:

Implement A* foí 8 puzzle píoblem(8/1/24)

```
# Online Python compiler (interpreter) to run Python online.
# Write Python 3 code in this online editor and run it.
class Node:     def__init__(self,data,level,fval):
self.data = data         self.level = level
        self.fval = fval

    def generate_child(self):         x,y =
self.find(self.data,'_')         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):         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):
        temp = []
for i in root:
            t = []
for j in i:
                t.append(j)
temp.append(t)
        return temp

    def find(self,puz,x):         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):
        self.n = size
self.open = []
self.closed = []

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

    def f(self,start,goal):         return
self.h(start.data,goal)+start.level

    def h(self,start,goal):
        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):         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)
        self.open.append(start)

        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(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.process()
```

Program 5

Implement A* for 8 puzzle.

Algorithm:-

Initialize the open list

Initialize the closed list

put starting node on open list

While open list is not empty

(a) find node with least f on open list, call it 'q'

(b) pop q off open list

(c) generate q's successors & set parent to q

(d) for each successor

(i) if successor is goal, stop search

(ii) else, compute for h & g.

successor.g = q.g + dist b/w successor & goal

(iii) if a node with same position as successor is in open list which has a lower f than successor then skip.

end (for loop)

(e) push q on the closed list

Output:

Enter vals, - [1, 2, 3, 5, 6, 0, 7, 8, 4]

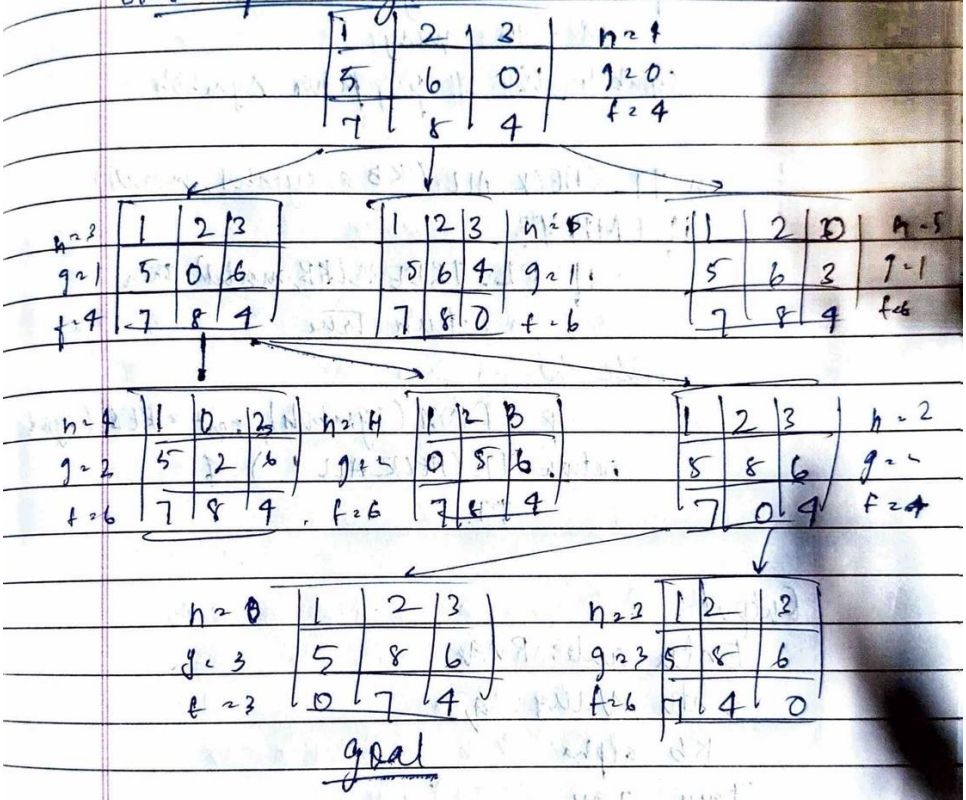
Enter val for goal state - [1, 2, 3, 5, 8, 6, 0, 7, 4]

```
1 2 3        1 2 3        1 2 3
5 6 0  →     5 0 6  →     5 8 6
7 8 4        7 8 4        7 0 4
```

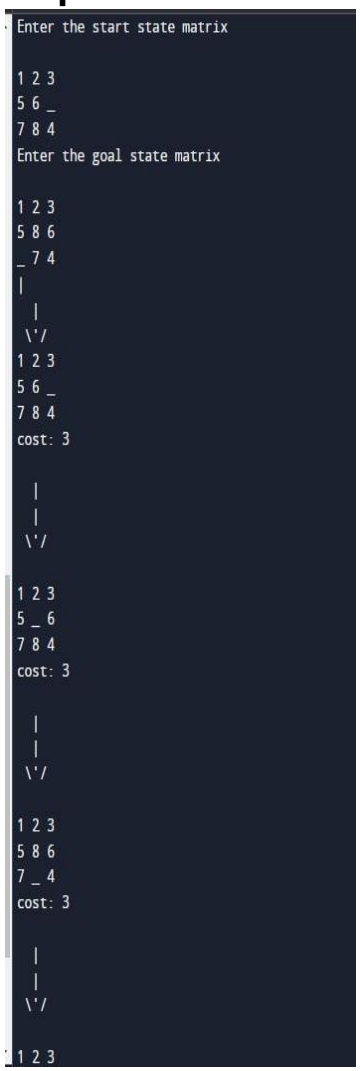
1 2 3
5 8 6
0 7 4

Steps to reach goal = 3
Total nodes visited = 3

State-space diagram:



output



Program 6:

Creation of Knowledge Base using prepositional logic and show that the query entails the KB or not (22/1/24)

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)] variable={'p':0,'q':1, 'r':2} kb='' q='' priority={'~':3,'v':1,'^':2} def input_rules(): global

```
kb, y     kb = (input("Enter rule: "))     y = input("Enter the Query: ") def entailment():
global kb, q
   print('*'*10+"Truth Table Reference"+'*'*10)
print('kb','alpha')     print('*'*10)     for comb in
combinations:         s =
evaluatePostfix(toPostfix(kb), comb)
        f = evaluatePostfix(toPostfix(y), comb)
print(s, f)         print('-'*10)         if s and not
f:             return False     return True def
isOperand(c):
   return c.isalpha() and c!='v'

def isLeftParanthesis(c):
   return c == '('

def isRightParanthesis(c):
   return c == ')'

def isEmpty(stack):
   return len(stack) == 0

def peek(stack):
return stack[-1]

def hasLessOrEqualPriority(c1, c2):
try:
        return priority[c1]<=priority[c2]     except
KeyError:         return False def toPostfix(infix):
stack = []     postfix = ''     for c in infix:         if
isOperand(c):             postfix += c         else:
if isLeftParanthesis(c):
stack.append(c)             elif
isRightParanthesis(c):                 operator =
stack.pop()                 while not
isLeftParanthesis(operator):
                    postfix += operator                     operator = stack.pop()             else:
while (not isEmpty(stack)) and hasLessOrEqualPriority(c, peek(stack)):
                    postfix += stack.pop()
stack.append(c)     while (not
isEmpty(stack)):         postfix +=
stack.pop()

   return postfix def
evaluatePostfix(exp, comb):
stack = []     for i in exp:         if
isOperand(i):
```

```
            stack.append(comb[variable[i]])
elif i == '~':
            val1 = stack.pop()
stack.append(not val1)          else:
            val1 = stack.pop()              val2
= stack.pop()
stack.append(_eval(i,val2,val1))
return stack.pop() def _eval(i, val1,
val2):
    if i == '^':
        return val2 and val1
return val2 or val1

input_rules() ans = entailment() if ans:
print("The Knowledge Base entails query")
else:
    print("The Knowledge Base does not entail query")
```

output:

```
Enter rule: (pvq)^(p^~r)
Enter the Query: p
**********Truth Table Reference**********
kb alpha
**********
False True
----------
True True
----------
False True
----------
True True
----------
False False
----------
False False
----------
False False
----------
False False
----------
The Knowledge Base entails query
>
```

Program - 6

Entailment

Algorithm:

function TT-entails? (KB, α) return true or false
input: KB, the knowledge Base.
α, the query a sentence.
Symbols: a list of the proposition Symbols in KB & α.

function TT-check-all (KB, α, symbols, model)
return true or false if empty?
(Symbols) then.

If PL-true? (KB, model) then return
PL-true? (α, model) else return true
else do.
P = first (symbols); rest = REST (symbols)
return TT-check-all (KB, α, test, extend
(P, true, model), and
TT-check-all (KB, α, rest, extend
(P, false, model))

output: Enter: pvq
Enter query: q

*** Truth Table Reference ***

KB alpha
* * *
True True
True True
True false => knowledge base doesn't entail query

Truth Table:

P	q	pVq
T	T	T
T	f	T
f	T	T
f	f	f

pVq ⊭ q

Resolution.

Algorithm:

function PL- Resolution (KB, α) return true or

inputs: KB, the knowledge base, a sentence in propositional logic. α, the query a sentence in propositional logic

clauses ← the set of clauses in the CNF representation of KB ∧ ¬α

new ← { }

Program 7:

Creation of Knowledge Base using prepositional logic and prove the query using resolution(22/1/24)

```
kb = []


def CLEAR():
global kb
    kb = []


def TELL(sentence):
global kb
    # If the sentence is a clause, insert directly.
if isClause(sentence):
kb.append(sentence)
    # If not, convert to CNF, and then insert clauses one by one.
else:
        sentenceCNF = convertCNF(sentence)
if not sentenceCNF:             print("Illegal
input")             return
        # Insert clauses one by one when there are multiple clauses
if isAndList(sentenceCNF):              for s in sentenceCNF[1:]:
kb.append(s)         else:
            kb.append(sentenceCNF)


def ASK(sentence):
global kb

    # Negate the sentence, and convert it to CNF accordingly.
    if isClause(sentence):
        neg = negation(sentence)
else:
        sentenceCNF = convertCNF(sentence)
        if not sentenceCNF:
print("Illegal input")              return
        neg = convertCNF(negation(sentenceCNF))
```

```
   # Insert individual clauses that we need to ask to ask_list.
   ask_list = []     if
isAndList(neg):
for n in neg[1:]:
           nCNF = makeCNF(n)            if
type(nCNF).__name__== 'list':
               ask_list.insert(0, nCNF)
else:
               ask_list.insert(0, nCNF)
else:         ask_list = [neg]
clauses = ask_list + kb[:]     while
True:
       new_clauses = []
for c1 in clauses:
for c2 in clauses:
if c1 is not c2:
                   resolved = resolve(c1, c2)
if resolved == False:
                      continue
if resolved == []:
return True
                   new_clauses.append(resolved)

       if len(new_clauses) == 0:
           return False

       new_in_clauses = True
for n in new_clauses:            if n
not in clauses:
new_in_clauses = False
               clauses.append(n)

       if           new_in_clauses:
return False     return False


def resolve(arg_one, arg_two):
resolved = False

   s1 = make_sentence(arg_one)
```

```
    s2 = make_sentence(arg_two)

    resolve_s1 = None
resolve_s2 = None

    # Two for loops that iterate through the two clauses.
for i in s1:         if isNotList(i):             a1 = i[1]
a1_not = True         else:             a1 = i
            a1_not = False
        for j in s2:             if
isNotList(j):                 a2
= j[1]                a2_not =
True             else:
a2 = j                a2_not
= False

            # cancel out two literals such as 'a' $ ['not', 'a']
if a1 == a2:                 if a1_not != a2_not:
                # Return False if resolution already happend
# but contradiction still exists.                     if resolved:
return False                     else:
                    resolved = True
resolve_s1 = i                         resolve_s2
= j                         break
                # Return False if not resolution happened
if not resolved:         return False

    # Remove the literals that are canceled
s1.remove(resolve_s1)     s2.remove(resolve_s2)

    # # Remove duplicates     result
= clear_duplicate(s1 + s2)

    # Format the result.
if len(result) == 1:
return result[0]     elif
len(result) > 1:
result.insert(0, 'or')

    return result
```

```
def make_sentence(arg):     if
isLiteral(arg) or isNotList(arg):
return [arg]     if isOrList(arg):
return clear_duplicate(arg[1:])
   return


def clear_duplicate(arg):
result = []     for i in range(0,
len(arg)):         if arg[i] not in
arg[i+1:]:
result.append(arg[i])
return result


def isClause(sentence):
if isLiteral(sentence):
       return True
   if isNotList(sentence):
if isLiteral(sentence[1]):
           return True
else:
           return False
if isOrList(sentence):
       for i in range(1, len(sentence)):
if len(sentence[i]) > 2:
               return False             elif
not isClause(sentence[i]):
return False         return True
   return False


 def isCNF(sentence):
 if isClause(sentence):
       return True     elif
isAndList(sentence):
for s in sentence[1:]:
if not isClause(s):
return    False      return
True  return False
```

```
def negation(sentence):
if isLiteral(sentence):
return ['not', sentence]     if
isNotList(sentence):
return sentence[1]

   # DeMorgan:     if
isAndList(sentence):
result = ['or']         for i in
sentence[1:]:             if
isNotList(sentence):
result.append(i[1])
else:
               result.append(['not', sentence])           return
result    if isOrList(sentence):       result = ['and']       for
i  in  sentence[:]:                    if  isNotList(sentence):
result.append(i[1])                                        else:
result.append(['not',    i])    return    result
   return None


def convertCNF(sentence):     while
not isCNF(sentence):         if
sentence is None:            return
None         sentence =
makeCNF(sentence)
   return sentence


def makeCNF(sentence):
if isLiteral(sentence):
return sentence

   if (type(sentence).__name__== 'list'):
operand = sentence[0]         if isNotList(sentence):
if isLiteral(sentence[1]):                 return sentence
cnf = makeCNF(sentence[1])            if cnf[0] ==
'not':                return makeCNF(cnf[1])            if
cnf[0] == 'or':                result = ['and']
```

```
for i in range(1, len(cnf)):
result.append(makeCNF(['not', cnf[i]]))
            return result            if
cnf[0] == 'and':                result =
['or']              for i in range(1,
len(cnf)):
result.append(makeCNF(['not',
cnf[i]]))              return result
return "False: not"

      if operand == 'implies' and len(sentence) == 3:            return makeCNF(['or',
['not', makeCNF(sentence[1])], makeCNF(sentence[2])])

      if operand == 'biconditional' and len(sentence) == 3:
s1 = makeCNF(['implies', sentence[1], sentence[2]])
s2 = makeCNF(['implies', sentence[2], sentence[1]])
return makeCNF(['and', s1, s2])

      if isAndList(sentence):
          result = ['and']            for i in
range(1, len(sentence)):                cnf
= makeCNF(sentence[i])              #
Distributivity:              if
isAndList(cnf):                  for i in
range(1, len(cnf)):
                  result.append(makeCNF(cnf[i]))
continue
            result.append(makeCNF(cnf))
          return result

      if isOrList(sentence):
          result1 = ['or']            for i in
range(1, len(sentence)):                cnf
= makeCNF(sentence[i])              #
Distributivity:              if isOrList(cnf):
for i in range(1, len(cnf)):
                  result1.append(makeCNF(cnf[i]))
continue
result1.append(makeCNF(cnf))              #
Associativity:            while True:
```

```
result2 = ['and']                and_clause = None
for r in result1:                   if isAndList(r):
                    and_clause = r
break

            # Finish when there's no more 'and' lists
            # inside of 'or' lists
if not and_clause:
return result1

            result1.remove(and_clause)

            for i in range(1, len(and_clause)):
temp = ['or', and_clause[i]]                    for
o in result1[1:]:
                    temp.append(makeCNF(o))
result2.append(makeCNF(temp))                result1 =
makeCNF(result2)
          return None
   return None


def isLiteral(item):     if
type(item).__name__== 'str':
       return True
return False


def isNotList(item):
   if type(item).__name__== 'list':
if len(item) == 2:            if item[0]
== 'not':                return True
return False


def isAndList(item):
   if type(item).__name__== 'list':
if len(item) > 2:             if item[0]
== 'and':                return True
return False
```

```
def isOrList(item):
    if type(item).__name__== 'list':
if len(item) > 2:              if item[0]
== 'or':                 return True
    return False


CLEAR()

TELL('p')
TELL(['implies', ['and', 'p', 'q'], 'r'])
TELL(['implies', ['or', 's', 't'], 'q'])
TELL('t') print(ASK('r'))
```

Output

Program 7

Knowledge base using P.L & query using resolution

Algorithm -

function PL-RESOLUTION(KB, α) returns true or false
    ip : KB the knowledge base
        α - the query a sentence
    clauses ← the set of clauses in the CNF
    new ← {}
    loop do
        for each pair of clauses Ci, Cj in clauses do
            resolutions ← PL-RESOLVE(Ci, Cj)
            if resolvents contain empty clause then
                return true
            new ← new ∪ resolvents

Output: True

Proof:

P ∧ Q ⇒ R is converted to CNF

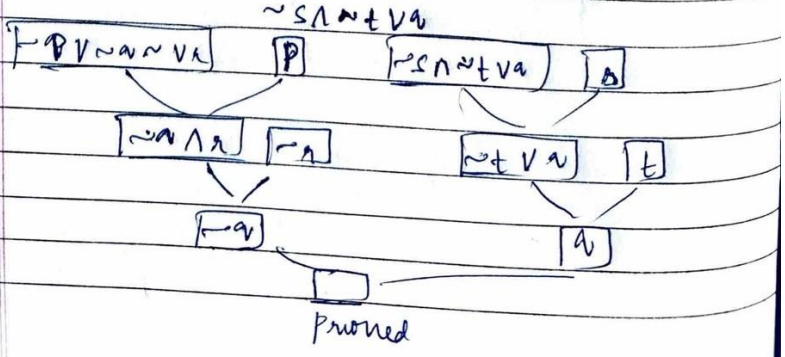
~(P ∧ Q) ∨ R

~(P ∨ ~Q) ∨ R

S ∨ T ⇒ A is converted to CNF.

~(S ∨ T) ∨ A

~S ∧ ~T ∨ A



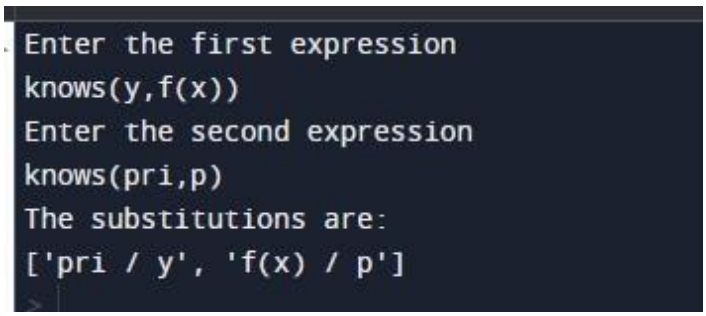
Program 8:

Implement unification in first order logic(29/1/24)

```
import re def
getAttributes(expression):
   expression = expression.split("(")[1:]
expression = "(".join(expression)
expression = expression.split(")")[:-1]
expression = ")".join(expression)
attributes = expression.split(',')    return
attributes

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)
predicate = getInitialPredicate(exp)    for
index, val in enumerate(attributes):       if
val == old:
          attributes[index] = new
   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:
          print(f"{exp1} and {exp2} are constants. Cannot be unified")
return []

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

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

   if isVariable(exp1):
      return [(exp2, exp1)] if not checkOccurs(exp1, exp2) else []

   if isVariable(exp2):
      return [(exp1, exp2)] if not checkOccurs(exp2, exp1) else []

   if getInitialPredicate(exp1) != getInitialPredicate(exp2):
      print("Cannot be unified as the predicates do not match!")
return []

   attributeCount1 = len(getAttributes(exp1))     attributeCount2 = len(getAttributes(exp2))     if
attributeCount1 != attributeCount2:        print(f"Length of attributes {attributeCount1} and
{attributeCount2} do not match. Cannot be unified")
      return []

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

```
      return []     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 []

   return initialSubstitution + remainingSubstitution
def main():     print("Enter the first expression")
e1 = input()
   print("Enter the second expression")
   e2 = input()     substitutions =
unify(e1, e2)     print("The
substitutions are:")
   print([' / '.join(substitution) for substitution in substitutions]) main()
```



Program 9

Unification in FOL

Algorithm:

Step 1: Begin making the substitute set empty
Step 2: Unify atomic sentences in a recursive
a) check for expressions are identical
b) If one exp is a variable v_i, & the other is a term t_i which does not contain variable v_i:
a) Substitute t_i/v_i in existing substitution.
b) Add t_i/v_i in existing substitutions
c) If both exps are functions, then function name must be similar & number of arguments must be same.

Output: Enter 1st exp: Knows(y, f(x))
Enter 2nd exp: Knows(NITIN, N)
Substitutions are:
['nithin/y', 'N/f(x)'].

Proof: Here, predicate is same
so by replacing y with NITHIN, we can unify both statements
Replace f(x) with N, unification is possible

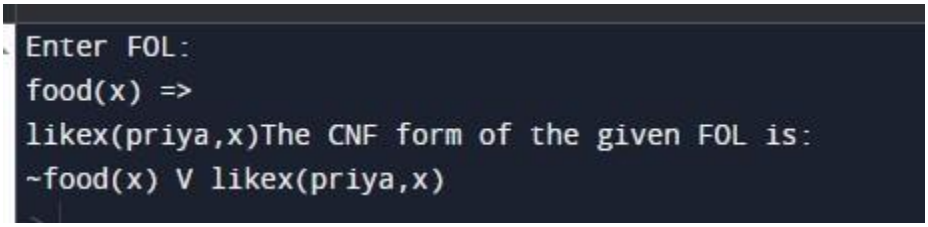
Program 9:

Convert a given first order logic statement into Conjunctive Normal Form (CNF).(29/1/24)

```
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
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
== 'V':            s[i] = '^'         elif c == '^':            s[i] = 'V'
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 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] + 'V' + 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 = '(~[∀V∃].)'
   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 def main():
print("Enter FOL:")     fol = input()
   print("The CNF form of the given FOL is: ")
print(Skolemization(fol_to_cnf(fol)))
main()
```



Program 1

Convert FOL into conjuctive Normal form (CNF)

Algorithm:

Step 1: Eliminate bi-conditionals ($\leftrightarrow$)
Step 2: Eliminate conditionals ($\rightarrow$)
Step 3: MOVE negation inward
Step 4: Standardize variables
Step 5: Skolemization
6: Distribute $\wedge$ over $\vee$
7: Move universal quantifiers outward
8: Convert to CNF

Output: Enter FOL

food(x) $\Rightarrow$ likes(pooja, x)

CNF form of given FOL is:

$\sim$ food(x) $\vee$ likes(pooja, x)

Proof: food(x) $\Rightarrow$ likes(pooja, x)

Remove conditionals by using

if $p \rightarrow q$

Then $\sim p \vee q$

$\therefore \sim$ food(x) $\vee$ likes(pooja, x)

Program 10:
Forward Chaining (29/1/24)

Code

```
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}') def main():      kb = KB()      print("Enter KB:
(enter e to exit)")      while True:          t = input()          if(t ==
'e'):              break
        kb.tell(t)
print("Enter Query:")      q
= input() kb.query(q)
kb.display() main()
```

Output

```
Enter KB: (enter e to exit)
missile(x) => weapon(x)
missile(m1)
enemy(x,america) => hostile(x)
american(west)
enemy(china,america)
owns(china,m1)
missile(x) & owns(china,x) => sells(west,x,china)
american(x)&weapon(y)&sells(x,y,z)&hostile(z)=>criminal(x)
e
Enter Query:
criminal(x)
Querying criminal(x):
    1. criminal(west)
All facts:
    1. weapon(m1)
    2. criminal(west)
    3. missile(m1)
    4. owns(china,m1)
    5. american(west)
    6. sells(west,m1,china)
    7. hostile(china)
    8. enemy(china,america)
>
```

Create KB consisting of FOL & prove given query using forward reasoning.

Program 10

1: Initialize the knowledge (KB):
- Start with an empty KB
- Add known FOL statements to KB

2: Initialize Agenda:
- Create an Agenda to store statements to processed.
- Add known facts & rules with satisfied

3: While Agenda is non empty:
- pop a statement from Agenda
- If the statement is query, then 'Query is true'
- If the statement is a fact:
  skip to next.
- If Statement is a rule with satisfied antecedent
  Apply rule to generate a new consequent
  Add new consequent to Agenda

4: Termination

Output: Enter KB: (enter e to exit)
missile(x) => weapon(x)
missile(m1)
enemy(x, america) => hostile(x)
enemy(china, america)
Own(china, m1)
missile(x) & Owns(china, x) => Sells(West, x, china)
Enter Query. criminal(x)
Querying criminal(x):
1) criminal(west)

All facts:	
criminal(west)	american(west)
weapon(m1)	hostile(china)
Owns(china, m1)	missile(m1)
enemy(china, america	
Sells(west, m1, china)	