VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT

On

ARTIFICIAL INTELLIGENCE

Submitted by

Kataraju M (1BM21CS088)

in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

in

COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING

(AutonomousInstitution under VTU)

BENGALURU-560019

Oct 2023-Feb 2024

B. M. S. College of Engineering,
Bull Temple Road, Bangalore 560019
(Affiliated To Visvesvaraya Technological University, Belgaum)
Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled “ARTIFICIAL INTELLIGENCE” carried out by Kataraju M (1BM21CS088), 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.

Dr. Asha G R	Dr. Jyothi S Nayak
Assistant Professor	Professor and Head
Department of CSE	Department of CSE
BMSCE, Bengaluru	BMSCE, Bengaluru

Table of Contents

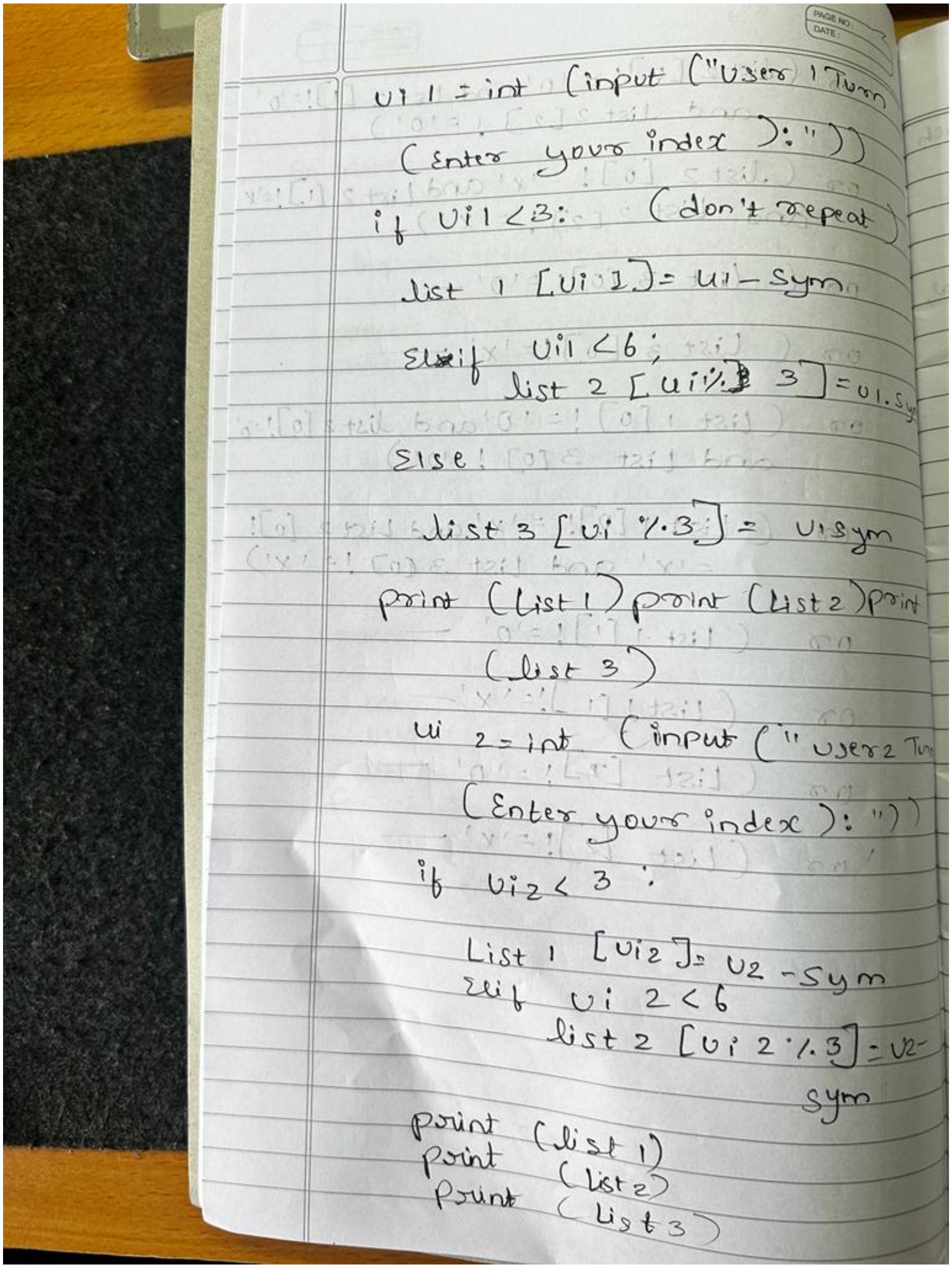
1.Implement Tic –Tac –Toe Game.

PAGE NO:
DATE: 17-11-23

AI - LAB-3

Qn write a python program to implement Tic - Tac - Toe

```
import random

print ("Tic-Tac-Toe")
print ("Index table ("choose your index
              while playing )")

Index = ''' 0  1  2
            3  4  5
            6  7  8
          '''

print (Index)

 list 1 = []
 list 2 = []
 list 3 = []
for i in range (3);
        list 1 [i] = i
        list 2 [i] = i+3
        list 3 [i] = i+6
u1-sym1 = input ("Enter your
          symbol ('0' /'x' ):" )
while ((list 1 [0] != '0' and List 1 [1]
          != '0' and List 1 [2] != '0')
     or (list 1 [0] != 'x' and List 1
          [1] != 'x' and list 1
          [2] != 'x')
```



```
ui 1 = int (input ("User 1 Turn
(Enter your index ):"))
if ui1 <3:          (don't repeat)
list 1 [ui 1] = u1-sym
Elif ui1 <6;
    list 2 [ui% 3] = u1.sym
Else:
list 3 [ui %3] = u1sym
print (List 1) print (List 2) print
    (list 3)
ui 2 = int (input ("user2 Turn
    (Enter your index ): "))
if ui2 < 3 :
    List 1 [ui2] = u2-sym
Elif ui 2 < 6
    list 2 [ui 2 %3] = u2-
                        sym
print (list 1)
print (list 2)
Print (List 3)
```

tic=[] import random

def board(tic):   for i

in range(0,9,3):

```
        print("+"+"-"*29+"+")         print("|"+" "*9+"|"+" "*9+"|"+" "*9+"|")
print("|"+" "*3,tic[0+i]," "*3+"|"+" "*3,tic[1+i]," "*3+"|"+" "*3,tic[2+i]," "*3+"|")
print("|"+" "*9+"|"+" "*9+"|"+" "*9+"|")     print("+"+"-"*29+"+")


def update_comp():     global
tic,num     for i in range(9):
if tic[i]==i+1:             num=i+1
tic[num-1]='X'             if
winner(num-1)==False:
#reverse the change
tic[num-1]=num
            else:
                return     for i in
range(9):         if tic[i]==i+1:
num=i+1             tic[num-1]='O'
if winner(num-1)==True:
                tic[num-
1]='X'                 return
else:                 tic[num-
1]=num

            num=random.randint(1,9)
    while num  not in tic:
        num=random.randint(1,9)
    else:
        tic[num-1]='X'
```

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

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



try:
    for i in range(1,10):
        tic.append(i)
count=0     #print(tic)
board(tic)     while
count!=9:         if
count%2==0:
print("computer's turn :")
            update_comp()
            board(tic)
count+=1         else:
            print("Your turn
:")            update_user()
```

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

OUTPUT:

```
[1, 2, 3, 4, 5, 6, 7, 8, 9]
+-------+-------+-------+
|       |       |       |
|   1   |   2   |   3   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   4   |   5   |   6   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   7   |   8   |   9   |
|       |       |       |
+-------+-------+-------+
Computer's turn:
+-------+-------+-------+
|       |       |       |
|   1   |   2   |   3   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   4   |   X   |   6   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   7   |   8   |   9   |
|       |       |       |
```

```
Your turn:
Enter a number on the board: 3
+-------+-------+-------+
|       |       |       |
|   1   |   2   |   O   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   4   |   X   |   6   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   7   |   8   |   9   |
|       |       |       |
+-------+-------+-------+
Computer's turn:
+-------+-------+-------+
|       |       |       |
|   1   |   2   |   O   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   X   |   X   |   6   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   7   |   8   |   9   |
|       |       |       |
```

```
Your turn:
Enter a number on the board: 6
+-------+-------+-------+
|       |       |       |
|   1   |   2   |   O   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   X   |   X   |   O   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   7   |   8   |   9   |
|       |       |       |
+-------+-------+-------+
Computer's turn:
+-------+-------+-------+
|       |       |       |
|   1   |   2   |   O   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   X   |   X   |   O   |
|       |       |       |
+-------+-------+-------+
|       |       |       |
|   7   |   8   |   X   |
|       |       |       |
```

```
Your turn:
Enter a number on the board: 1
+-----------------------------+
|         |         |         |
|    O    |    2    |    O    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    X    |    X    |    O    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    8    |    X    |
|         |         |         |
+-----------------------------+
Computer's turn:
+-----------------------------+
|         |         |         |
|    O    |    2    |    O    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    X    |    X    |    O    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    X    |    X    |
|         |         |         |
+-----------------------------+
```

```
Your turn:
Enter a number on the board: 2
+-----------------------------+
|         |         |         |
|    O    |    O    |    O    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    X    |    X    |    O    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    7    |    X    |    X    |
|         |         |         |
+-----------------------------+
Computer's turn:
+-----------------------------+
|         |         |         |
|    O    |    O    |    O    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    X    |    X    |    O    |
|         |         |         |
+-----------------------------+
|         |         |         |
|    X    |    X    |    X    |
|         |         |         |
+-----------------------------+
Winner is X
```

2 .Solve 8 puzzle problems.

3. 8-puzzle:

Initialize the puzzle:

1) Create a Puzzle 8 class with the initial state, goal state & possible moves

initial = [1, 2, 3, 4, 5, 6, 0, 7, 8]

2) ~~Define me~~ goal = [1, 2, 3, 4, 5, 6, 7, 8, 0]

moves = [(0, 1), (1, 0), (0, -1), (-1, 0)]

3) define methods to print the current state, check if the puzzle is solved, get the index of blank tile & apply move.

Print current state:

~~loop~~ for i in range(0, 9, 3):

print (state[i : i+3])

Check if Puzzle is solved:

state == self.goal

Get index of the blank tile (represented by '0')

Apply Move function:

Implement a method to apply a move to the current state, swapping the blank tile with adjacent tile.

BFS Algorithm

initialize visited set to keep track of puzzle state to avoid revisiting.

visited = set( )

Create an empty Queue. It stores tuples where each tuple consists of puzzle state & corresponding path taken to reach state.

Queue = Queue( )

Queue. put ((self.initial_state, [ ]))

Until queue is empty over the loop:

i) Deque a state & its path.

ii) Check if the state is the goal state. if yes print solution path & break out of loop..

iii) if ~~tuple~~ state is not visited mark is as visited

iv) Get index of blank tile

v) Apply all moves & enqueues the resulting states & path.

ex: ~~Initial State~~: [1, 2, 3, ~~4, 5, 6~~, 0, 7

Queue [(new state_1, [move_1]), (new state 2 [move 2]]

```
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
-----------
Success
```

3. Implement Iterative deepening search algorithm.

A 8/12/23

PAGE NO:
DATE: 8/12/23

Implement iterative deepening Search algorithm

CODE:

```
def depth-limited-search (node, goal,
depth-limit):
 if node == goal:
     return True:
 if depth-limit it <=0:
     return False
for Child in get-Children (node):
if depth-limited-Search (Child,
goal, depth-limited):
     return True
return False

def iterative deepening-search
        (start, goal):
   if result:
~~depth limit = 0~~

print (" goal found!")

else:
print (" goal not reachable
      within depth limit.");
```

Algorithm

- Start with a depth of 0
- perform depth - limited Search (DFS limited by depth) Starting from the root node.
- if the goal is found at the current dep: limit, increase the depth limit by 1 and repeat the Search
- Continue This process until the goal if found or the maximum depth limit is reached.
- Iterative Deepening Search guarantees to find the sole, with the least depth (Similar to Breadth - First Search) while only using linear Space. However, it may Explore the Same node multiple times due to repeated Searches at increasing depth levels.

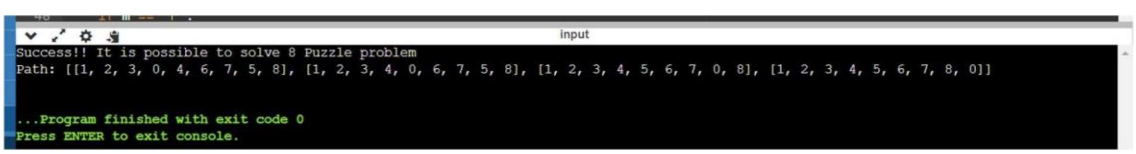
Remember to adopt the Code of your specific problem by implementing the 'get_children()' function according to your problem's space and transition rules

```
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")
```

OUTPUT



4. Implement A* search algorithm.

DATE: 8/12/23

Implement A* Search algorithm

CODE :

```
import heapq

def a star - search (start, goal, heuristic-func, get-neighbours,
    cost - func)
    frontier = []

    heapq. heappush (frontier, (0 + heuristic-func (start, goal), 0, start, []))
    explored = set()

    while frontier :
    f, g, current, path = heapq. heappop (frontier)

        if current = = goal :
            return path + [current]

    if current in explored :
            continue
    explored . add (current)
    for neighbour in get - neighbour (current) :
    neighbour - g = g + cost- func (current, neighbour)
    neighbour - g, neighbor, path + [current] ))
    return None
```

```
def Euclidean_distance (node, goal):
    x1, y1 = node
    x2, y2 = goal
    return ((x1-x2)**2+(y1-y2)**2)**0.5

def get_neighbors (node):
    return []

def Constant_cost (node1, node2):
    return 1

Start_node = (0,0)
goal_node = (5,5)

result = astar_Search (Start_node, goal_node, Euclitean_distance, get_neighbours, constant_cost)

if result:
    print ("Path found:", result)

else:
    print ("goal not reachable")
```

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

```
Success! 8 puzzle problem solved
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]]
```

5. Implement vaccum cleaner agent.

PAGE NO :
DATE :

Vaccum Cleaner Agent Algorithm

→ Initialize Environment :

Create a grid representing the Environment where the vaccum cleaner operates. Each cell in the grid can be clean ('0') or dirty ('1') place the vaccum cleaner in a random position with the Environment

→ ~~Action~~ Class Vaccum CleanerAgent:

def -- int-- (self, size):

self. size = size

self. environment = [[radom. choice ([0,1]) for_in range (size)] for_in range (size)]

self. position = (random. radiant (0, size-1), random. radiant (0, size -1)]

intializes the agent with a specified Environment size

- Creates a 2D grid of random 0s and 1s.
- Randomly places the vaccum cleaner within the Environment.

PAGE NO : 2
DATE :

→ Repeat
The agent Countories this cycle
Untill all

def Clean_Environment (self):
while any (1 in row for row in

Self. Clean ()
Self. ~~€~~ move()
print ("Cleaning Completed!")

→ initiates the cleaning process by Continuously Checking for dirt in the Environment Calls 'Clean()' to Clean the current position and 'move ()' to move to the next position until the Entire Environment is Clean.

Size - of - Environment = 5

1. Vaccum - agent = Clean - Environ - ment ()

→ here it sets of the Size of the Environment grid and initializes the Vacum, Cleaner agent Calls the 'Clean Environment () method to start the Cleaning process.

A2

```
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:

```
clean()
```

```
Enter Location of Vacuumb
Enter status of b1
Enter status of other room1
Initial Location Condition{'A': '0', 'B': '0'}
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 .

PAGE NO :
DATE : 29/12/23

Knowledge base entailment :

Entailment refers to the logical relationship between a KB (A set of statements or rules) and a query.
If KB entails a statement, it means that whenever the statements in the KB are true, the given query must also be true

KB |=> Q

Knowledge base resolution -
The resolution rule involves taking two clauses that contain complementary literals and resolving them to produce a new clause

Knowledge base Entailment

- If its raining (P) then ground is wet
- If the ground is wet (Q), then the plants will grow (R).
- It's not the case that plants will grow (¬R)

Query: whether it is raining

NOT R and R are compliment of each other the ground is wet
Which means that it is raining be-cause the ground is wet 'P' entails

```
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:

```
Enter the knowledge base: (p^q)v(~pvq)
Enter the query: pvq
[True, True, True] :kb= True :q= True
[True, True, False] :kb= True :q= True
[True, False, True] :kb= False :q= True
[True, False, False] :kb= False :q= True
[False, True, True] :kb= True :q= True
[False, True, False] :kb= True :q= True
[False, False, True] :kb= True :q= False
Doesn't entail!!
```

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

query

Knowledge base Resolution

Input a KB and an Expression.
negotiate the Expression add it to KB and find a Contradiction, if Contradiction is found, the negated statement is false hence the original Statement is true.

Is it ~~Sunny~~ SUNNY ? Sunny = TRUE?
prove sunny.

Sunny
daytime
Sunny → night
¬ Sunny

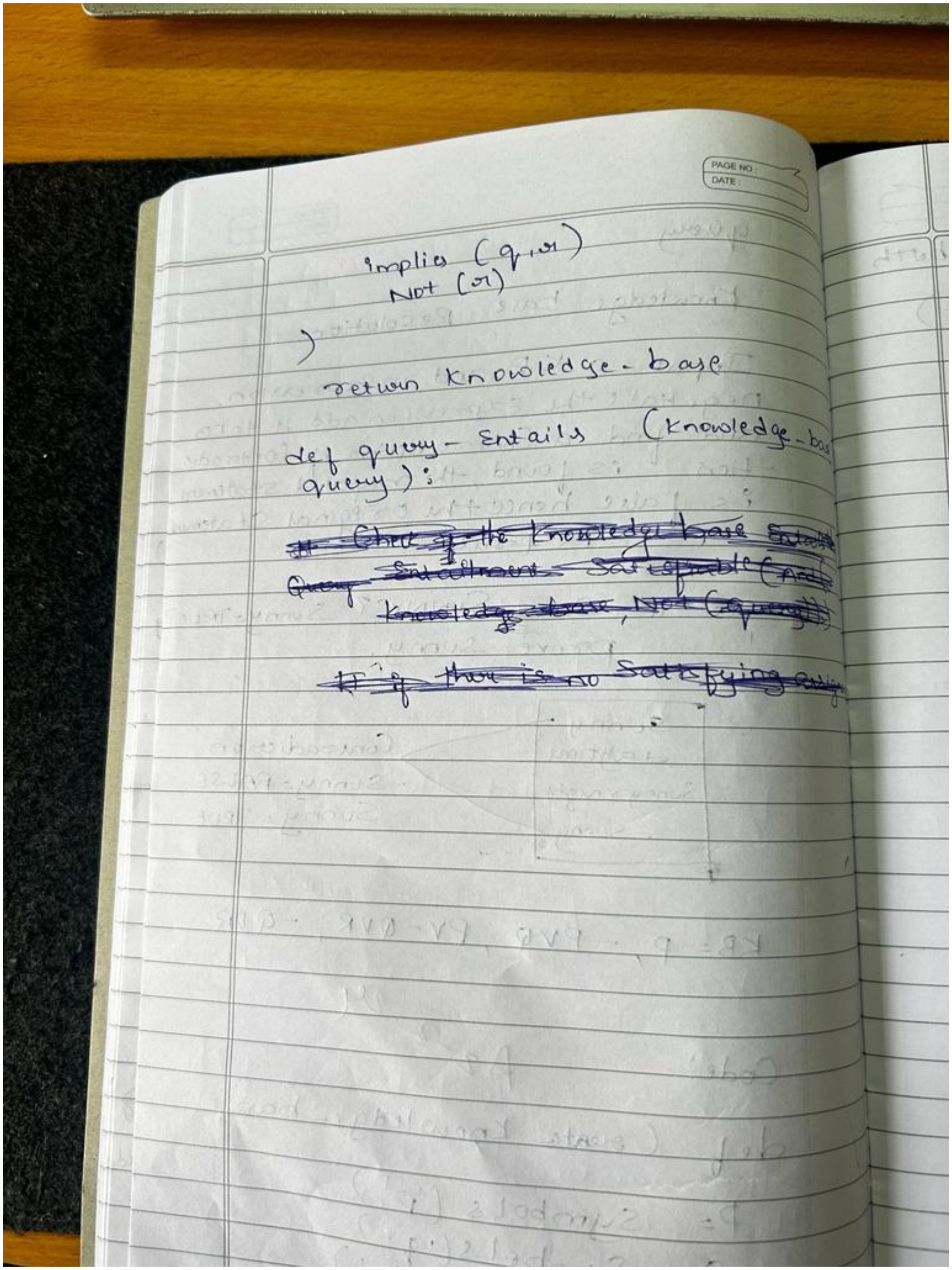
Contradiction
¬ Sunny = FALSE
Sunny = TRUE

KB = P, ¬P∨Q , P∨¬Q∨R , ¬Q∨R

A2-2-24

Code:

```
def Create knowledge_base()
  p = symbols ('p')
  q = symbols('q')
  r = symbols ('r')
  knowledge_base = And(
    implies (p,q)
```



implies (q, r)
Not (r)
)
return knowledge_base

def query_Entails (knowledge_bas
query):
~~# Check if the knowledge base entails~~
~~query Entailment = satisfiable(And(~~
~~knowledge_base, Not(query)))~~
~~# if there is no satisfying assig~~

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:

```
Enter the clauses separated by a space: p v ~q ~r v p ~q
Enter the query: ~p
Trying to prove (p)^(v)^(~q)^(~r)^(v)^(p)^(~q)^(~p) by contradiction....
Knowledge Base entails the query, proved by resolution
```

```
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 :

PAGE NO :
DATE :

Unification

Eg: Knows (John, x) Known (John, Jane) : {x / Jane}

Step 1: If term 1 or term2 ~~are identical return nil~~ is variable / Constant then:

a> ~~step~~ term 1 or term 2 are identical, return NIL

b> Else if term 1 is available
if term 1 occurs is term2
return FAIL.
Else
return {(term 2 / term1)}

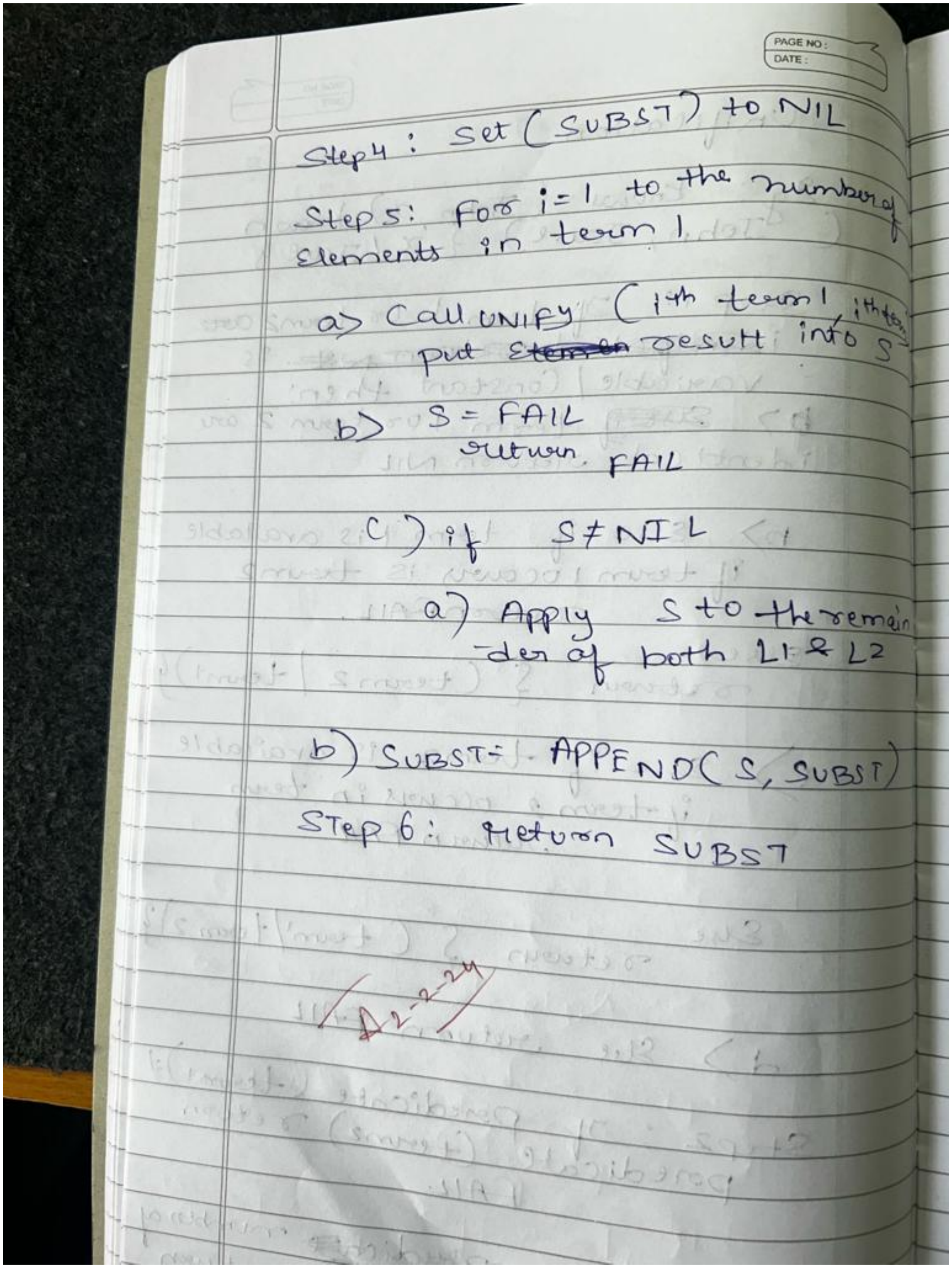
c> Else if term2 is available
if term 2 occurs in term
return FAIL

Else
return {(term1 / term 2)}

d> Else return FAIL

Step2 : If predicate (term1) ≠ predicate (term2) return FAIL

Step3 : ~~If predicate~~ number of arguments not Equal return FALL



PAGE NO :
DATE :

Step4 : Set (SUBST) to NIL

Step 5: For i=1 to the number of elements in term 1

a) Call UNIFY (ith term1, ith term2) put ~~Sterm~~ result into S

b) S = FAIL
return FAIL

c) if S ≠ NIL

a) Apply S to the remainder of both L1 & L2

b) SUBST = APPEND(S, SUBST)

Step 6: return SUBST

A 2-2-24

```
import re


def getAttributes(expression):
    expression = expression.split("(")[1:]
expression = "(".join(expression)
```

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

def getInitialPredicate(expression):
return expression.split("(")[0] def
isConstant(char):
    return char.isupper() and len(char) == 1

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

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

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

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

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



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



def unify(exp1, exp2):
if exp1 == exp2:
        return []

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

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

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

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

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

            return False

else:

            return [(exp1, exp2)]


    if getInitialPredicate(exp1) != getInitialPredicate(exp2):

print("Predicates do not match. Cannot be unified")

return False


    attributeCount1 = len(getAttributes(exp1))

attributeCount2 = len(getAttributes(exp2))

if attributeCount1 != attributeCount2:

        return False


    head1 = getFirstPart(exp1)     head2 =

getFirstPart(exp2)     initialSubstitution =

unify(head1, head2)     if not

initialSubstitution:

        return   False              if

attributeCount1       ==       1:

return initialSubstitution


    tail1 = getRemainingPart(exp1)

tail2 = getRemainingPart(exp2)


    if initialSubstitution != []:

        tail1 = apply(tail1, initialSubstitution)

tail2 = apply(tail2, initialSubstitution)
```

```
remainingSubstitution = unify(tail1, tail2)
if not remainingSubstitution:
        return False

    initialSubstitution.extend(remainingSubstitution)
return initialSubstitution



exp1 = "knows(X)" exp2 =
"knows(Richard)" substitutions
= unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

OUTPUT

```
Substitutions:
[('X', 'Richard')]
```

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

```
Substitutions:
[('A', 'y'), ('mother(y)', 'x')]
```

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

Lab-8

~~Create a list of Skolt~~

Step-1 Create a list of SKOLEM Constants

Step-2 Find

If the attributes are lower Case, replace them with a SKOLEM Constant.

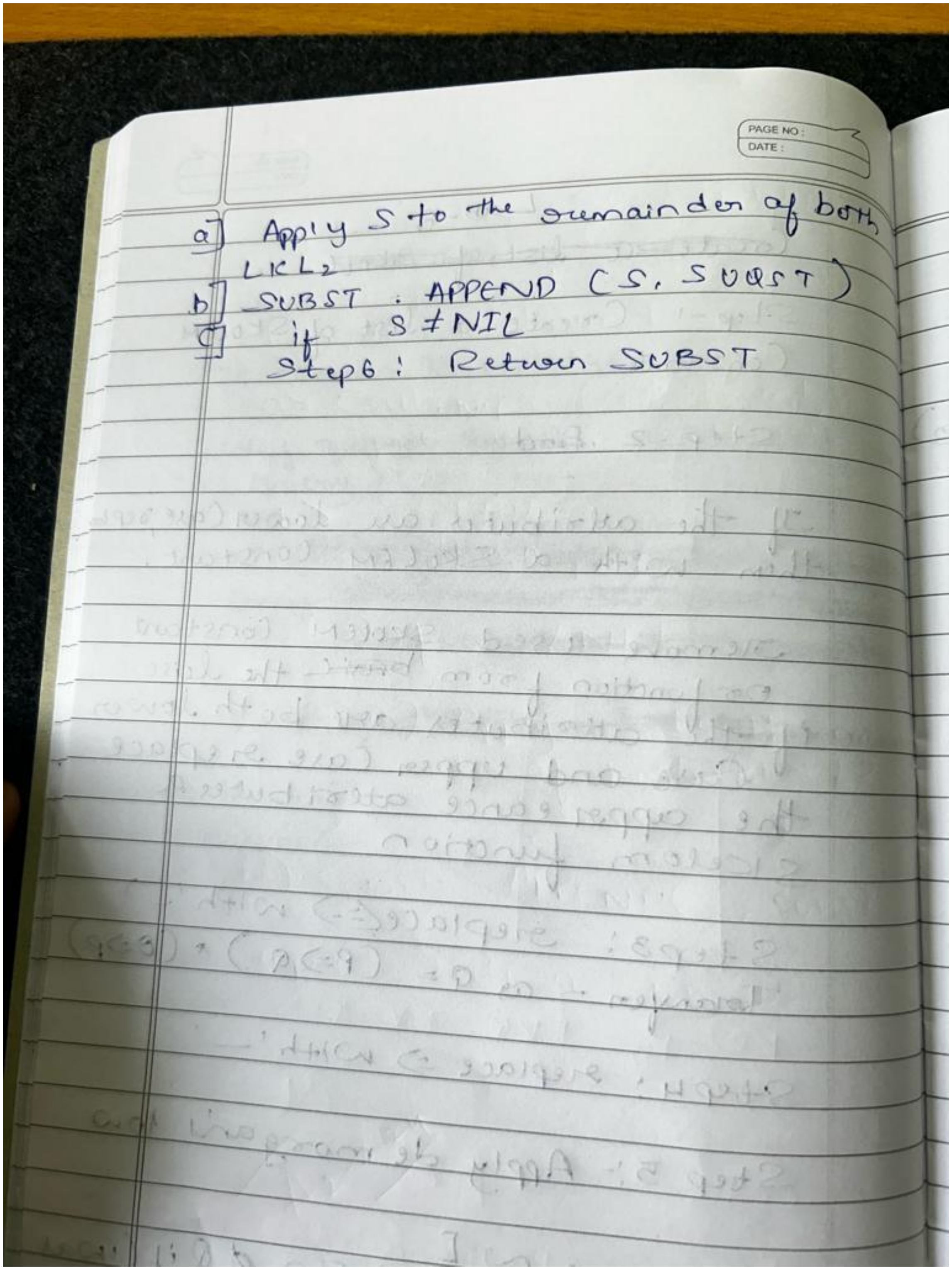
remove used SKOLEM Constant or function from ~~basic~~ the lisc if the attributes are both lower Case and upper Case replace the apperance attributes a Skelom function

Step3: replace(⇔) with '—'
Transfer — as Q = (P⇒Q) * (Q⇒P)

Step4: replace ⇒ with '—'

Step 5:- Apply de morgan's low

replace ~ [
as ~ P &~ Q if (I was present)
replace ~ [
as ~P|~Q if (& was present)
replace or ~ with " "



a] Apply S to the remainder of both
LKL2
b] SUBST : APPEND (S, SUBST)
c] if S ≠ NIL
Step6 : Return SUBST

```
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

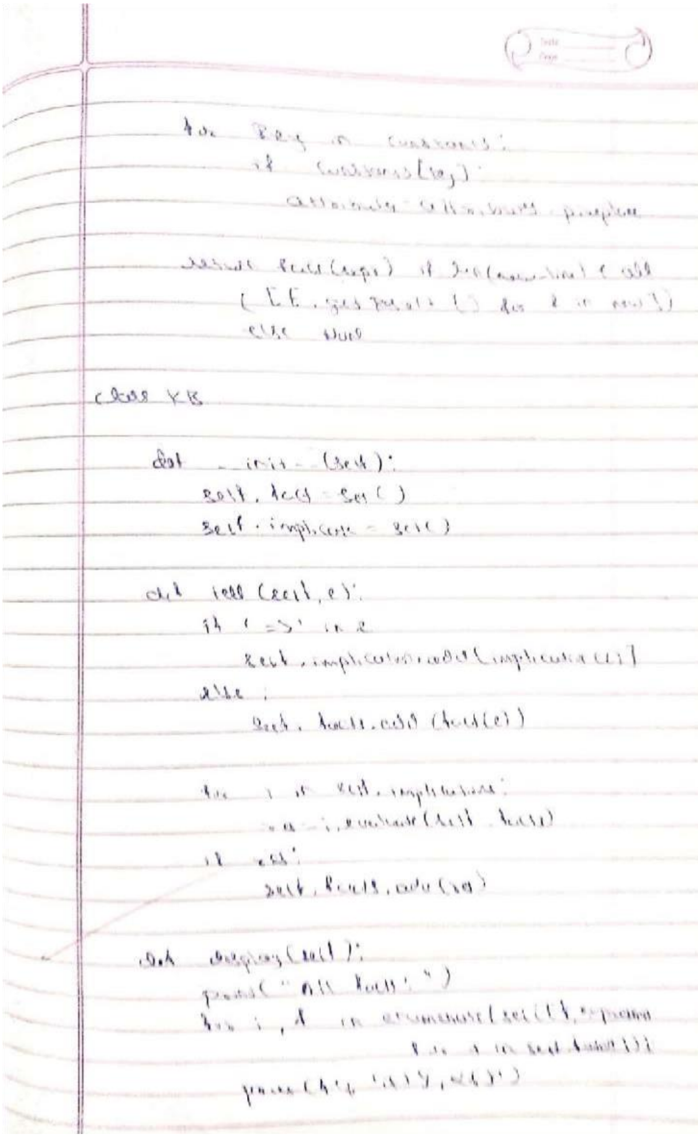
```
Enter FOL statement: x+y_z*s
FOL converted to CNF: [~x+y|z*s]&[~z*s|x+y]
```

10. Create a knowledge base consisting of first order logic statements and prove the given query using forward reasoning

10.

3) Code for KB consisting for prove the given query using forward reasoning

```
import re

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

def getPredicate(string)
    expr = '([a-z~]+)\(([^&|]+)\)'
    return re.findall(expr, string)

Class Fact:
    def __init__(self, expression):
        self.expression = expression
        predicate, params = self.splitExpression()
        self.predicate = predicate
        self.params = params
        self.result = any(self.getConstants())

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 key in constants:
    if constants[key]:
        attributes = attributes.replace(...)

return Fact(expr) if len(new_line) < all
    ([f.getResult() for f in new])
    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 display(self):
        print("All facts: ")
        for i, f in enumerate(set([f.expression
                               for f in self.facts])):
            print(f'\t{i+1}. {f}')
```

```
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

```
Enter number of statements in Knowledge Base: 4
Elephant(x) => Mammal(x)
Lion(Mufasa)
Mammal(x) => Animal(x)
Animal(Simba)
Enter Query:
Mammal(x)
Querying Mammal(x):
All facts:
        1. Lion(Mufasa)
        2. Animal(Simba)
```