VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
On

ARTIFICIAL INTELLIGENCE
s

Submitted by

SANNIDHI M (1BM21CS189)

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

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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 **SANNIDHI M (1BM21CS189)**, 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.

Madhavi R P
Associate Professor
Department of CSE
BMSCE, Bengaluru

Dr. Jyothi S Nayak
Professor and Head
Department of CSE
BMSCE, Bengaluru

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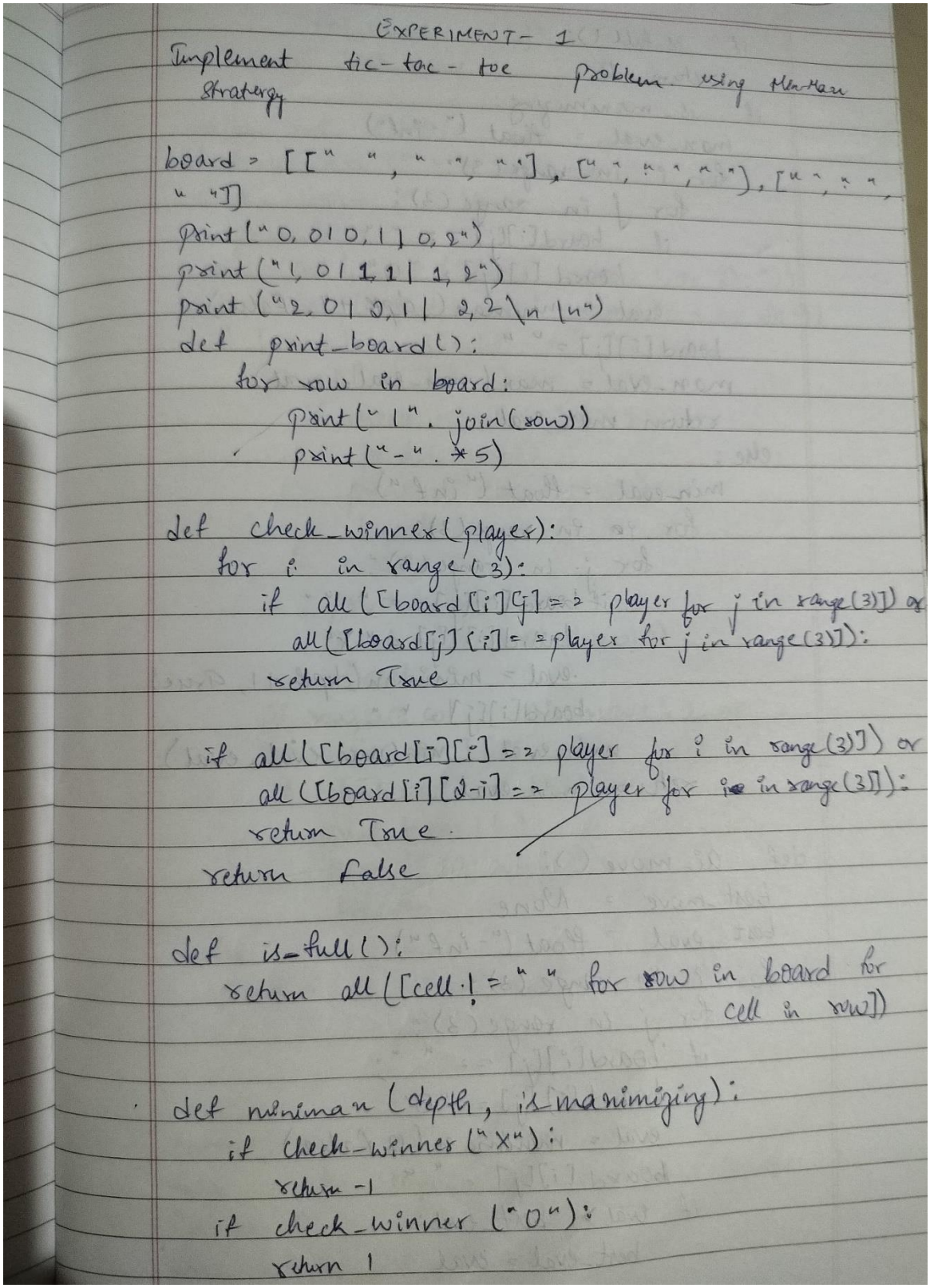
1.Implement Tic –Tac –Toe Game.

```
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.")
```

OBSERVATION



EXPERIMENT - 1

Implement tic-tac-toe problem using MinMax Strategy

```
board = [[" ", " ", " "], [" ", " ", " "], [" ", " ", " "]]
print("0,0|0,1|0,2")
print("1,0|1,1|1,2")
print("2,0|2,1|2,2\n|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
```

```
            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")
```

OUTPUT

```
[1, 2, 3, 4, 5, 6, 7, 8, 9]
+-------------------------------+
|         |         |         |
|    1    |    2    |    3    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    4    |    5    |    6    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-------------------------------+
computer's turn :
+-------------------------------+
|         |         |         |
|    1    |    X    |    3    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    4    |    5    |    6    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-------------------------------+
Your turn :
enter a number on the board :4
```

```
Your turn :
enter a number on the board :4
+-------------------------------+
|         |         |         |
|    1    |    X    |    3    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    O    |    5    |    6    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-------------------------------+
computer's turn :
+-------------------------------+
|         |         |         |
|    X    |    X    |    3    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    O    |    5    |    6    |
|         |         |         |
+-------------------------------+
|         |         |         |
|    7    |    8    |    9    |
|         |         |         |
+-------------------------------+
Your turn :
enter a number on the board :5
+-------------------------------+
```

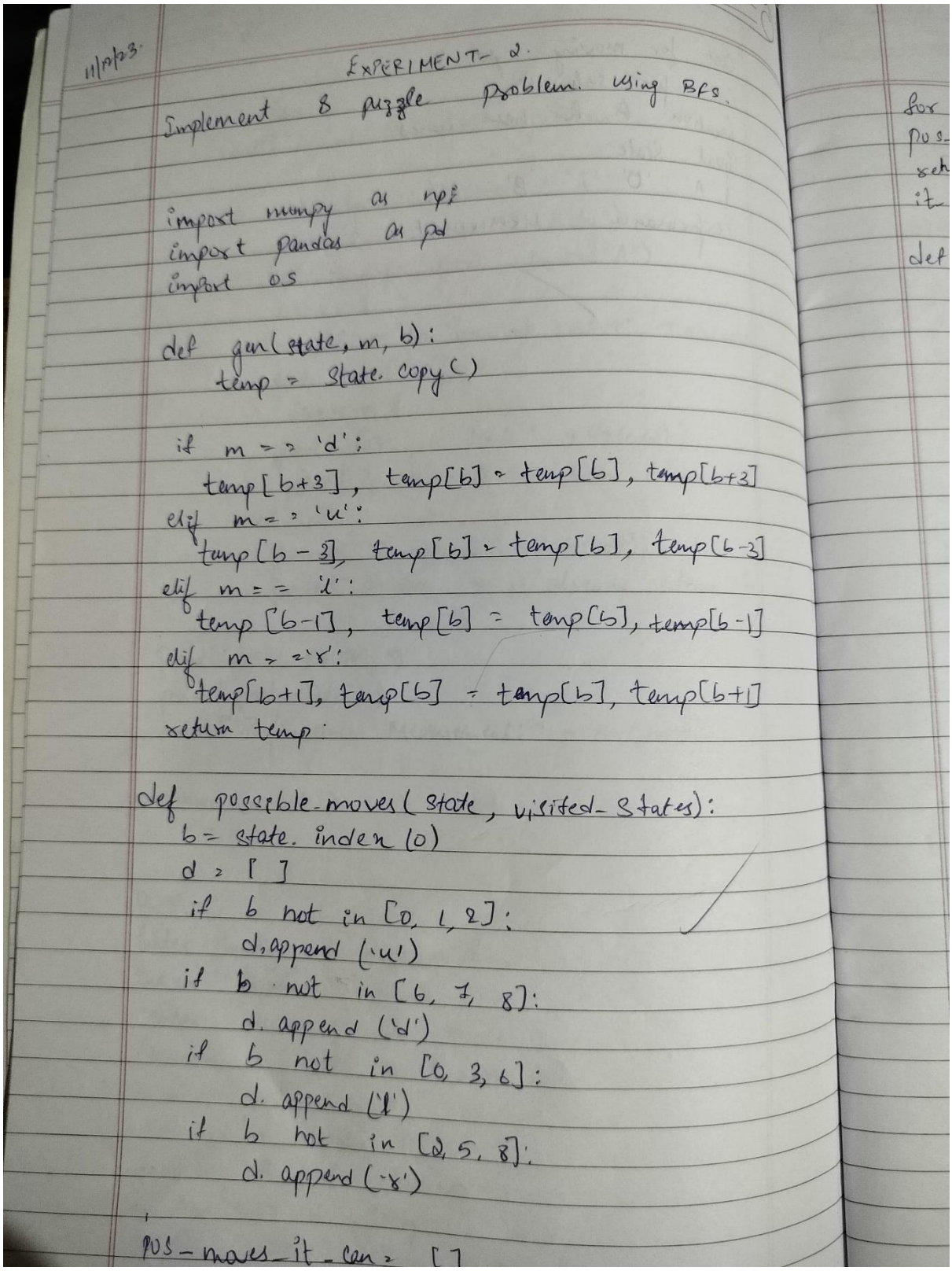
```
+-----------------------------+
Your turn :
enter a number on the board :5
+-----------------------------+
|             |             |             |
|      X      |      X      |      3      |
|             |             |             |
+-----------------------------+
|             |             |             |
|      O      |      O      |      6      |
|             |             |             |
+-----------------------------+
|             |             |             |
|      7      |      8      |      9      |
|             |             |             |
+-----------------------------+
computer's turn :
+-----------------------------+
|             |             |             |
|      X      |      X      |      X      |
|             |             |             |
+-----------------------------+
|             |             |             |
|      O      |      O      |      6      |
|             |             |             |
+-----------------------------+
|             |             |             |
|      7      |      8      |      9      |
|             |             |             |
+-----------------------------+
winner is  X
```

2 .Solve 8 puzzle problems.

```
def bfs(src,target):
    queue=[]
    queue.append(src)
    exp=[]
    while len(queue)>0:
        source=queue.pop(0)
        #print("queue",queue)
        exp.append(source)

        print(source[0],'|',source[1],'|',source[2])
        print(source[3],'|',source[4],'|',source[5])
        print(source[6],'|',source[7],'|',source[8])
        print("------------")
        if source==target:
            print("Success")
            return
        poss_moves_to_do=[]
        poss_moves_to_do=possible_moves(source,exp)
        #print("possible moves",poss_moves_to_do)
        for move in poss_moves_to_do:
            if move not in exp and move not in queue:
              #print("move",move)
              queue.append(move)

def possible_moves(state,visited_states):
    b=state.index(0)

    #direction array
    d=[]
```

```
    if b not in [0,1,2]:
        d.append('u')
    if b not in [6,7,8]:
            d.append('d')
    if b not in [0,3,6]:
        d.append('l')
    if b not in [2,5,8]:
        d.append('r')


    pos_moves_it_can=[]


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


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


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

OBSERVATION



11/09/23.

EXPERIMENT- 2.

Implement 8 puzzle problem using BFS.

```
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

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)
    exp = [ ]
    while len(queue) > 0:
        source = queue.pop (0)
        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
    pos_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)
```

OUTPUT

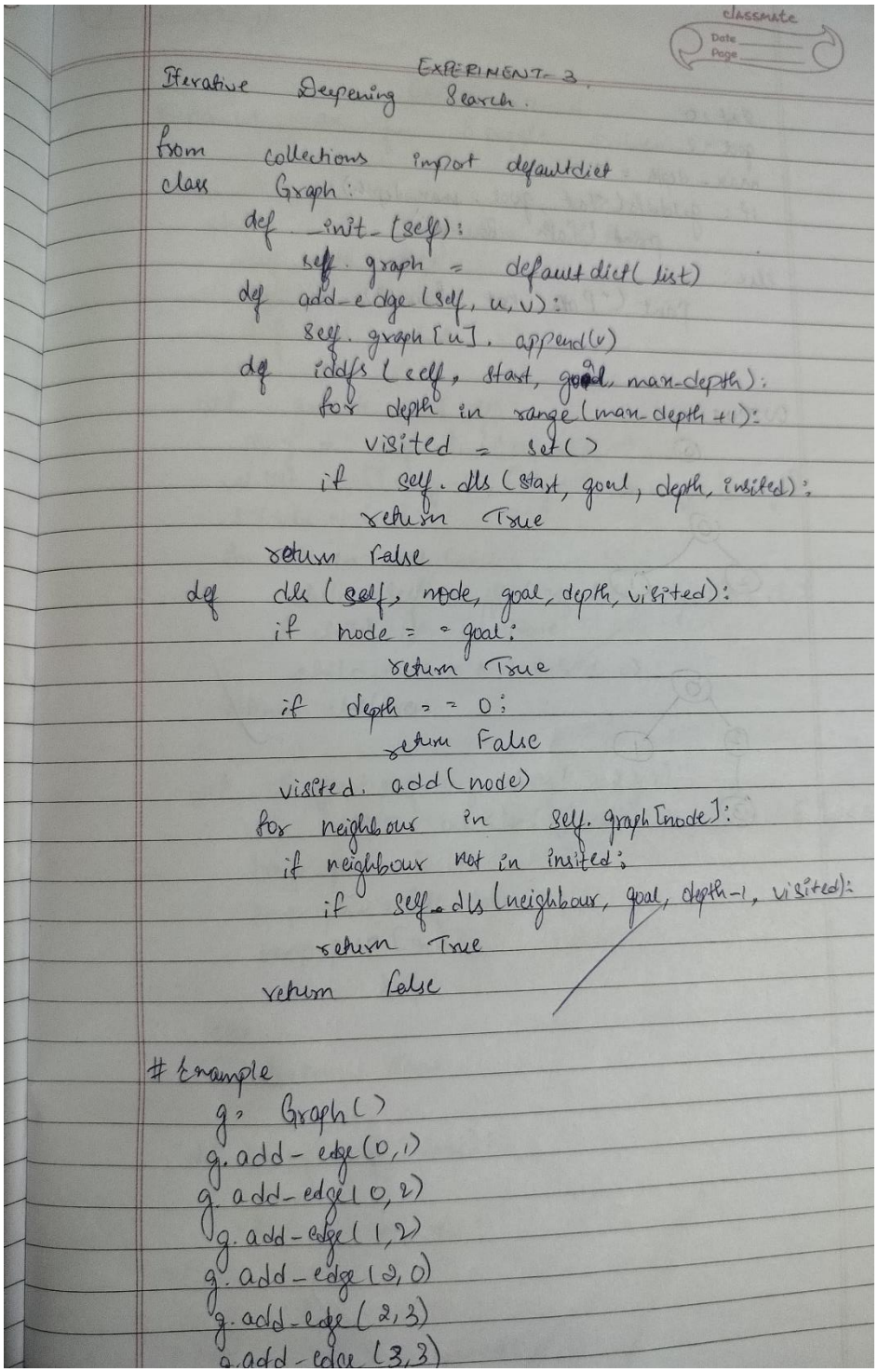
```
1 | 2 | 3
4 | 5 | 6
0 | 7 | 8
-----------
1 | 2 | 3
0 | 5 | 6
4 | 7 | 8
-----------
1 | 2 | 3
4 | 5 | 6
7 | 0 | 8
-----------
0 | 2 | 3
1 | 5 | 6
4 | 7 | 8
-----------
1 | 2 | 3
5 | 0 | 6
4 | 7 | 8
-----------
1 | 2 | 3
4 | 0 | 6
7 | 5 | 8
-----------
1 | 2 | 3
4 | 5 | 6
7 | 8 | 0
-----------
Success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

3. Implement Iterative deepening search algorithm.

```
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")
```

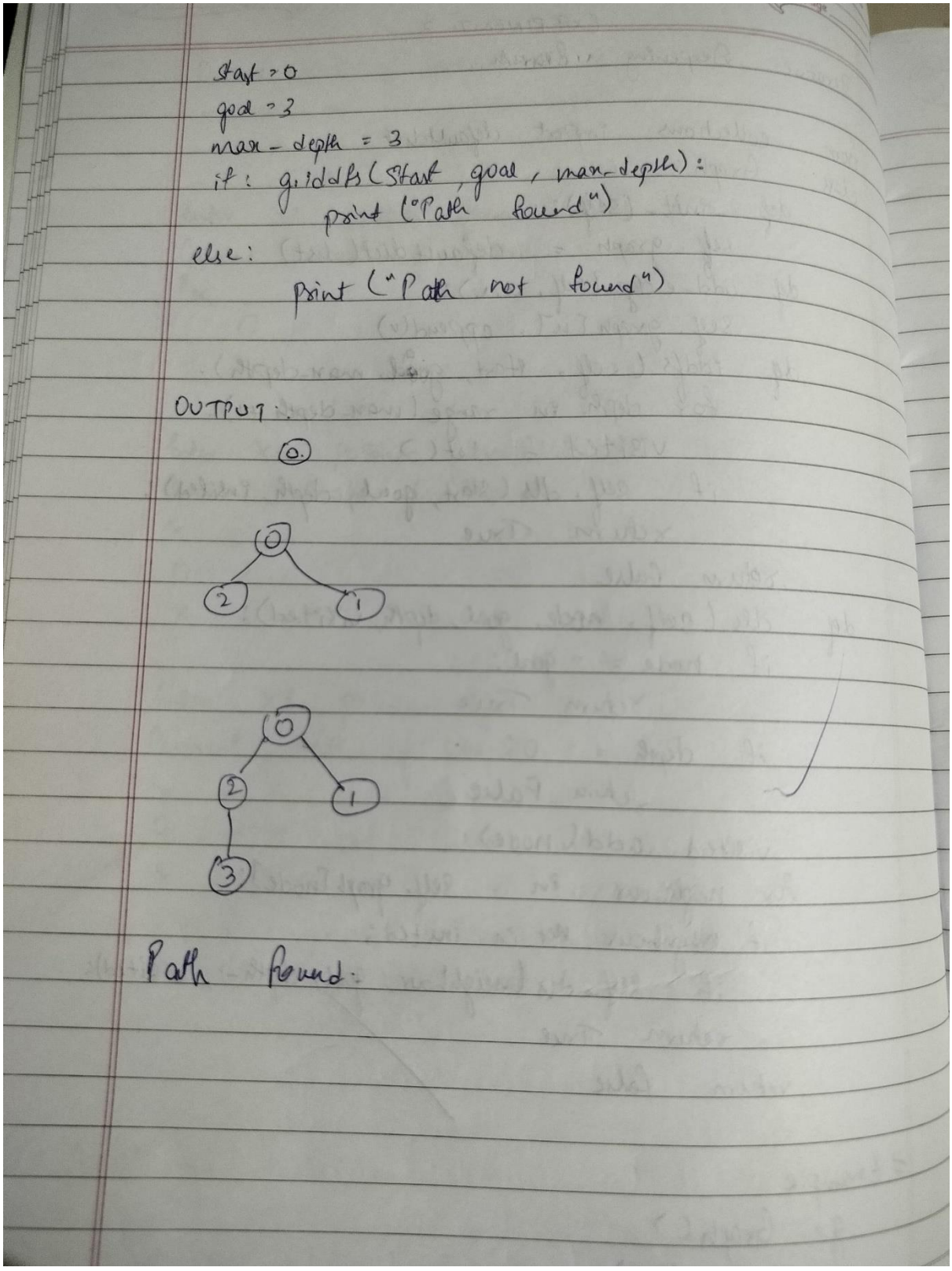
OBSERVATION



EXPERIMENT-3

Iterative Deepening Search.

```
from collections import defaultdict
class Graph:
    def __init__(self):
        self.graph = defaultdict(list)
    def add_edge(self, u, v):
        self.graph[u].append(v)
    def iddfs(self, start, goal, max_depth):
        for depth in range(max_depth+1):
            visited = set()
            if self.dls(start, goal, depth, visited):
                return True
        return False
    def dls(self, node, goal, depth, visited):
        if node == goal:
            return True
        if depth == 0:
            return False
        visited.add(node)
        for neighbour in self.graph[node]:
            if neighbour not in visited:
                if self.dls(neighbour, goal, depth-1, visited):
                    return True
        return False

# Example
g = Graph()
g.add_edge(0,1)
g.add_edge(0,2)
g.add_edge(1,2)
g.add_edge(2,0)
g.add_edge(2,3)
g.add_edge(3,3)
```



OUTPUT

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

4. Implement A* search algorithm.

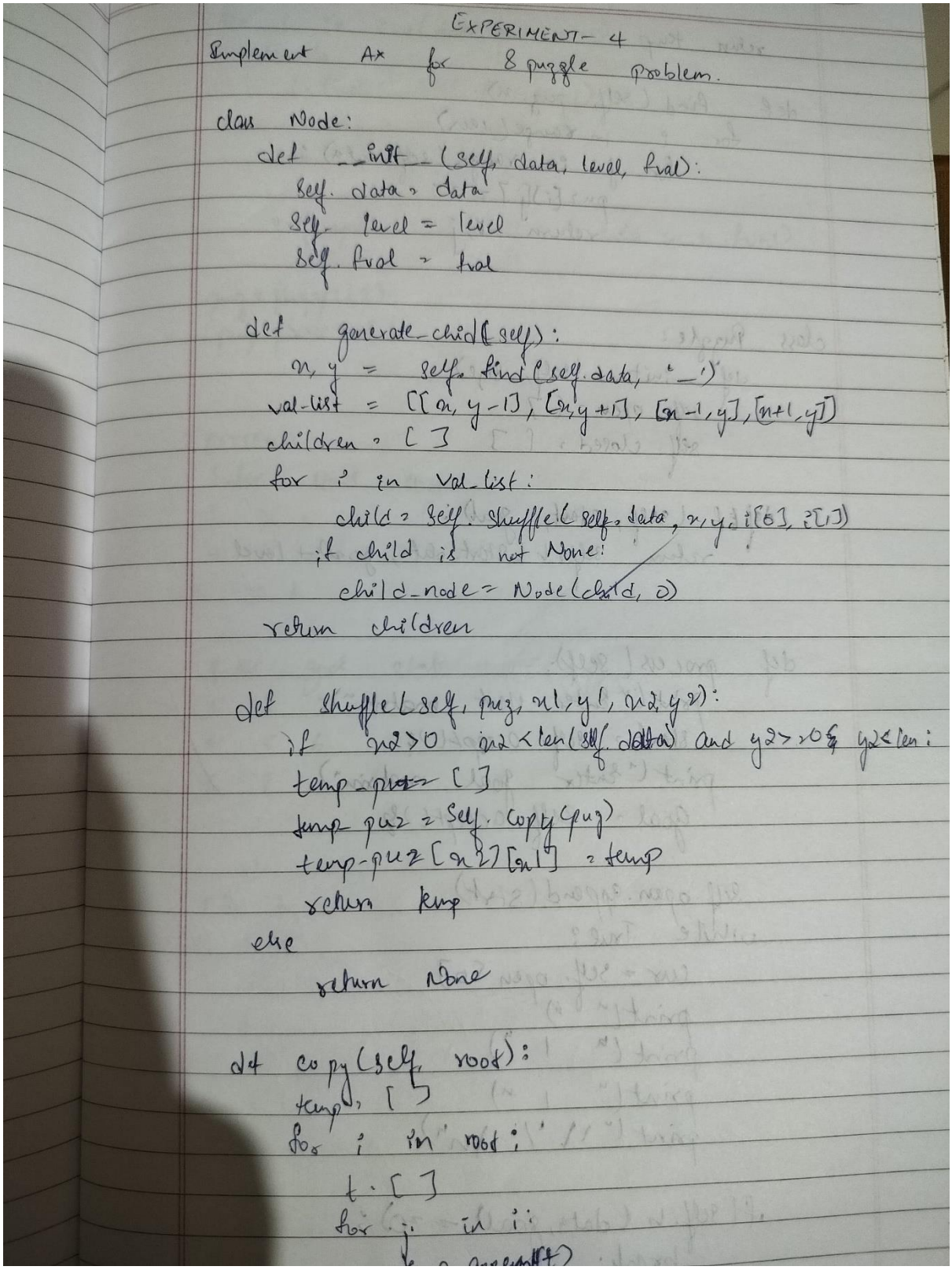
```
class Node:
    def __init__(self,data,level,fval):
        """ Initialize the node with the data, level of the node and the calculated fvalue """
        self.data = data
        self.level = level
        self.fval = fval

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

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

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

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

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



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

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

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

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



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

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

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



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

OBSERVATION

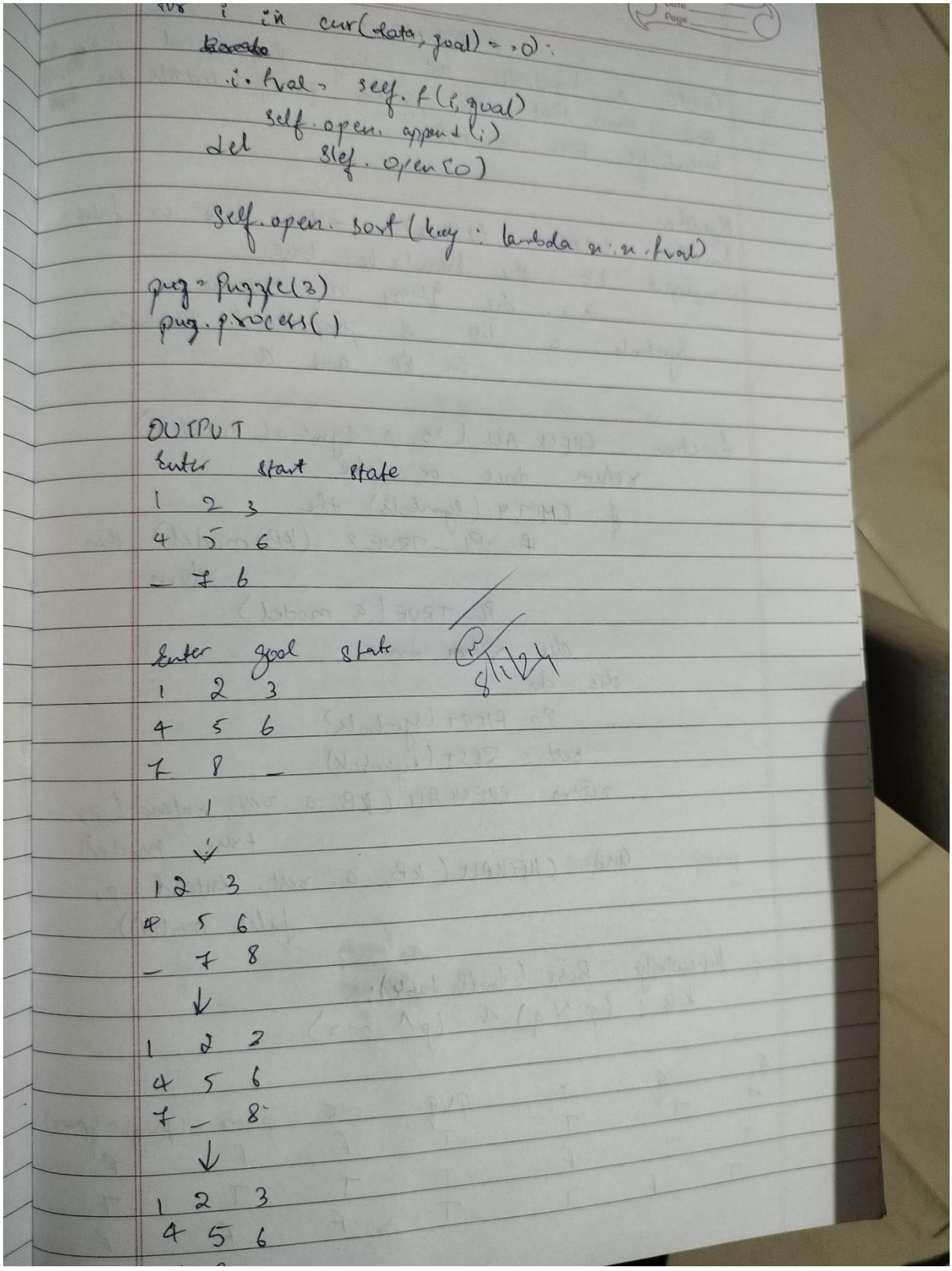


EXPERIMENT- 4

Implement A* for 8 puzzle problem.

```
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, 0)
        return children

    def shuffle(self, puz, x1, y1, x2, y2):
        if x2>0 x2<len(self.data) and y2>=0 & y2<len:
        temp_puz = []
        temp_puz = self.copy(puz)
        temp_puz[x2][x1] = temp
        return temp
    else
        return None

    def copy(self, root):
        temp = []
        for i in root:
            t = []
            for j in i:
                t.append(j)
```

```
return temp

def find(self, puz, n):
    for i in range(len)
        for j in range(self.data):
            puz[i][j] = n:
            return i, j


class Puzzle:
    def __init__(self, size)
        self.open = []
        self.closed = []

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


def process(self):
    print("\nEnter start matrix")
    start = self.accept()
    print("\nEnter goal matrix")
    goal = self.accept()

    self.open.append(start)
    while True:
        cur = self.open[0]
        print("  ")
        print("  |  :")
        print("  |  ")
        print(" \|/ :|\n")

    if(self.h(data, goal) == 0):
        break
```



```
for i in cur(data, goal) == 0):
    i.fval = self.f(i, goal)
    self.open.append(i)
del  self.open[0]

self.open.sort(key = lambda x: x.fval)

pug = Puzzle(3)
pug.process()
```

OUTPUT

Enter start state

1 2 3
4 5 6
_ 7 8

Enter goal state

1 2 3
4 5 6
7 8 _

1

↓

1 2 3
4 5 6
_ 7 8

↓

1 2 3
4 5 6
7 _ 8

↓

1 2 3
4 5 6

OUTPUT

```
Enter the start state matrix

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

1 2 3
4 5 6
7 8 _




  |
  |
 \'/

1 2 3
4 5 6
_ 7 8

  |
  |
 \'/

1 2 3
4 5 6
7 _ 8

  |


  _

  |
  |
 \'/

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

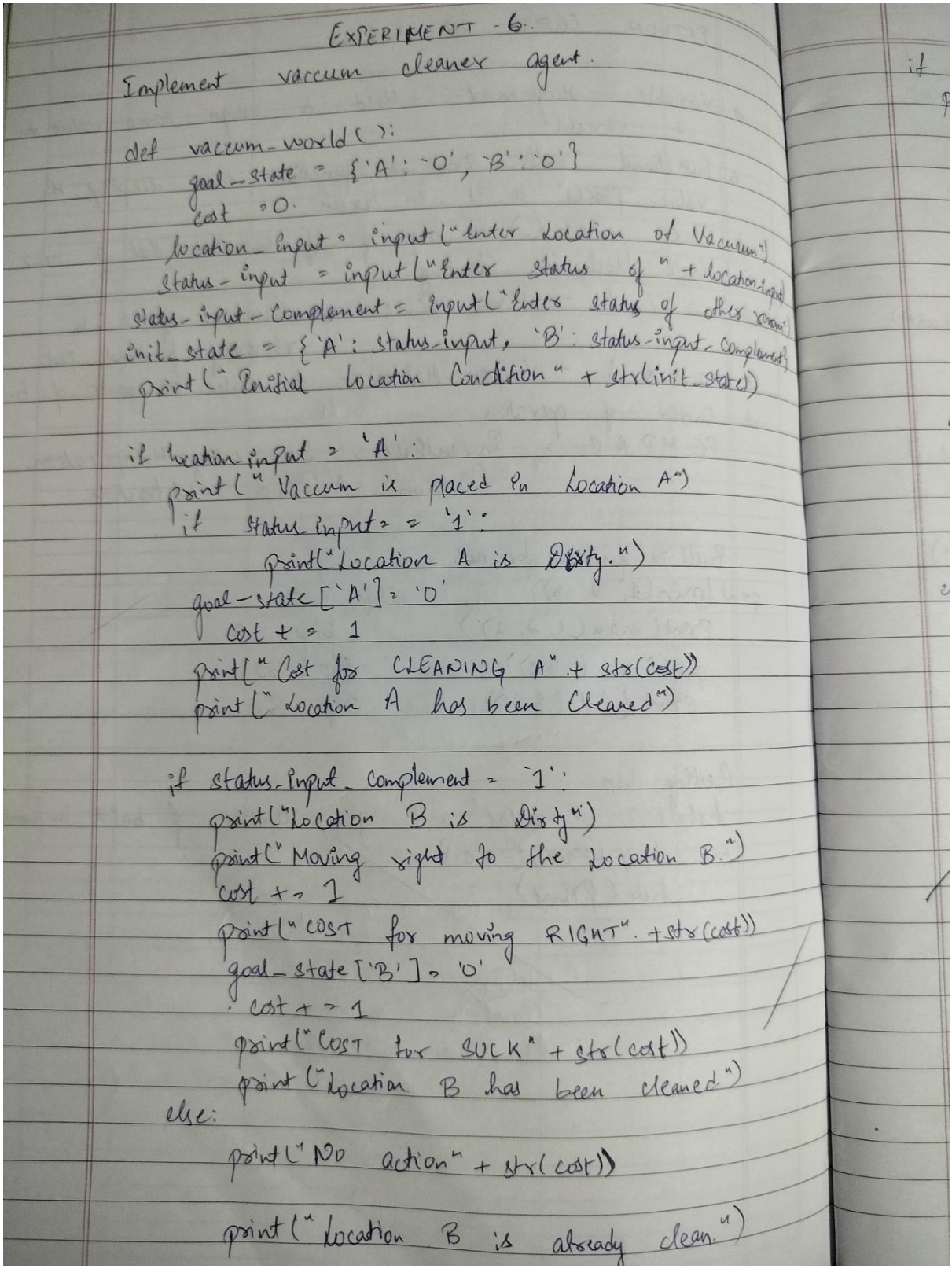
5. Implement vaccum cleaner agent.

```
def vacuum_world():
    # 0 indicates Clean and 1 indicates Dirty
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    location_input = input("Enter Location of Vacuum")
    status_input = input("Enter status of " + location_input)
    status_input_complement = input("Enter status of other room")
    if location_input == 'A':
        # Location A is Dirty.
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            # suck the dirt  and mark it as clean
            cost += 1                    #cost for suck
            print("Cost for CLEANING A " + str(cost))
            print("Location A has been Cleaned.")

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

```
            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()
```

OBSERVATION



EXPERIMENT - 6.

Implement vaccum cleaner agent.

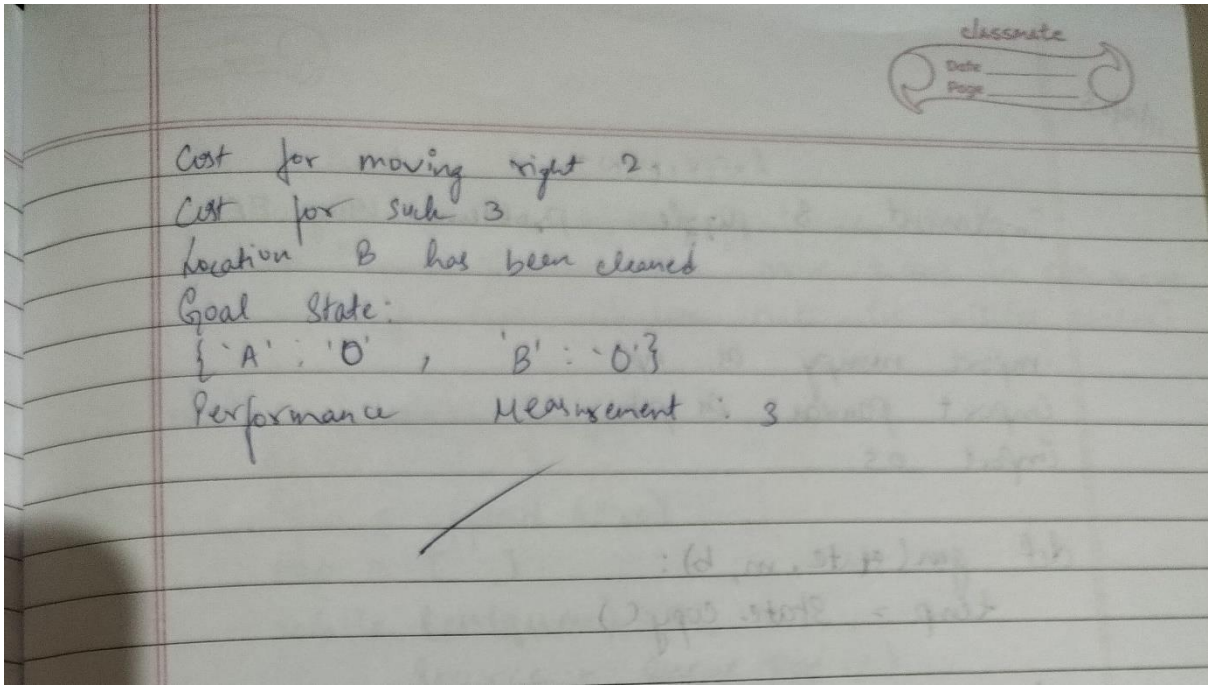
```
def vaccum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0
    location_input = input("Enter location of Vacuum")
    status_input = input("Enter status of " + location_input)
    status_input_complement = input("Enter status of other room")
    init_state = {'A': status_input, 'B': status_input_complement}
    print("Initial location Condition" + str(init_state))

if location_input == 'A':
    print("Vaccum is placed in location A")
    if status_input == '1':
        print("Location A is Dirty.")
    goal_state['A'] = '0'
    cost += 1
    print("Cost for CLEANING A" + str(cost))
    print("Location A has been Cleaned")

if status_input_complement == '1':
    print("Location B is Dirty")
    print("Moving right to the location B.")
    cost += 1
    print("COST for moving RIGHT" + str(cost))
    goal_state['B'] = '0'
    cost += 1
    print("COST for SUCK" + str(cost))
    print("Location B has been cleaned")
else:
    print("No action" + str(cost))

    print("Location B is already clean.")
```

```
if status_input == '0':
    print("Location A is already clean")
    if status_input_complement == '1':
        print("Location B is Dirty.")
        print("Moving RIGHT to the Location B.")
        cost += 1
        print("COST for moving RIGHT" +str(cost))
        goal_state['B'] = '0'
        cost += 1.
        print("Cost for SUCK" + str(cost))
        print("Location B has been Cleaned.")
    else:
        print("No action" + str(cost))
        print(cost)
        print("Location B is already clean.")

else:
    print("Vaccum is placed in location B")
    if status_input == '1':
        print("Location B is Dirty")
        goal_state['B'] = '0'
        cost += 1.
        print("COST for CLEANING" +str(cost))
        print("Location B has been Cleaned.")

    if status_input_complement == '1':
        print("Location A is Dirty.")
        print("Moving LEFT to the location A")
        cost += 1.
        print("COST for moving LEFT" + str(cost))
        goal_state['A'] = 0
        cost += 1.
        print("COST for SUCK", + str(cost))
        Cleaned.")
```

```
else:
    print(cost)
    print("Location B is already clean")

if status_input_complement == '1':
    print("Location A is Dirty")
    print("Moving left to location A")
    cost += 1
    print("COST for moving LEFT" + str(cost))
    goal_state['A'] = 0
    cost += 1
    print("Cost for SUCK", + str(cost))
    print("Location A has been cleaned.")
else:
    print("No action " + str(cost))
    print("Location A is already clean")

print("GOAL STATE: ")
print(goal_state)
print("Performance Measurement: " + str(cost))

vacuum_world()
```

OUTPUT:

```
Enter location of vacuum A
Enter Status of A 1
Enter status of other room 1
Vacuum is placed in location A
Location is dirty
Cost for cleaning A 1
Location A is cleaned
Location B is dirty
Moving right to the location B
```



OUTPUT:

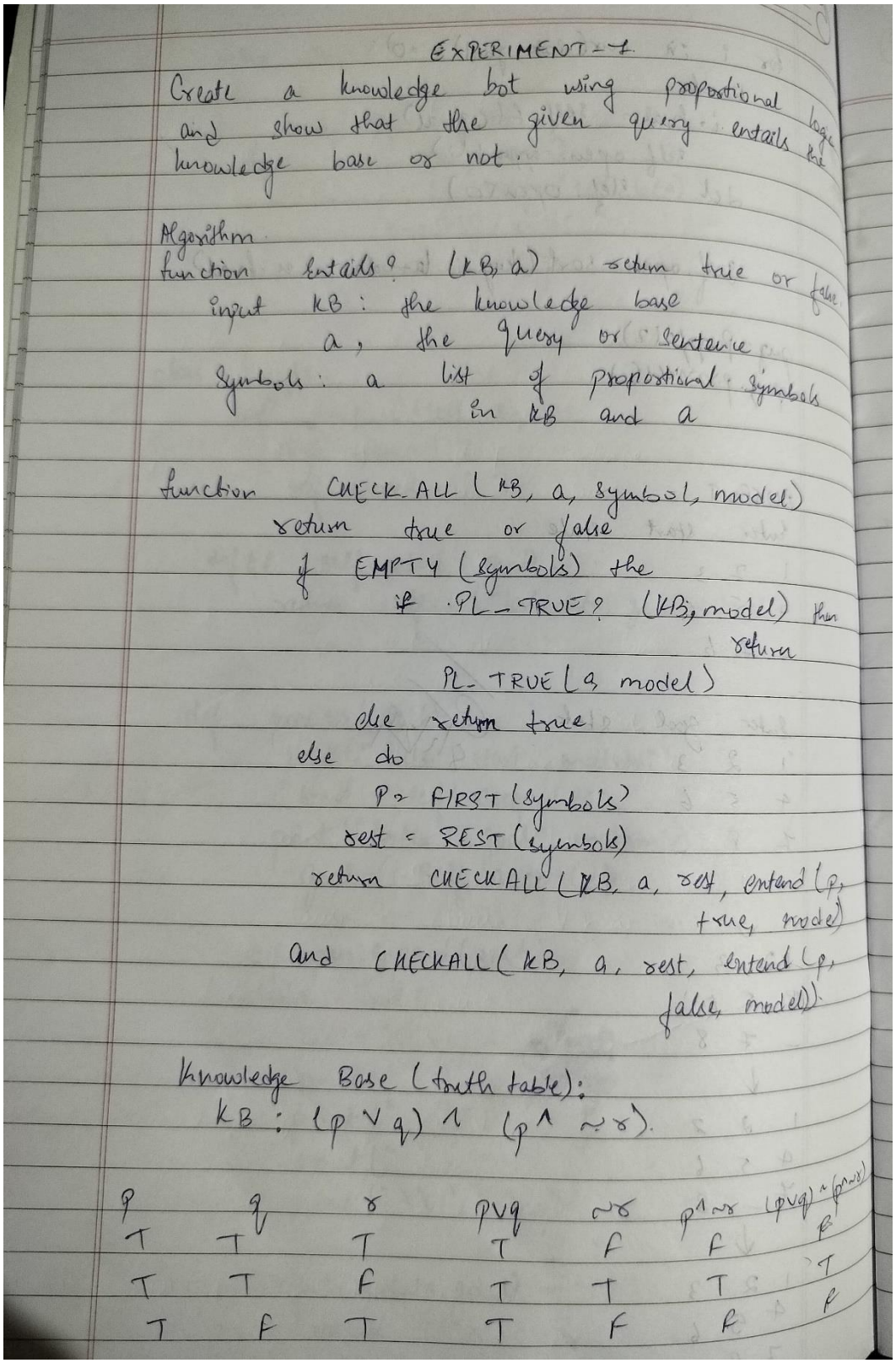
```
0 indicates clean and 1 indicates dirty
Enter Location of Vacuumb
Enter status of b1
Enter status of other room1
Vacuum is placed in location B
Location B is Dirty.
COST for CLEANING 1
Location B has been Cleaned.
Location A is Dirty.
Moving LEFT to the Location A.
COST for moving LEFT2
COST for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

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

```
from sympy import symbols, And, Not, Implies, satisfiable
def create_knowledge_base():
    # Define propositional symbols
    p = symbols('p')
    q = symbols('q')
    r = symbols('r')
    # Define knowledge base using logical statements
    knowledge_base = And(
        Implies(p, q),       # If p then q
        Implies(q, r),       # If q then r
        Not(r)               # Not r
    )
    return knowledge_base

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

OBSERVATION



EXPERIMENT-7

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

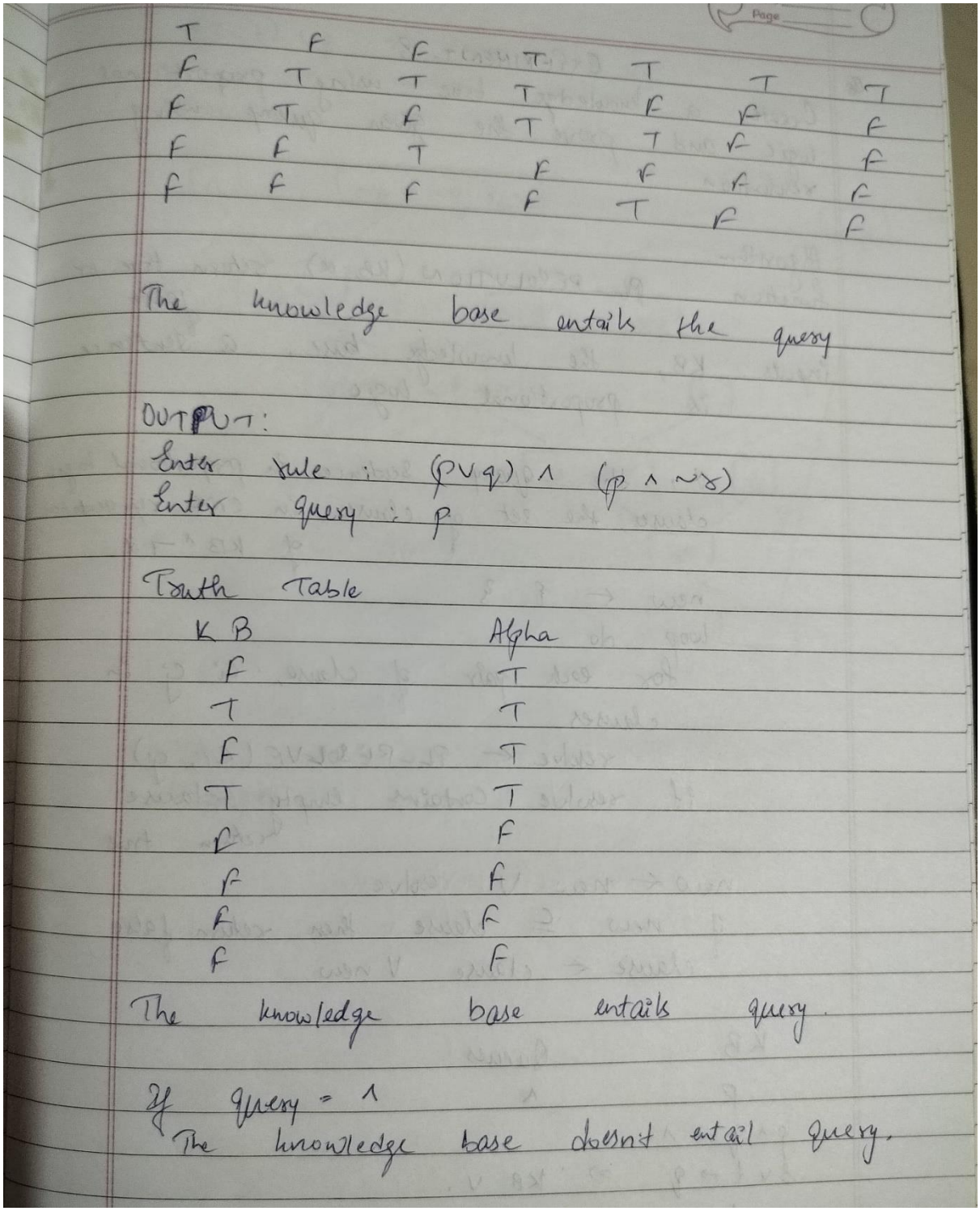
Algorithm

function entails? (KB, a) return true or false
  input KB: the knowledge base
    a, the query or sentence
  Symbols: a list of proposition symbols in KB and a

function CHECK_ALL (KB, a, symbol, model)
  return true or false
  if EMPTY (symbols) then
    if PL-TRUE? (KB, model) then return PL_TRUE (a, model)
    else return true
  else do
    P = FIRST (symbols)
    rest = REST (symbols)
    return CHECKALL (KB, a, rest, extend (p, true, model)
    and CHECKALL (KB, a, rest, extend (p, false, model)).

Knowledge Base (truth table):
KB: (p ∨ q) ∧ (p ∧ ~r).

p	q	r	p∨q	~r	p∧~r	(p∨q)∧(p∧~r)
T	T	T	T	F	F	F
T	T	F	T	T	T	T
T	F	T	T	F	F	F



T F F T T T T
F T T T F F F
F T F T T F F
F F T F F F F
F F F F T F F

The knowledge base entails the query

OUTPUT:
Enter rule : $(p \vee q) \wedge (p \wedge \sim s)$
Enter query : p

Truth Table

KB	Alpha
F	T
T	T
F	T
T	T
F	F
F	F
F	F
F	F

The knowledge base entails query.

If query = 1
The knowledge base doesn't entail query.

OUTPUT:

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

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

```
import re


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



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


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



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


split_terms('~PvR')
```

OUTPUT:

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

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


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

```
                if gen[0] != negate(gen[1]):
                    clauses += [f'{gen[0]}v{gen[1]}']
                else:
                    if contradiction(goal,f'{gen[0]}v{gen[1]}'):
                        temp.append(f'{gen[0]}v{gen[1]}')
                        steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
                        \nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal} is true."
                        return steps
            elif len(gen) == 1:
                clauses += [f'{gen[0]}']
            else:
                if contradiction(goal,f'{terms1[0]}v{terms2[0]}'):
                    temp.append(f'{terms1[0]}v{terms2[0]}')
                    steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
                    \nA contradiction is found when {negate(goal)} is assumed as true. Hence, {goal} is true."
                    return steps
            for clause in clauses:
                if clause not in temp and clause != reverse(clause) and reverse(clause) not in temp:
                    temp.append(clause)
                    steps[clause] = f'Resolved from {temp[i]} and {temp[j]}.'
            j = (j + 1) % n
        i += 1
    return steps
rules = 'Rv~P Rv~Q ~RvP ~RvQ' #(P^Q)<=>R : (Rv~P)v(Rv~Q)^(~RvP)^(~RvQ)
goal = 'R'
main(rules, goal)
```

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

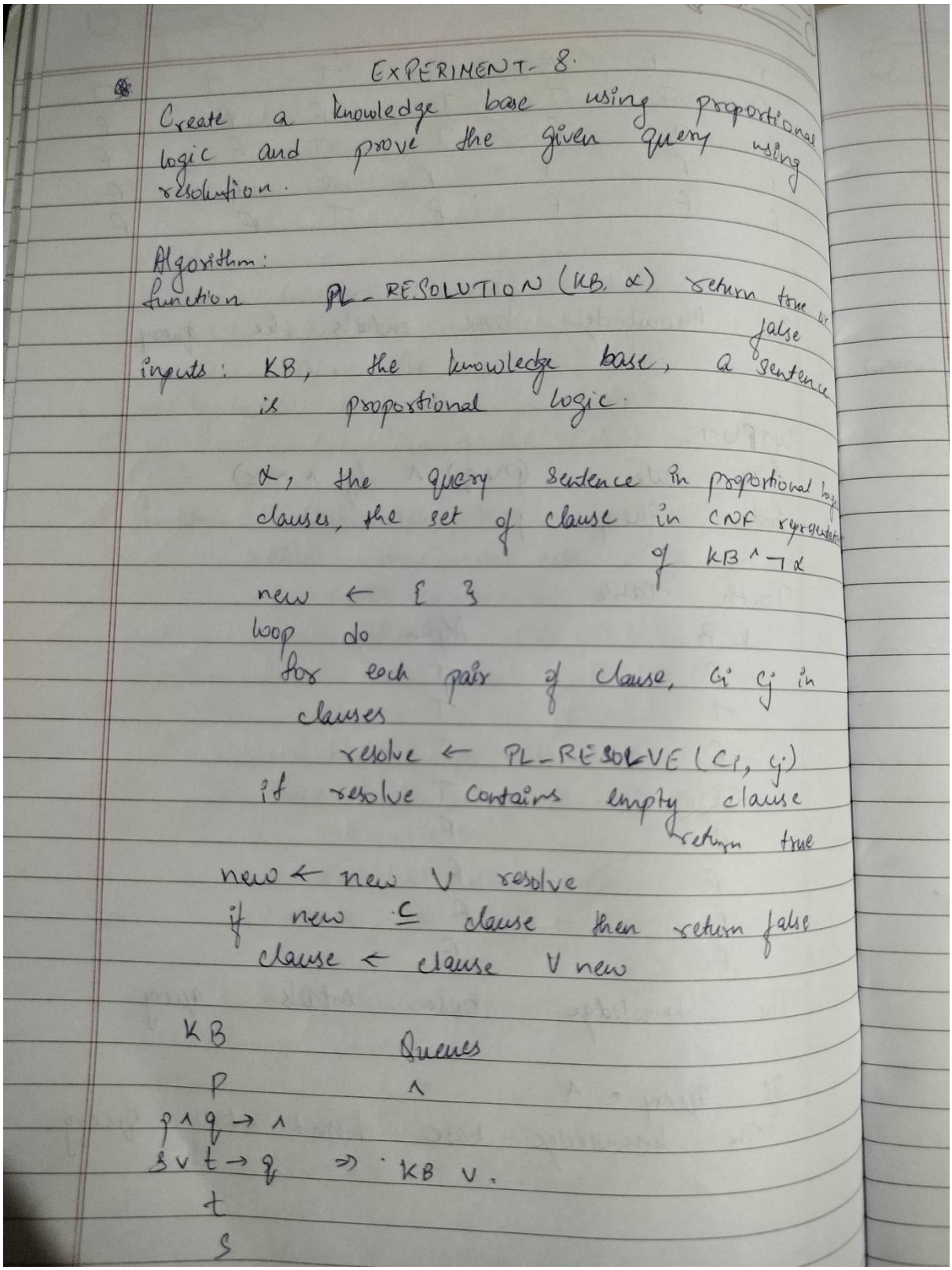
rules = 'PvQ ~PvR ~QvR' #P=vQ, P=>Q : ~PvQ, Q=>R, ~QvR

goal = 'R'

main(rules, goal)

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

OBSERVATION



EXPERIMENT- 8.

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

Algorithm:

function PL-RESOLUTION (KB, α) return true or false

inputs: KB, the knowledge base, a sentence in proportional logic.

α, the query sentence in proportional logic

clauses, the set of clause in CNF representation of KB ∧ ¬α

new ← { }

loop do

for each pair of clause, Ci Cj in clauses

resolve ← PL-RESOLVE (Ci, Cj)

if resolve contains empty clause return true

new ← new ∪ resolve

if new ⊆ clause then return false

clause ← clause ∪ new

KB

p

p ∧ q → r

s ∨ t → q

t

s

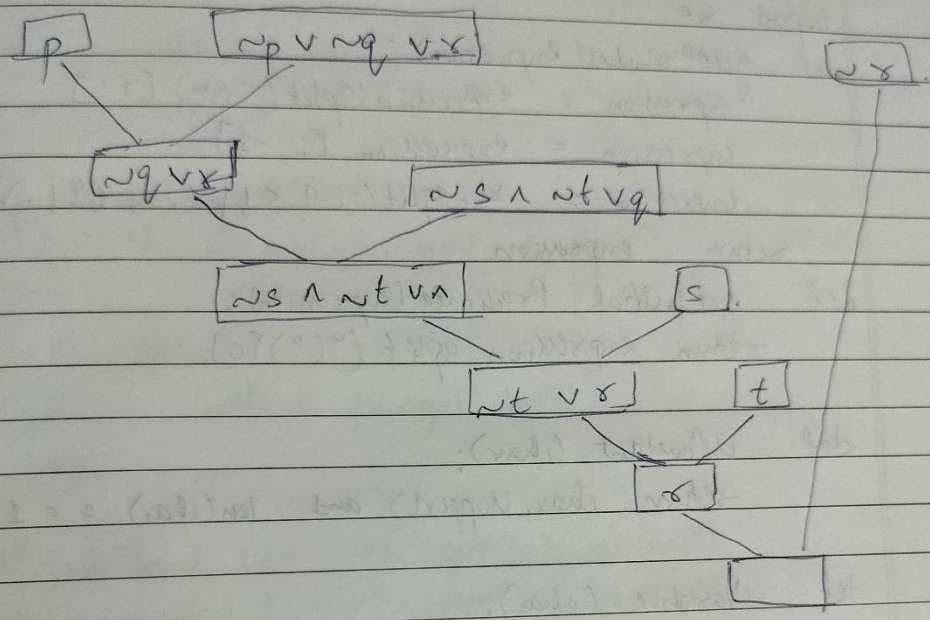
Queries

r

⇒ KB ∪ .

$\sim(s \vee t) \vee q \rightarrow \sim s \wedge \sim t \vee q$

Resolution:



OUTPUT:

true.

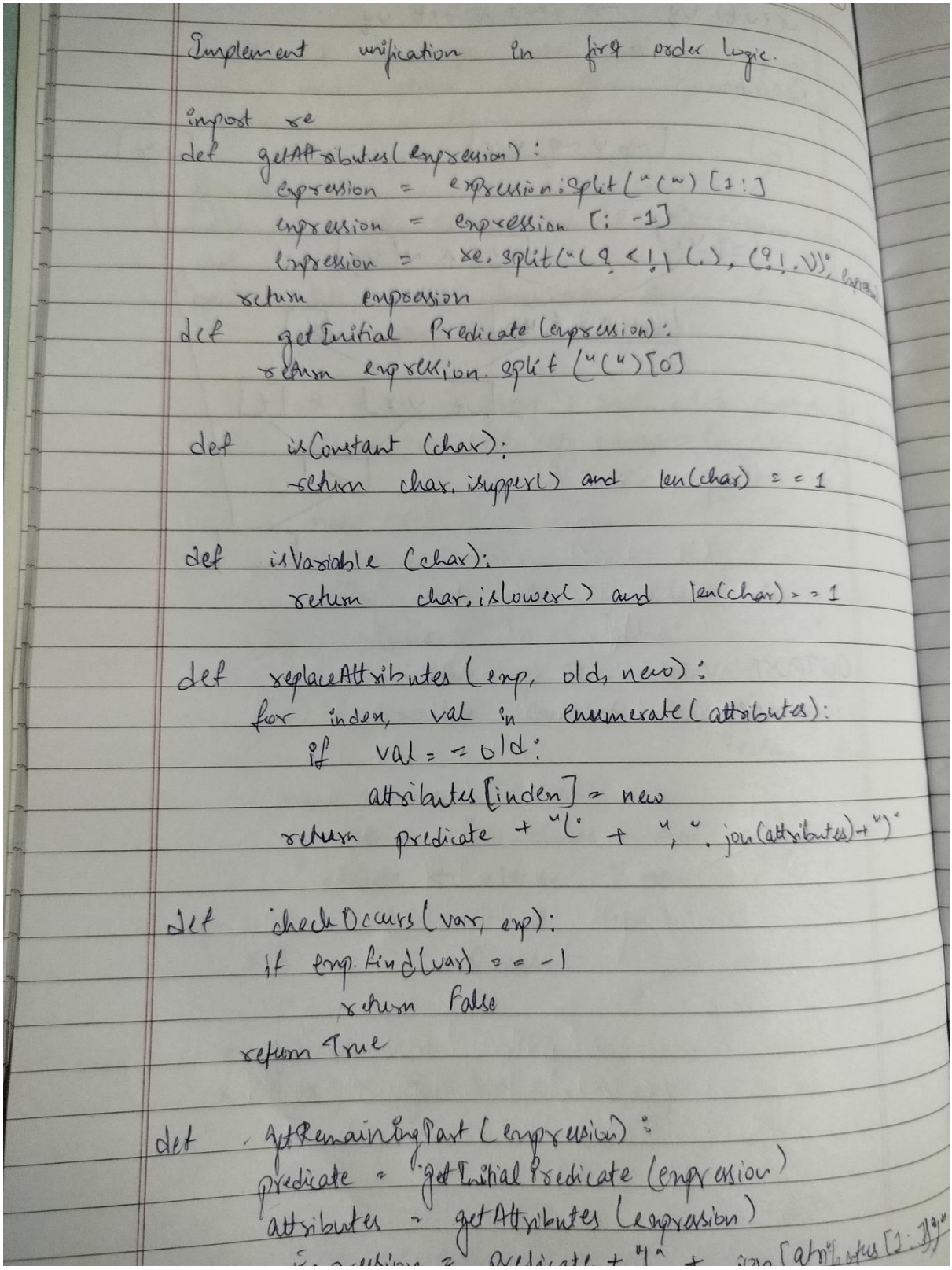
8. Implement unification in first order logic

```
import re
def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression[:-1]
    expression = re.split("(?
def getInitialPredicate(expression):
    return expression.split("(")[0]
def isConstant(char):
    return char.isupper() and len(char) == 1
def isVariable(char):
    return char.islower() and len(char) == 1
def replaceAttributes(exp, old, new):
    attributes = getAttributes(exp)
    for index, val in enumerate(attributes):
        if val == old:
            attributes[index] = new
    predicate = getInitialPredicate(exp)
    return predicate + "(" + ",".join(attributes) + ")"
def apply(exp, substitutions):
    for substitution in substitutions:
        new, old = substitution
        exp = replaceAttributes(exp, old, new)
    return exp
def checkOccurs(var, exp):
    if exp.find(var) == -1:
        return False
    return True
def getFirstPart(expression):
```

```
    attributes = getAttributes(expression)
    return attributes[0]
def getRemainingPart(expression):
    predicate = getInitialPredicate(expression)
    attributes = getAttributes(expression)
    newExpression = predicate + "(" + ",".join(attributes[1:]) + ")"
    return newExpression
def unify(exp1, exp2):
    if exp1 == exp2:
        return []
    if isConstant(exp1) and isConstant(exp2):
        if exp1 != exp2:
            return False
    if isConstant(exp1):
        return [(exp1, exp2)]
    if isConstant(exp2):
        return [(exp2, exp1)]
    if isVariable(exp1):
        if checkOccurs(exp1, exp2):
            return False
         else:
            return [(exp2, exp1)]
    if isVariable(exp2):
        if checkOccurs(exp2, exp1):
            return False
        else:
            return [(exp1, exp2)]
    if getInitialPredicate(exp1) != getInitialPredicate(exp2):
        print("Predicates do not match. Cannot be unified")
        return False
```

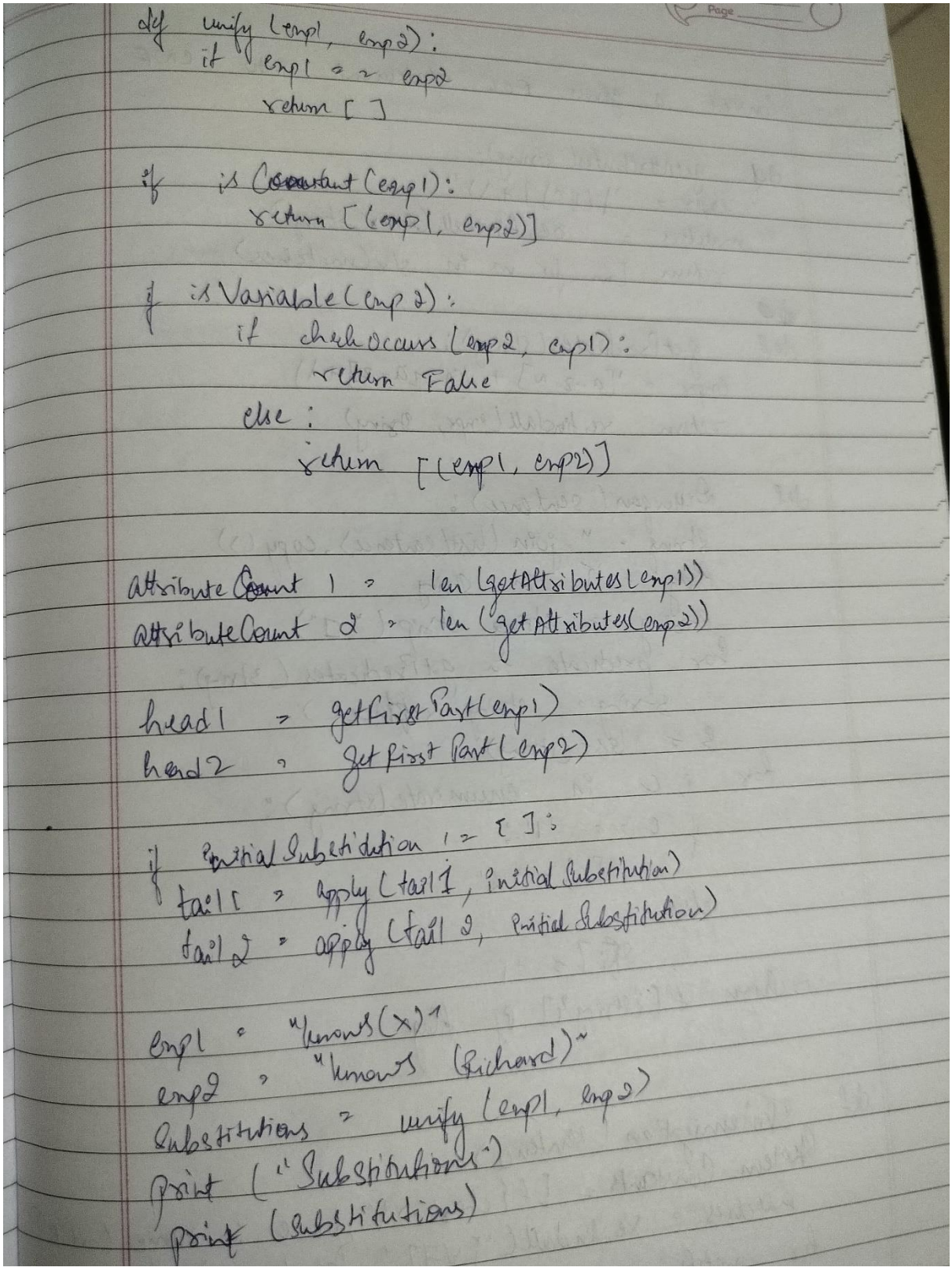
```
    attributeCount1 = len(getAttributes(exp1))
    attributeCount2 = len(getAttributes(exp2))
    if attributeCount1 != attributeCount2:
        return False
    head1 = getFirstPart(exp1)
    head2 = getFirstPart(exp2)
    initialSubstitution = unify(head1, head2)
    if not initialSubstitution:
        return False
    if attributeCount1 == 1:
        return initialSubstitution
    tail1 = getRemainingPart(exp1)
    tail2 = getRemainingPart(exp2)
    if initialSubstitution != []:
        tail1 = apply(tail1, initialSubstitution)
        tail2 = apply(tail2, initialSubstitution)
remainingSubstitution = unify(tail1, tail2)
    if not remainingSubstitution:
        return False
    initialSubstitution.extend(remainingSubstitution)
    return initialSubstitution
exp1 = "knows(X)"
exp2 = "knows(Richard)"
substitutions = unify(exp1, exp2)
print("Substitutions:")
print(substitutions)
```

OBSERVATION



Implement unification in first order logic.

```
import re
def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = expression[:-1]
    expression = re.split("(?<!\(),(?!\))", expression[0])
    return expression
def getInitialPredicate(expression):
    return expression.split("(")[0]

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

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

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

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

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



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

if   is Constant(exp1):
        return [(exp1, exp2)]

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

attributeCount 1 = len(getAttributes(exp1))
attributeCount 2 = len(getAttributes(exp2))

head1 = getFirstPart(exp1)
head2 = getFirstPart(exp2)

if initialSubstitution != []:
tail1 = apply(tail1, initialSubstitution)
tail2 = apply(tail2, initialSubstitution)

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

OUTPUT

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

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

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

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

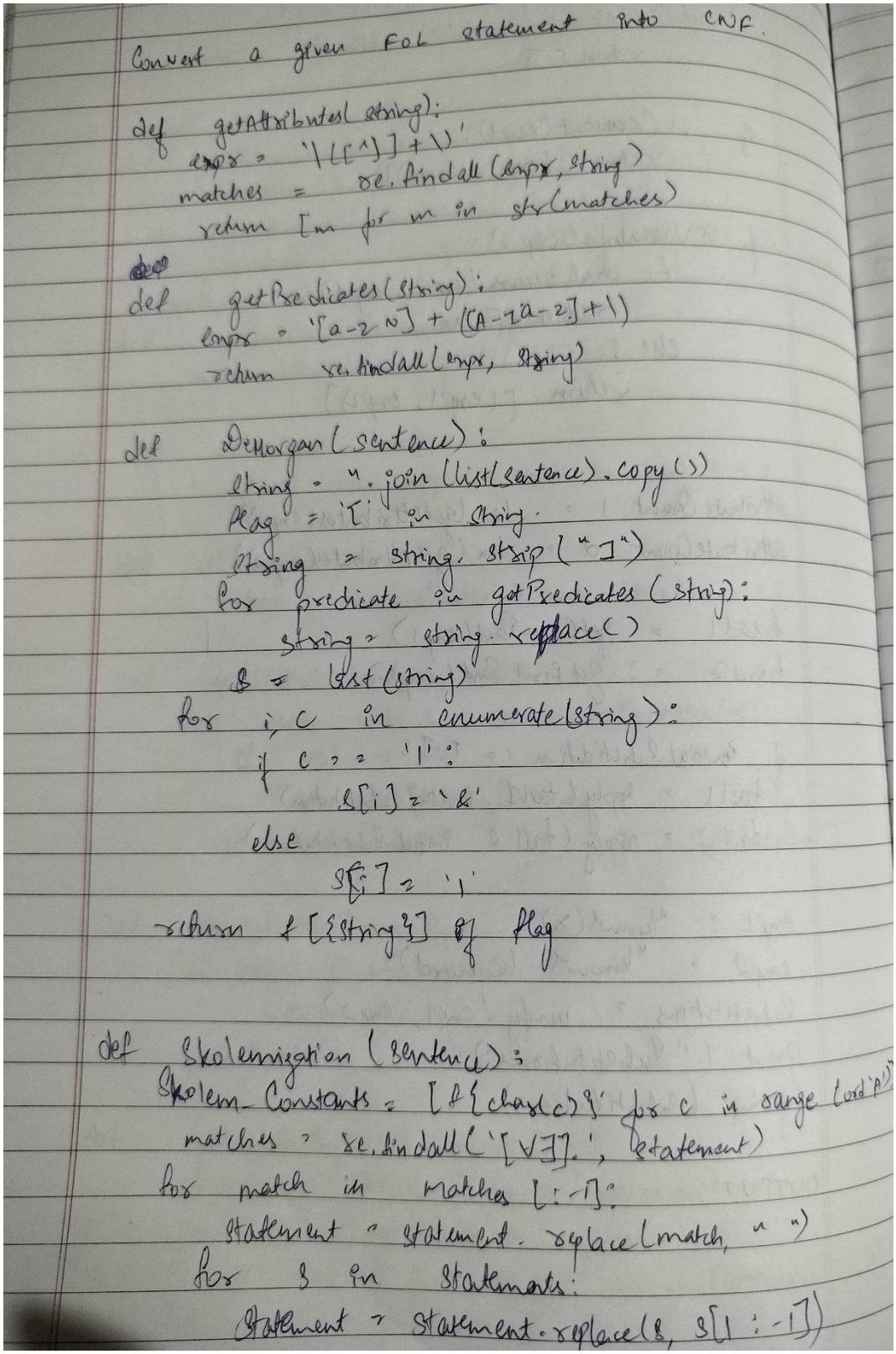
```
def getAttributes(string):
    expr = '
'
    matches = re.findall(expr, string)
    return [m for m in str(matches) if m.isalpha()]

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

def DeMorgan(sentence):
    string = ''.join(list(sentence).copy())
    string = string.replace('~~','')
    flag = '[' in string
    string = string.replace('~[','')
    string = string.strip(']')
    for predicate in getPredicates(string):
        string = string.replace(predicate, f'~{predicate}')
    s = list(string)
```

```
    for i, c in enumerate(string):
        if c == '|':
            s[i] = '&'
        elif c == '&':
            s[i] = '|'
    string = ''.join(s)
    string = string.replace('~~','')
    return f'[{string}]' if flag else string


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

OBSERVATION

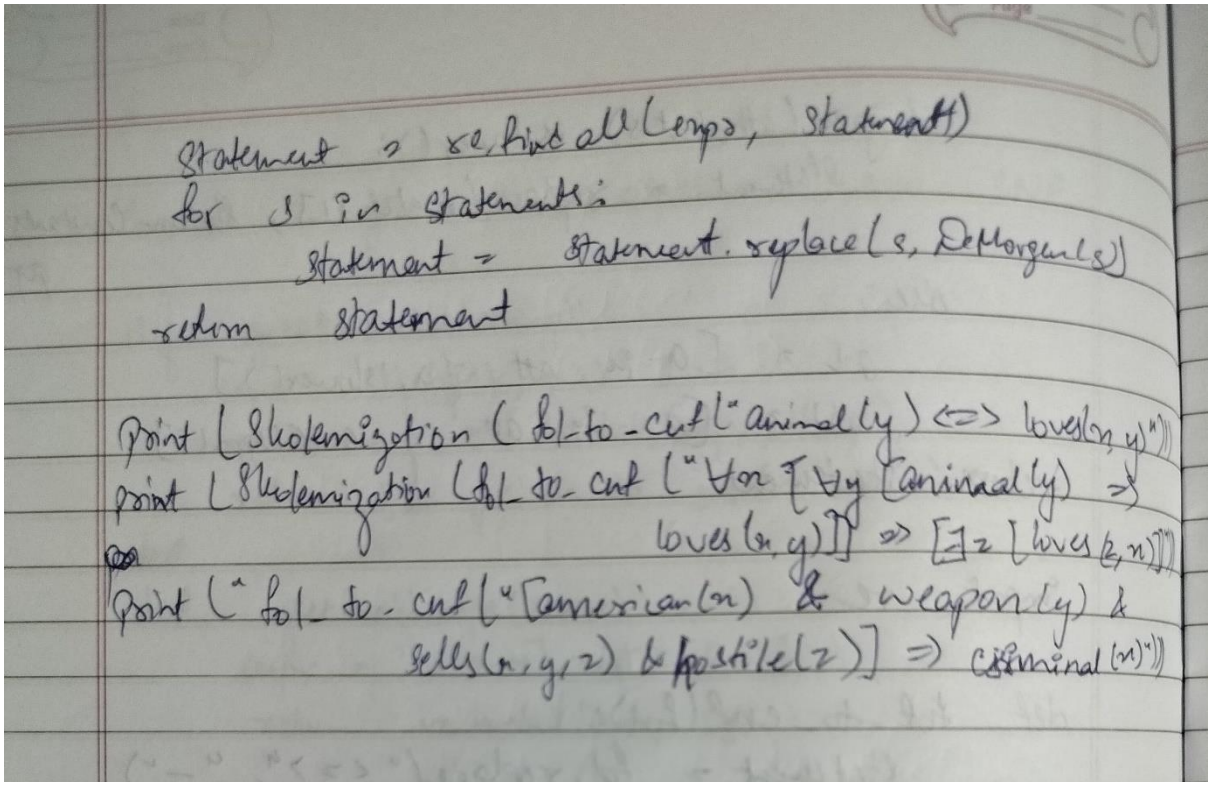


Convert a given FOL statement into CNF.

```
def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return [m for m in str(matches)
def
def getPredicates(string):
    expr = '[a-zA-Z~]+\([A-z,]+\)'
    return re.findall(expr, string)

def DeMorgan(sentence):
    string = ''.join(list(sentence).copy())
    flag = '[' in string
    string = string.strip("]")
    for predicate in getPredicates(string):
        string = string.replace()
    s = list(string)
    for i, c in enumerate(string):
        if c == '|':
            s[i] = '&'
        else
            s[i] = '|'
    return ''.join(s[1:-1]) if flag
```

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

```
if join(attributes).islower():
    statement = replace(match[1], Student-Courses.pop(0))
else:
    aL = [a in att if a.islower()]
    aU = [a in att if a.isupper()]
return statement

import re

def fol_to_cnf(fol):
    statement = fol.replace("<=>", "_")
    while '_' in statement
        i = statement.index("_")
        statement = new_statement
    statements = re.findall(expr)
for i, s in enumerate
    if ']' in s and '[' not in s:
        statement[i] += ']'
for s in statements
    statement = replace(s, fol_to_cnf(s))
    while '-' in statement
        i = statement.index("-")
        br = statement.index("[")
        new_statement = '~' + statement[br:i]
        statement = statement[:5x]
    while '~∀' in statement:
        i = statement.index('~∀')
    statement = list(statement)
    statement = "".join(statement)
while '~∃' in statement:
    p = statement.index('~∃')
    s = list(statement)
    expr = '([~[∀|∃].)'
```



OUTPUT

```
[~animal(y)|loves(x,y)]&[~loves(x,y)|animal(y)]
[animal(G(x))&~loves(x,G(x))]|[loves(F(x),x)]
[~american(x)|~weapon(y)|~sells(x,y,z)|~hostile(z)]|criminal(x)
```

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

```
import re


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


def getAttributes(string):
    expr = '
'
    matches = re.findall(expr, string)
    return matches


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



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

    def splitExpression(self, expression):
        predicate = getPredicates(expression)[0]
        params = getAttributes(expression)[0].strip('()').split(',')
        return [predicate, params]
```

```
    def getResult(self):
        return self.result

    def getConstants(self):
        return [None if isVariable(c) else c for c in self.params]

    def getVariables(self):
        return [v if isVariable(v) else None for v in self.params]

    def substitute(self, constants):
        c = constants.copy()
        f = f"{self.predicate}({','.join([constants.pop(0) if isVariable(p) else p for p in self.params])})"
        return Fact(f)

class Implication:
    def __init__(self, expression):
        self.expression = expression
        l = expression.split('=>')
        self.lhs = [Fact(f) for f in l[0].split('&')]
        self.rhs = Fact(l[1])

    def evaluate(self, facts):
        constants = {}
        new_lhs = []
        for fact in facts:
            for val in self.lhs:
                if val.predicate == fact.predicate:
                    for i, v in enumerate(val.getVariables()):
                        if v:
```

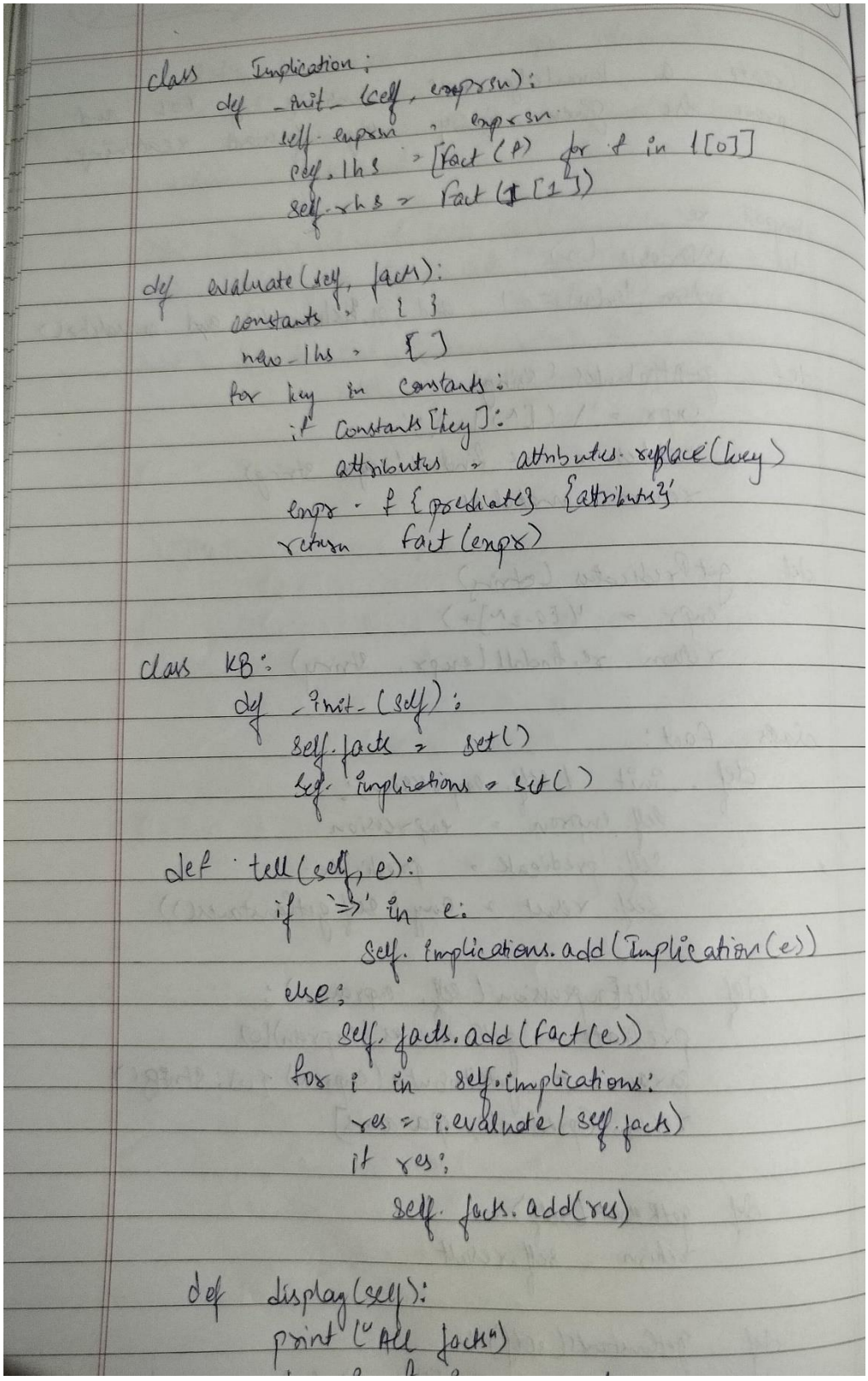
```
                    constants[v] = fact.getConstants()[i]
                new_lhs.append(fact)
        predicate, attributes = getPredicates(self.rhs.expression)[0],
str(getAttributes(self.rhs.expression)[0])
        for key in constants:
            if constants[key]:
                attributes = attributes.replace(key, constants[key])
        expr = f'{predicate}{attributes}'
        return Fact(expr) if len(new_lhs) and all([f.getResult() for f in new_lhs]) else None


class KB:
    def __init__(self):
        self.facts = set()
        self.implications = set()


    def tell(self, e):
        if '=>' in e:
            self.implications.add(Implication(e))
        else:
            self.facts.add(Fact(e))
        for i in self.implications:
            res = i.evaluate(self.facts)
            if res:
                self.facts.add(res)


    def query(self, e):
        facts = set([f.expression for f in self.facts])
        i = 1
        print(f'Querying {e}:')
        for f in facts:
            if Fact(f).predicate == Fact(e).predicate:
```

```
            print(f'\t{i}. {f}')
            i += 1

    def display(self):
        print("All facts: ")
        for i, f in enumerate(set([f.expression for f in self.facts])):
            print(f'\t{i+1}. {f}')


kb = KB()
kb.tell('missile(x)=>weapon(x)')
kb.tell('missile(M1)')
kb.tell('enemy(x,America)=>hostile(x)')
kb.tell('american(West)')
kb.tell('enemy(Nono,America)')
kb.tell('owns(Nono,M1)')
kb.tell('missile(x)&owns(Nono,x)=>sells(West,x,Nono)')
kb.tell('american(x)&weapon(y)&sells(x,y,z)&hostile(z)=>criminal(x)')
kb.query('criminal(x)')
kb.display()
```

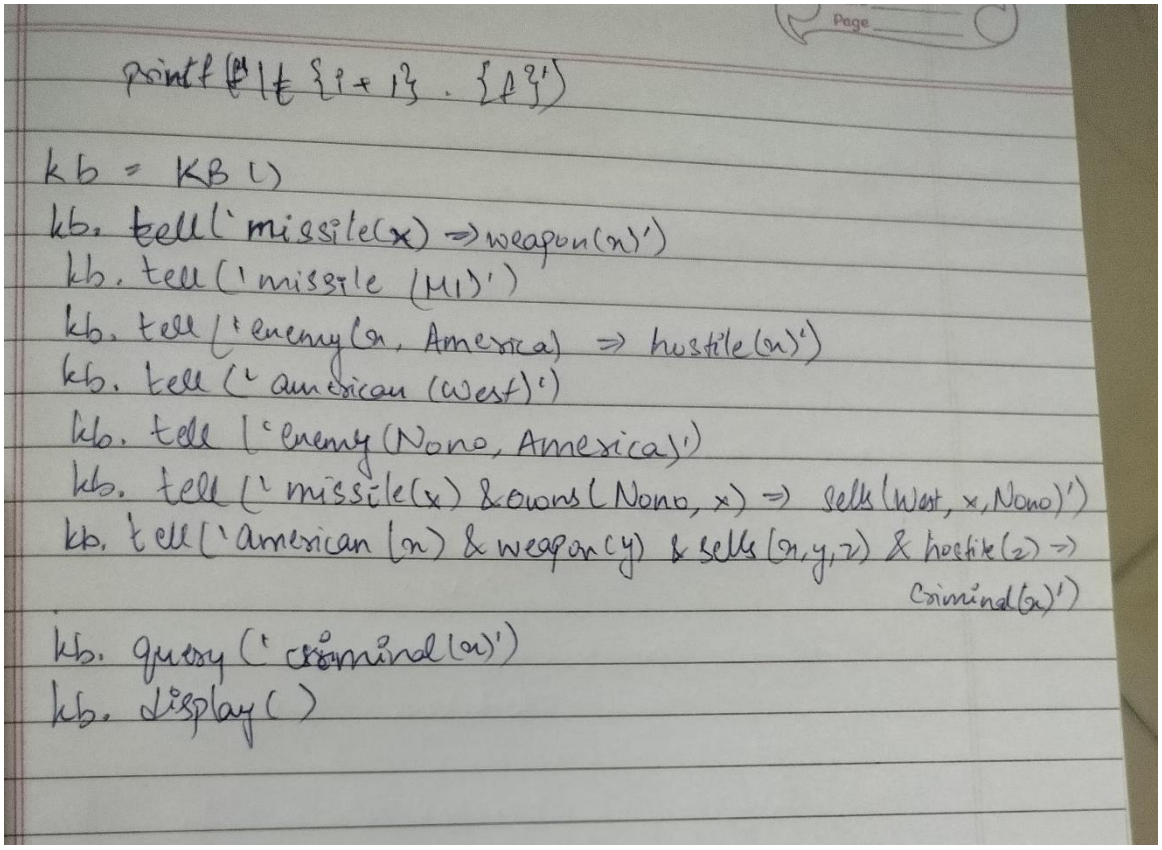
OBSERVATION

Create a knowledge base consisting of FOL and prove the given query using forward reasoning.

```
import re
def isVariable(x)
    return len(x) == 1 and x.islower() and x.isalpha()

def getAttributes(string)
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return matches

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

class Fact:
    def __init__(self, expression):
        self.expr = expression
        self.predicate = predicate
        self.result = any(self.getConstants())

    def splitExpression(self, expression):
        predicate = getPredicates(expr)[0]
        params = getAttributes(expr)[0].strip()
        return [predicate, params]

    def getResult(self):
        return self.result

    def getConstants(self):
        return [None if isVariable(c) else c for c in self.params]
```



```
class Implication:
    def __init__(self, expression):
        self.expr = expression
        self.lhs = [Fact(p) for p in l[0]]
        self.rhs = Fact(l[1])

def evaluate(self, facts):
    constants = {}
    new_lhs = []
    for key in constants:
        if constants[key]:
            attributes = attributes.replace(key)
    expr = f'{predicate}{attributes}'
    return Fact(expr)


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")
```



OUTPUT

```
Querying criminal(x):
        1. criminal(West)
All facts:
        1. enemy(Nono,America)
        2. hostile(Nono)
        3. sells(West,M1,Nono)
        4. criminal(West)
        5. owns(Nono,M1)
        6. weapon(M1)
        7. american(West)
        8. missile(M1)
```