VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

AI Lab Report

Submitted by

CHINMAYI (1BM21CS045)

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

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
BENGALURU-560019
NOV-2023 to 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 "Internet of things lab" carried out by **CHINMAYI (1BM21CS045),** who is bonafide student of **B. M. S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum during the year 2023. The Lab report has been approved as it satisfies the academic requirements in respect of a **Artificial Intelligence lab - (22CS5PCAIN)** work prescribed for the said degree.

Dr. Asha G R
Assistant professor
Department of CSE
BMSCE, Bengaluru

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

`

Table of Contents

Program 1 : Tic Tac Toe

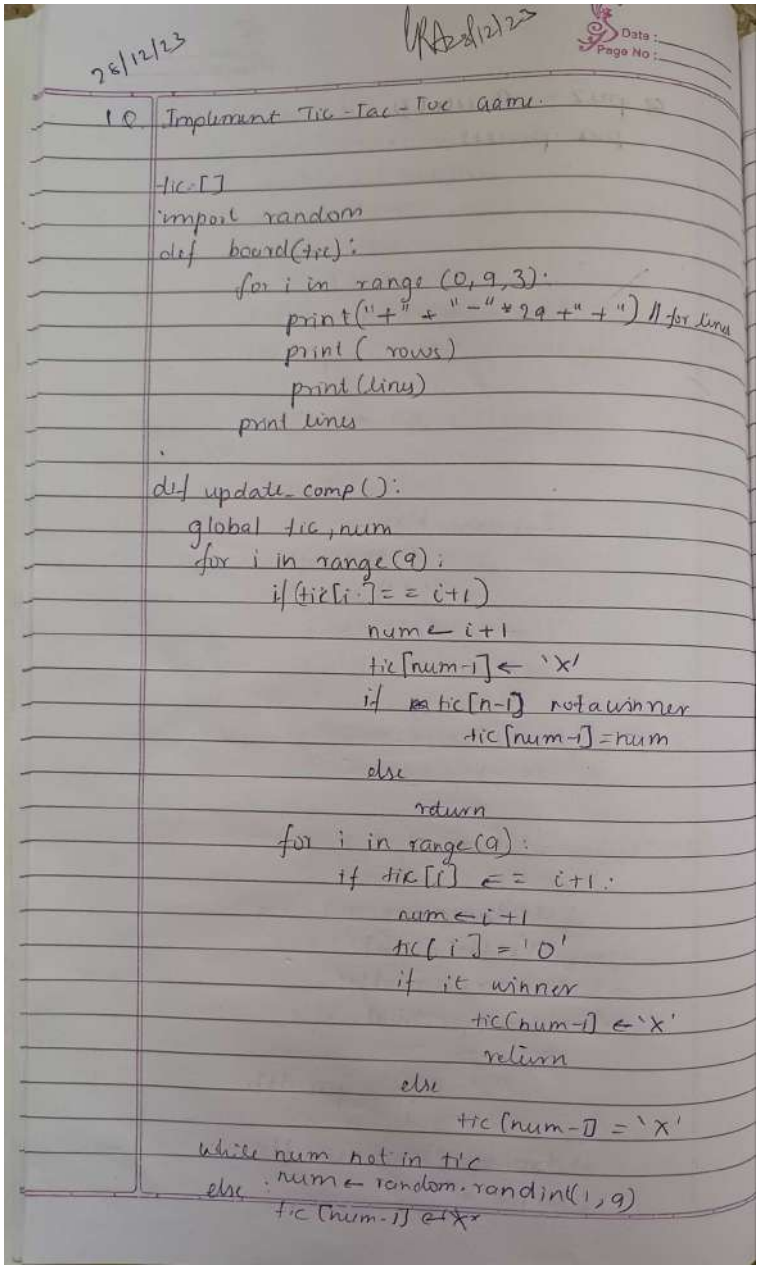
Code:

```
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")
```

Observation:



```
def userupdu()
    global tic, num
    take num as input from user
    while num not in tic:
        take input from user
    else:
        tic[num-1] = 'O'

def winner(num):
    if right diagonal (0,4) (4,8) or left diagon (2,4) (4,6) fills
        return true
    if column is filled
        return true
    if row is filled
        return true
    else
        return false:

Try:
    for i in range (1,10)
        append i to tic
    count = 0
    print(tic)
    print (board (tic))
    while count != 9
        if count is even
            computers turn
            upade-comp()
            board (tic)
            count ++
```

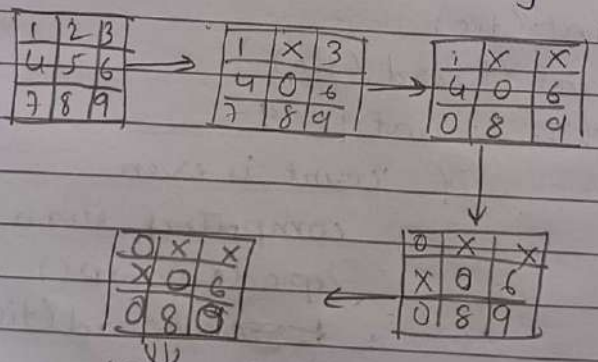
```
else:
    User turn
    update_user
    board(tic)
    count+=1
if count>=5:
    if (winner(num-1):
        print(winner)
        break
    else:
        continue
except:
    print error.
```

Working:

computer first check if there's any cell where it can place to win

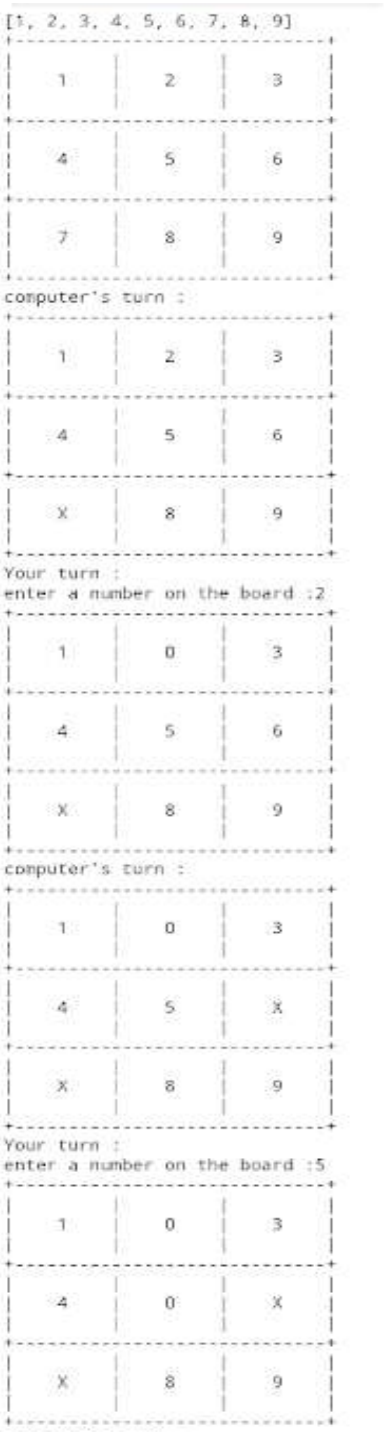
Then it check if there's any place where user can place anywhere to ~~where~~ win

Else it places randomly.



Winner is 'O'

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 5 6
X 8 9
Your turn :
enter a number on the board :2
1 0 3
4 5 6
X 8 9
computer's turn :
1 0 3
4 5 X
X 8 9
Your turn :
enter a number on the board :5
1 0 3
4 0 X
X 8 9

```
+---+---+---+
computer's turn :
+---+---+---+
| 1 | 0 | 3 |
+---+---+---+
| 4 | 0 | X |
+---+---+---+
| X | X | 9 |
+---+---+---+
Your turn :
enter a number on the board :9
+---+---+---+
| 1 | 0 | 3 |
+---+---+---+
| 4 | 0 | X |
+---+---+---+
| X | X | 0 |
+---+---+---+
computer's turn :
+---+---+---+
| X | 0 | 3 |
+---+---+---+
| 4 | 0 | X |
+---+---+---+
| X | X | 0 |
+---+---+---+
Your turn :
enter a number on the board :4
+---+---+---+
| X | 0 | 3 |
+---+---+---+
| 0 | 0 | X |
+---+---+---+
| X | X | 0 |
+---+---+---+
computer's turn :
+---+---+---+
| X | 0 | X |
+---+---+---+
|   |   |   |
```

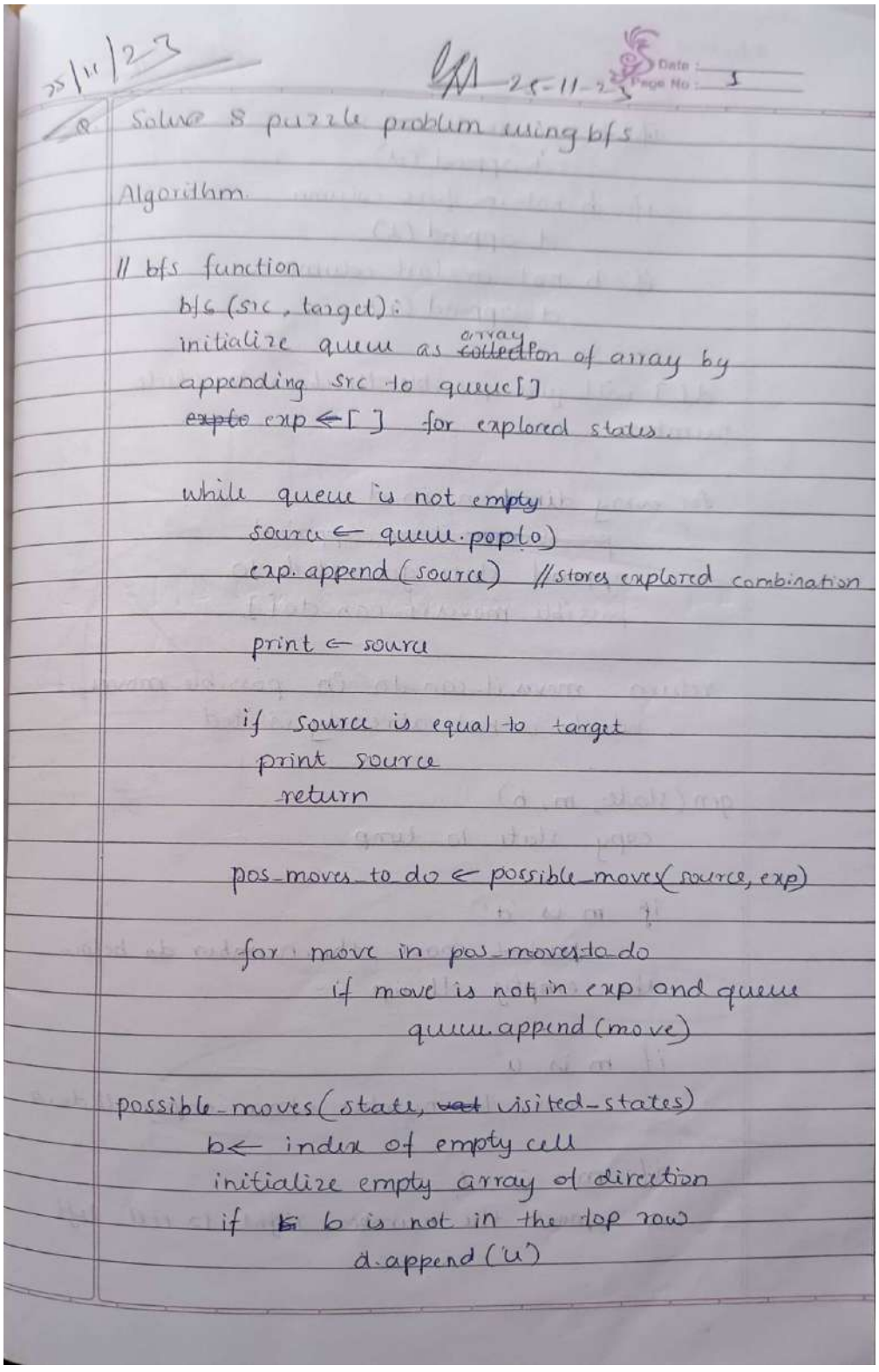
Program 2 : 8 Puzzle Breadth First Search Algorithm

Code:

```
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:



Solve 8 puzzle problem using bfs

Algorithm

// bfs function

bfs (src, target):

initialize queue as ~~collection~~ array of array by appending src to queue[]

~~explo~~ exp ← [ ] for explored states.

while queue is not empty

source ← queue.pop(0)

exp.append(source) //stores explored combination

print ← source

if source is equal to target

print source

return

pos_moves_to_do ← possible_moves(source, exp)

for move in pos_moves_to_do

if move is not in exp and queue

queue.append(move)

possible_moves(state, ~~val~~ visited_states)

b ← index of empty cell

initialize empty array of direction

if ~~b~~ b is not in the top row

d.append('u')

Addition subtraction table

Date :
Page No : 2

if b not in bottom row
d.append('d')
if b not in first column
d.append('l')
if b not in last column
d.append('r')

d[] will give possible direction's to slide numbers.

for every direction in d
~~possible moves it can append~~
append state generated to possible_moves_it_can_do[].

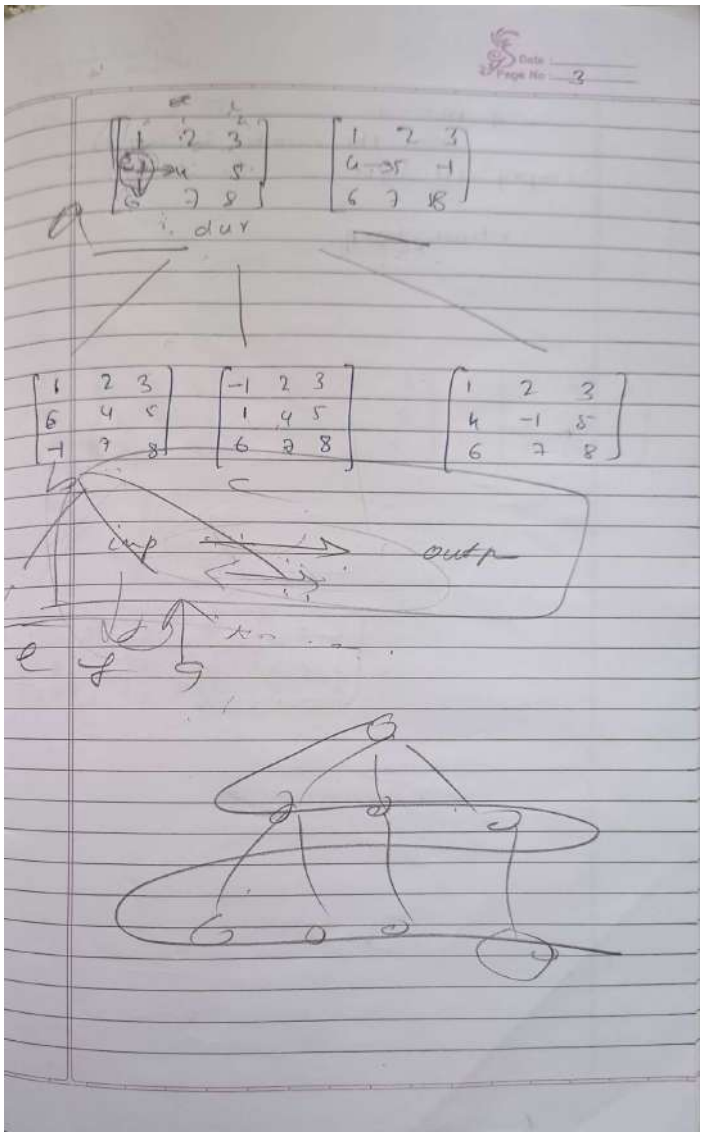
return moves_it_can_do in possible_moves_it_can
which is not already visited

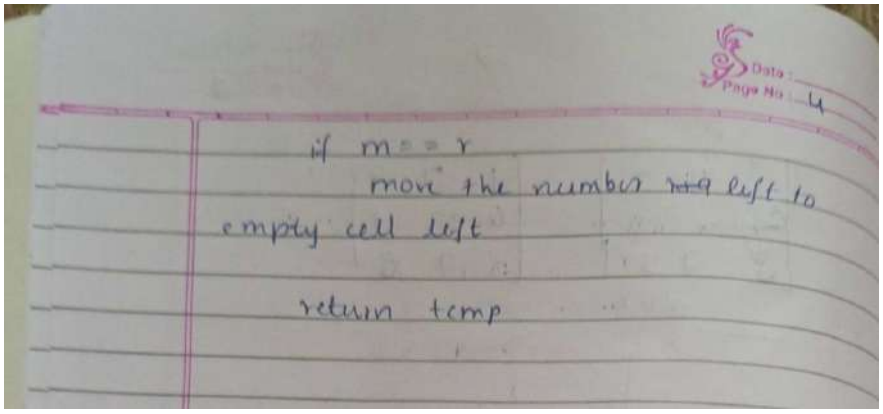
gen(state, m, b)
copy state to temp

if m is 'd'
~~push~~ move the number ~~do~~ below the empty cell up

if m is 'u'
move the number above empty cell down

if m is 'l'
move the number right to cell left




if m == r
move the number left to
empty cell left
return temp

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
```

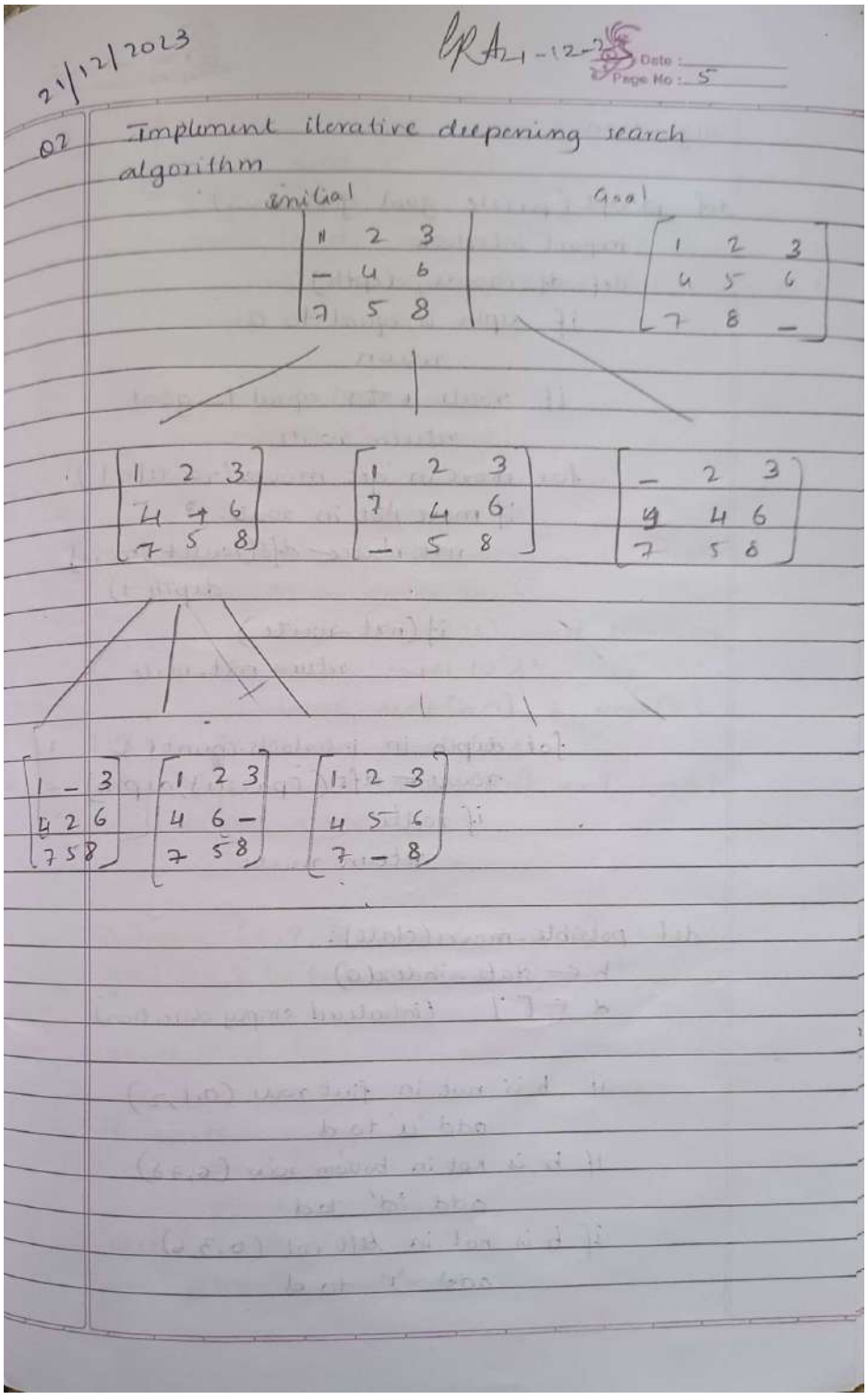
Program 3 : 8 Puzzle Iterative Deepening Search Algorithm

Code:

```
# 8 Puzzle problem using Iterative deepening depth first 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')
```

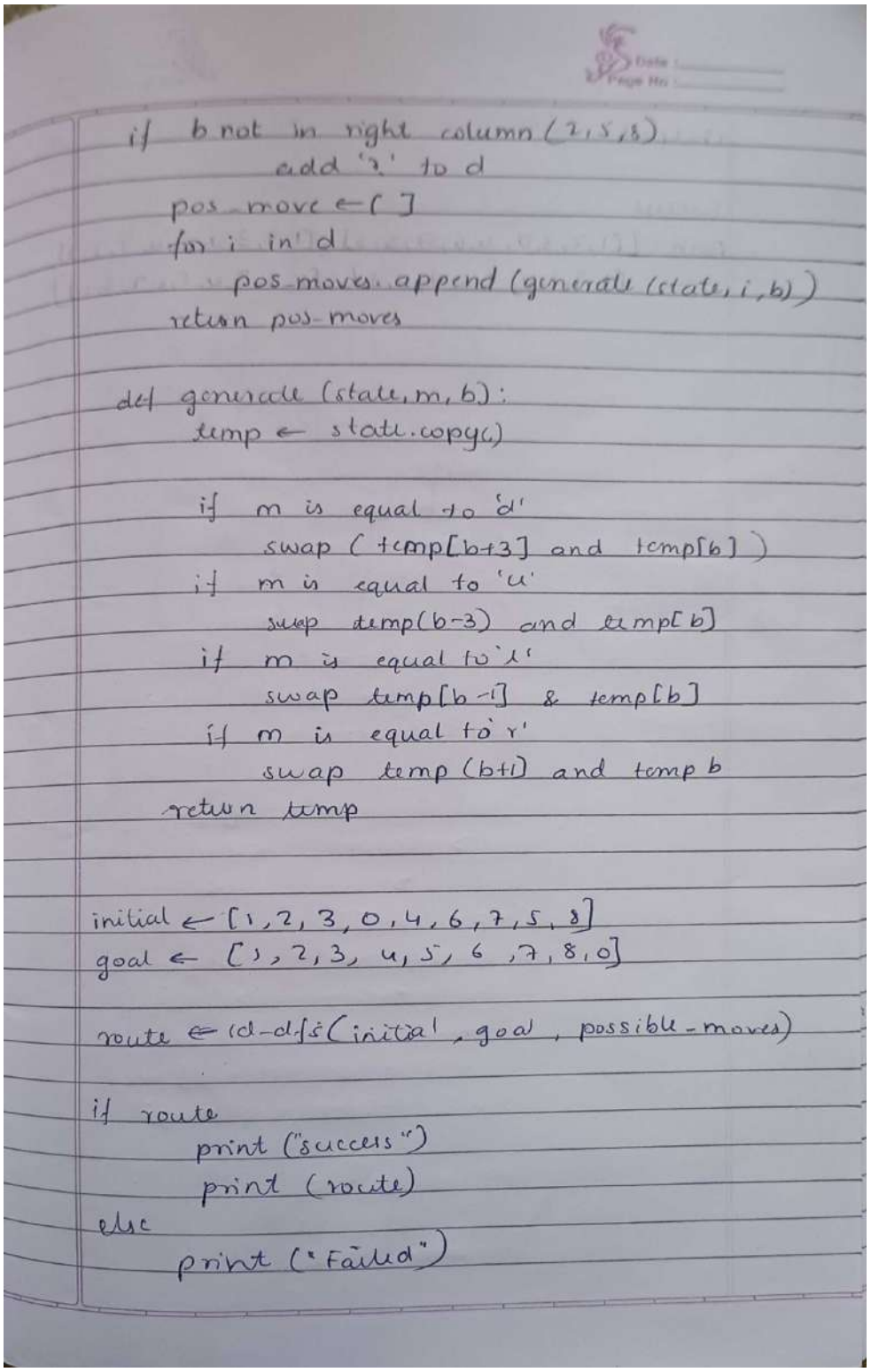
```
    pos_moves = []
    for i in d:
        pos_moves.append(generate(state, i, b))
    return pos_moves


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:



Algorithm

```
def id_dfs(puzzle, goal, get_moves):
    import intertools
    def dfs(route, depth):
        if depth is equal to 0
            return
        if route is equal to goal
            return route
        for move in get_moves(route[-1]):
            if move not in route:
                nxt_route ← dfs(route + [move],
                                depth - 1)
                if (nxt_route)
                    return nxt_route

    for depth in intertools.count():
        route ← dfs([puzzle], depth)
        if route:
            return route

def possible_moves(state):
    b ← state.index(0)
    d ← [ ]   (initialised empty direction)

    if b is not in first row (0,1,2)
        add 'u' to d
    if b is not in bottom row (6,7,8)
        add 'd' to d
    if b is not in left col (0,3,6)
        add 'l' to d
```



```
if b not in right column (2,5,8)
        add '3' to d
    pos_move ← [ ]
    for i in d
        pos_moves.append (generate (state, i, b))
    return pos_moves

def generate (state, m, b):
    temp ← state.copy()

    if m is equal to 'd'
        swap (temp[b+3] and temp[b])
    if m is equal to 'u'
        swap temp(b-3) and temp[b]
    if m is equal to 'l'
        swap temp[b-1] & temp[b]
    if m is equal to 'r'
        swap temp (b+1) and temp b
    return temp


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")
        print (route)
else
        print ("Failed")
```

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]]
```

Program 4 : 8 Puzzle A* Search Algorithm

Code:

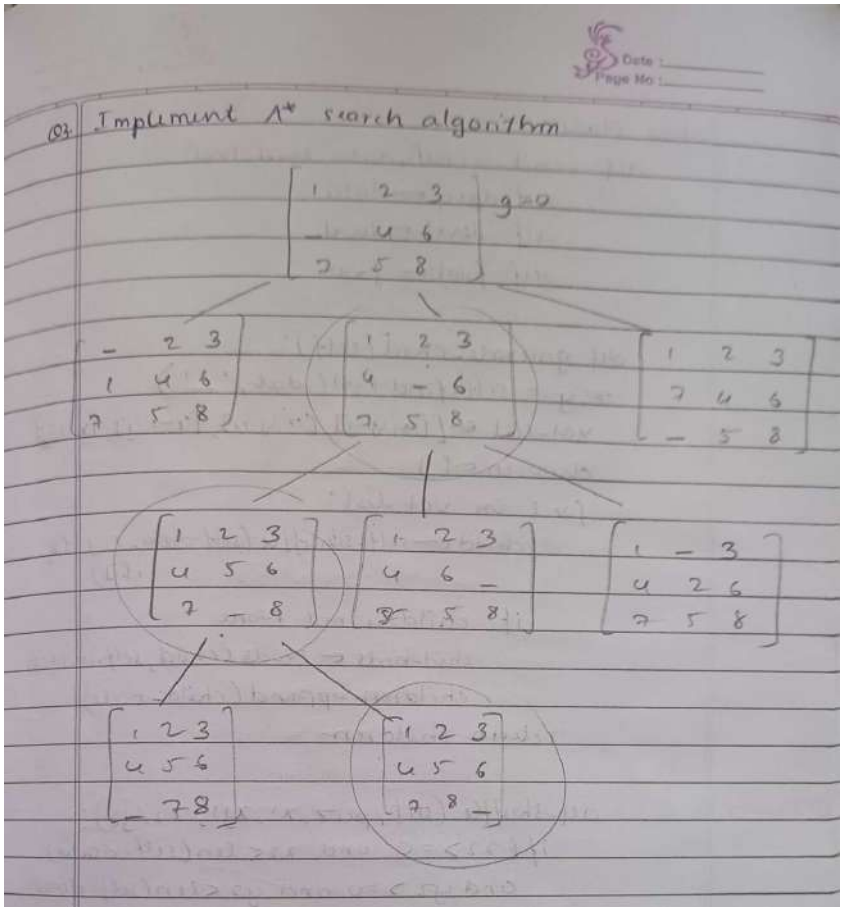
```
class Node:
    def __init__(self,data,level,fval):
        """ Initialize the node with the data, level of the node and the calculated fvalue """
        self.data = data
        self.level = level
        self.fval = fval

    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
```

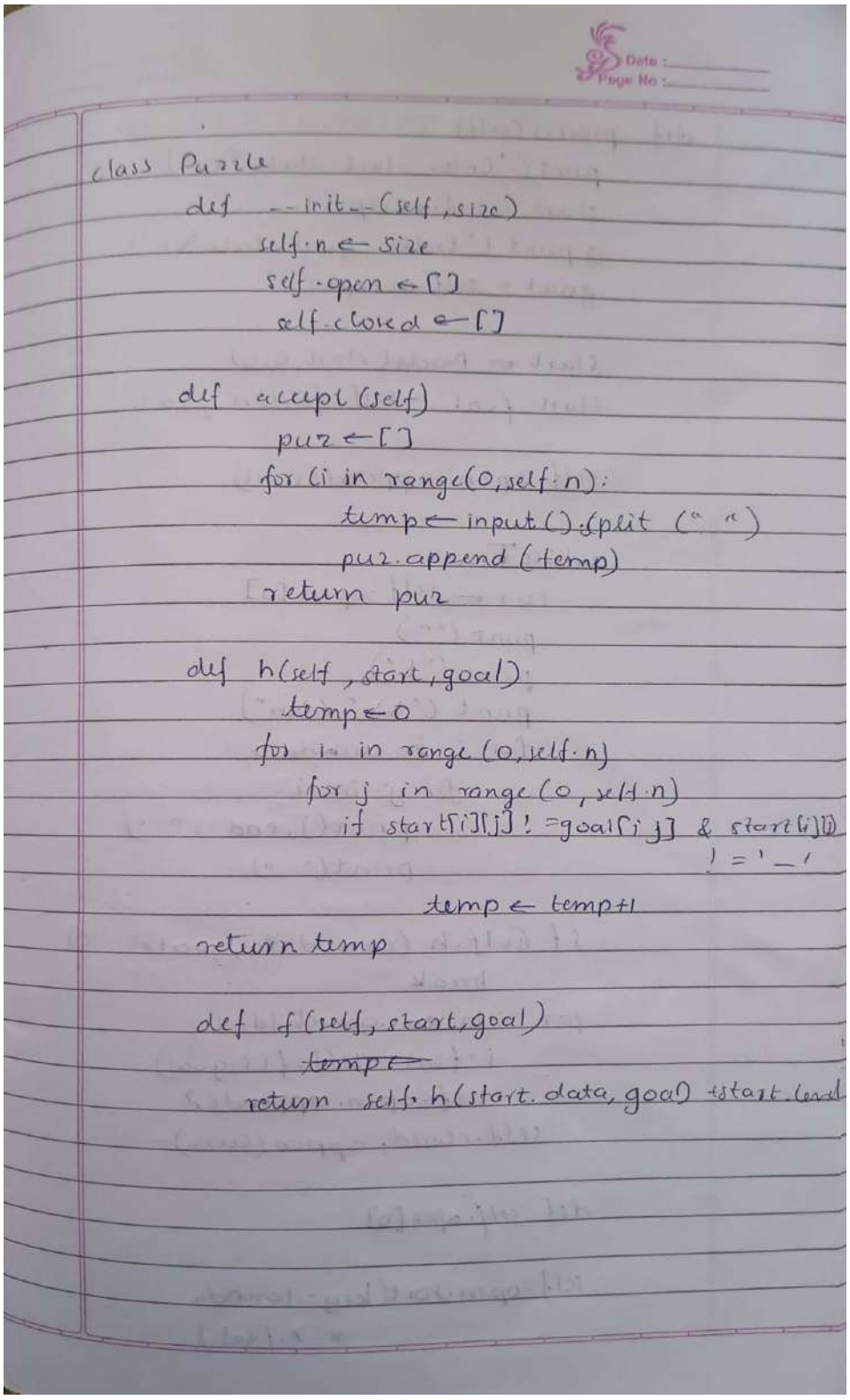
```
def h(self,start,goal):
    """ Calculates the different between the given puzzles """
    temp = 0
    for i in range(0,self.n):
        for j in range(0,self.n):
            if start[i][j] != goal[i][j] and start[i][j] != '_':
                temp += 1
    return temp


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.process()
```

Observation:



```
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.dat, '_')
        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)
                children.append(child_node)
        return children

    def shuffle(self, puz, x1, y1, x2, y2):
        if (x2 >=0 and x2 < len(self.data)
            and y2 >=0 and y2 < len(self.data)
            temp_puz ← []
            temp_puz ← self.copy(puz)
            temp ← temp_puz[x2][y2]
            swap temp_puz[x2, y2] and
                 temp_puz[x1, y1]

        return temp_puz
    else:
        return None
```



```
class Puzzle
    def __init__(self, size)
        self.n ← size
        self.open ← []
        self.closed ← []

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

    def h(self, start, goal):
        temp ← 0
        for i in range(0, self.n)
            for j in range(0, self.n)
                if start[i][j] != goal[i][j] & start[i][j]
                                                != '_'
                    temp ← temp+1
        return temp

    def f(self, start, goal)
        temp ←
        return self.h(start.data, goal) + start.level
```

```
def process(self)
    print("Enter start state\n")
    start = self.accept()
    print("Enter goal state\n")
    goal = self.accept()

    start ← Node(start,0,0)
    start.fval = self.f(start,goal)

    self.open.append(start)

    while True:
        cur ← self.open[0]
        print("\n")
        print(" | ")
        print(" \\ ' / \n")
        for i in cur.data
            for j in i
                print(j, end = " ")
            print(" ")

        if (self.h(curr.data,goal)==0)
            break
        for i in cur.genchild()
            i.fval = self.f(i,goal)
            self.open.append(i)
        self.closed.appin(curr)

    del self.open[0]

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

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 _
```

Program 5 : Vacuum Cleaner

Code:

```
def clean_room(floor, room_row, room_col):
    if floor[room_row][room_col] == 1:
        print(f"Cleaning Room at ({room_row + 1}, {room_col + 1}) (Room was dirty)")
        floor[room_row][room_col] = 0
        print("Room is now clean.")
    else:
        print(f"Room at ({room_row + 1}, {room_col + 1}) is already clean.")

def main():
    rows = 2
    cols = 2
    floor = [[0, 0], [0, 0]]  # Initialize a 2x2 floor with clean rooms

    for i in range(rows):
        for j in range(cols):
            status = int(input(f"Enter clean status for Room at ({i + 1}, {j + 1}) (1 for dirty, 0 for
clean): "))
            floor[i][j] = status

    for i in range(rows):
        for j in range(cols):
            clean_room(floor, i, j)

    print("Returning to Room at (1, 1) to check if it has become dirty again:")
    clean_room(floor, 0, 0)  # Checking Room at (1, 1) after cleaning all rooms

if __name__ == "__main__":
    main()
```

Four rooms:

```
def clean_room(room_name, is_dirty):
   if is_dirty:
      print(f"Cleaning {room_name} (Room was dirty)")
      print(f"{room_name} is now clean.")
```

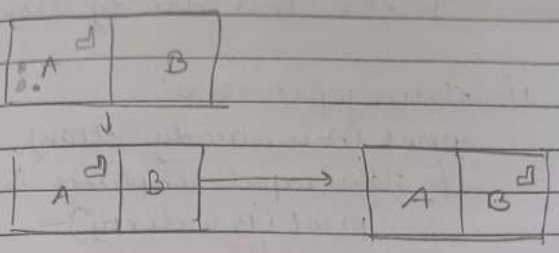
```
        return 0  # Updated status after cleaning
    else:
        print(f"{room_name} is already clean.")
        return 0  # Status remains clean

def main():
    rooms = ["Room 1", "Room 2"]
    room_statuses = []

    for room in rooms:
        status = int(input(f"Enter clean status for {room} (1 for dirty, 0 for clean): "))
        room_statuses.append((room, status))
    print(room_statuses)

    for i, (room, status) in enumerate(room_statuses):
        room_statuses[i] = (room,clean_room(room, status)) # Update status after cleaning

    print(f"Returning to {rooms[0]} to check if it has become dirty again:")
    room_statuses[0]=status = (rooms[0],clean_room(rooms[0], room_statuses[0][1])) # Checking
Room 1 after cleaning all rooms

    print(f"{rooms[0]} is {'dirty' if room_statuses[0][1] else 'clean'} after checking.")

if __name__ == "__main__":
    main()
```

Observation:

28/12/23

Date :
Page No :

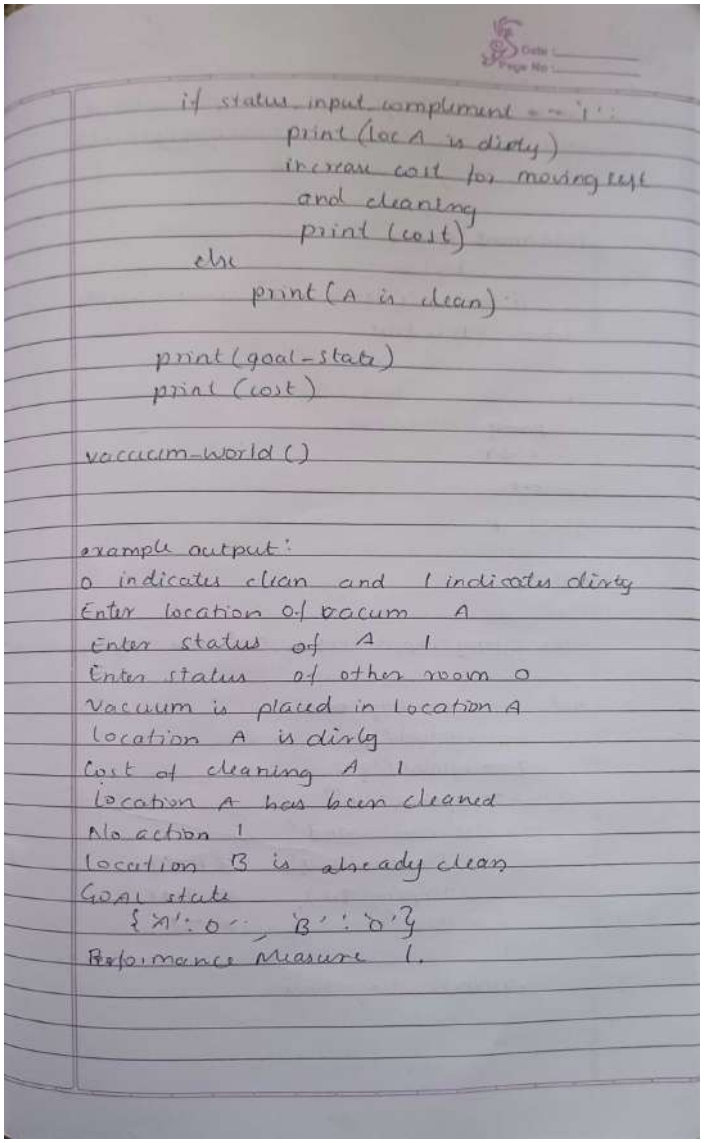
6. Implement vaccum cleaner agent



Program:

```
def vacuum_world():
    goal_state ← {'A': '0', 'B': '0'}
    cost ← 0
    get location input
    take status input
    take status input for other room.

    if location is A
        print (vacuum is in location A)
        if status input is 1
            print Room is dirty
            cost += 1;
            print ('cost for cleaning A ' +str(cost))
            print ("location A is cleaned")

        if status_input_complument == '1':
            print ( location B is dirty)
            print (moving right to B)
                cost++
            print (cost)
```

```
else:
    print ("no action" )
    print ( "B is already cleaned")

if status_input == '0'
    print ('A is already clean)
    if status input complemnt is 1
        print ('B is dirty')
        print ('move RIGHT to B')
        cost ++
        print (cost)
        cost ++
        print (sucking cost)
        print ('B is cleaned')
    else
        print ('B is clean')
else
    print ( "Vaccuum is in loc B")
    if status input is 1
        print ('B is dirty')
        cost ++
        print( cost)
        print (B is clean)
    if complement is 1
        print A is dirty
        cost ++ for moving
        cost ++ for cleaning
        print (cost)
    else
        print(loc B is clean)
```



Output:

```
vacuum_world()
```

```
0 indicates clean and 1 indicates dirty
Enter Location of VacuumA
Enter status of A1
Enter status of other room0
Vacuum is placed in Location A
Location A is Dirty.
Cost for CLEANING A 1
Location A has been Cleaned.
No action1
Location B is already clean.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 1
```

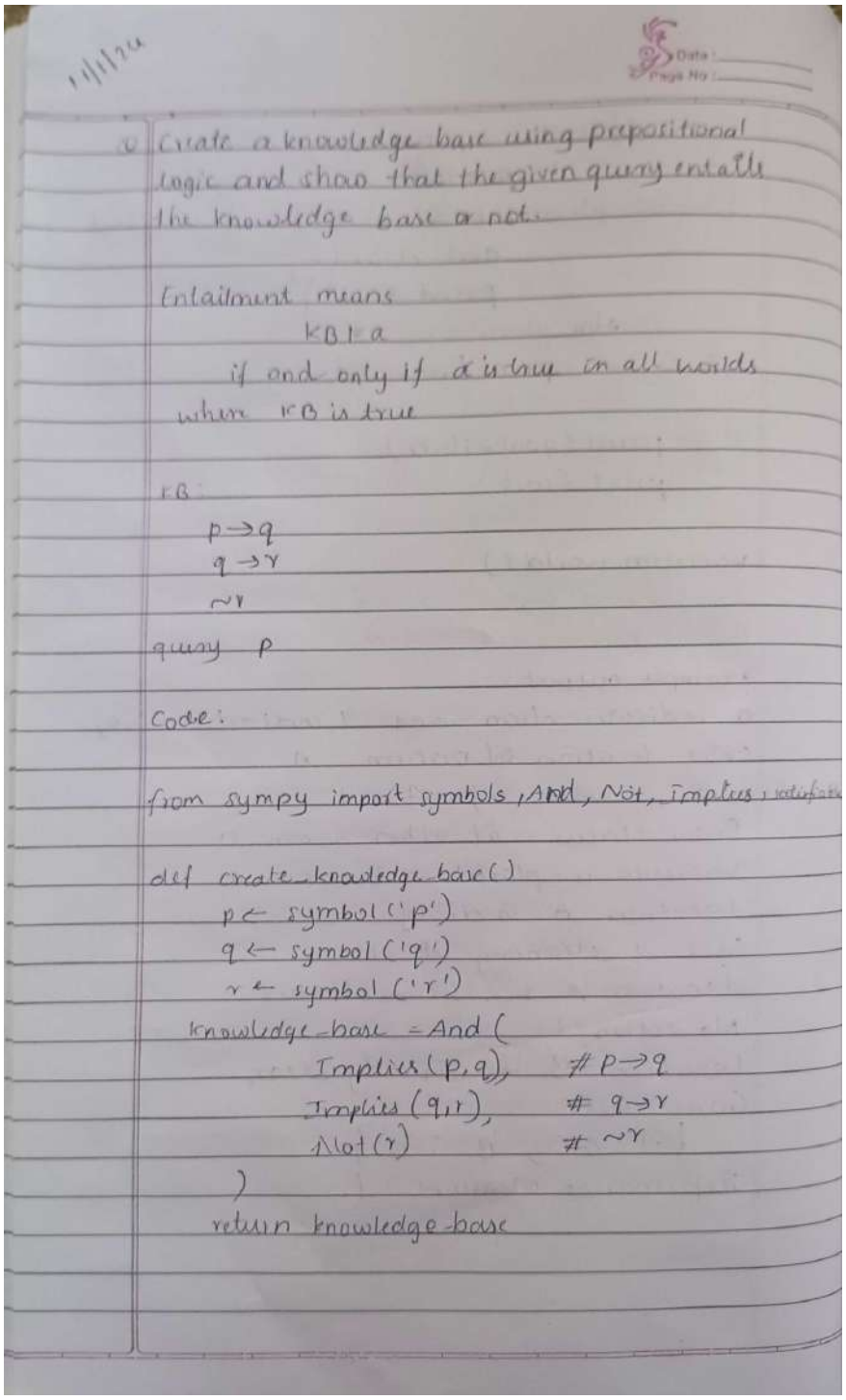
Program 6 : Knowledge Base Entailment

Code:

```
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)
```

Observation:



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

Entailment means

KB ⊨ α

if and only if α is true in all worlds when KB is true

KB:

p → q

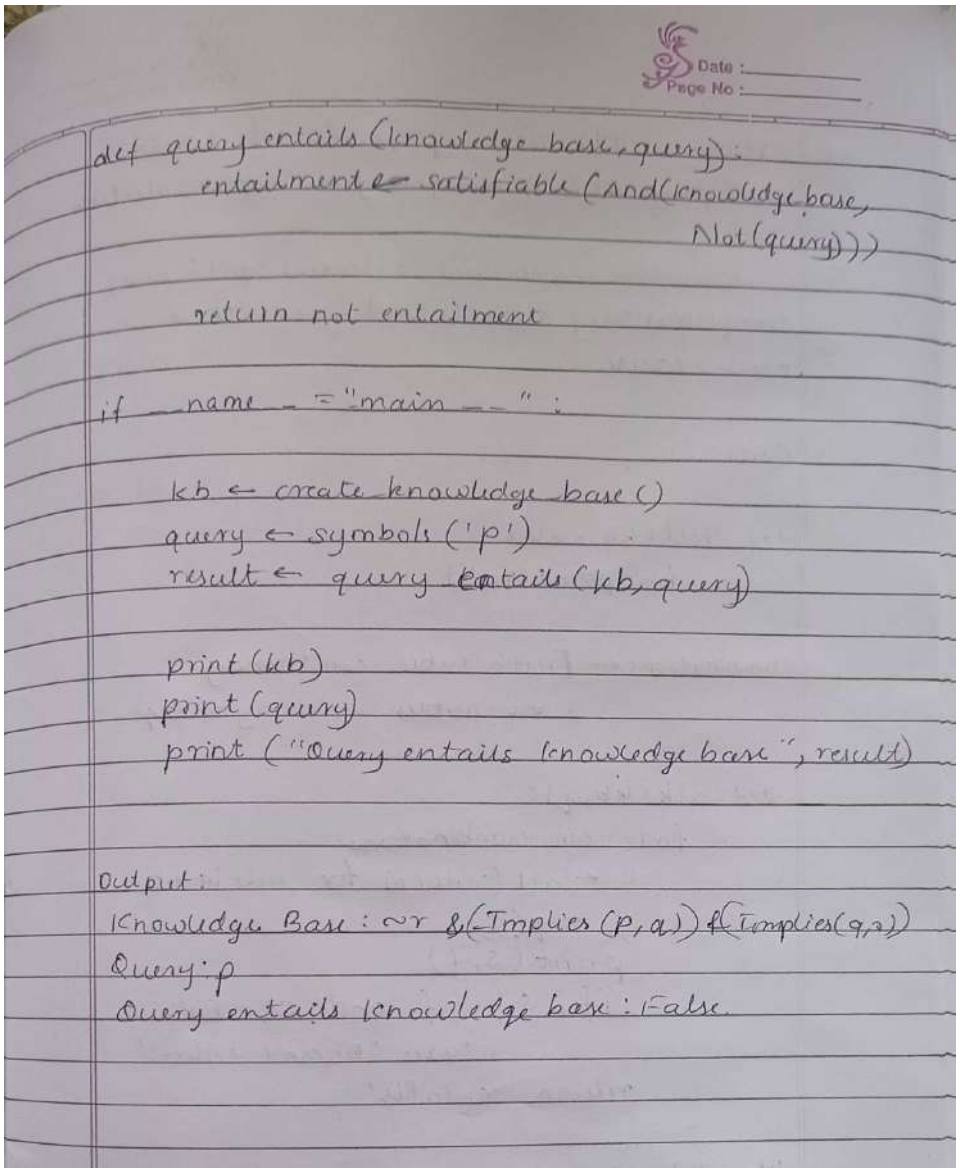
q → r

~r

query p

Code:

```
from sympy import symbols, And, Not, Implies
def create_knowledge_base():
    p = symbol('p')
    q = symbol('q')
    r = symbol('r')
    knowledge_base = And(
        Implies(p, q),   # p → q
        Implies(q, r),   # q → r
        Not(r)           # ~r
    )
    return knowledge_base
```



Output:

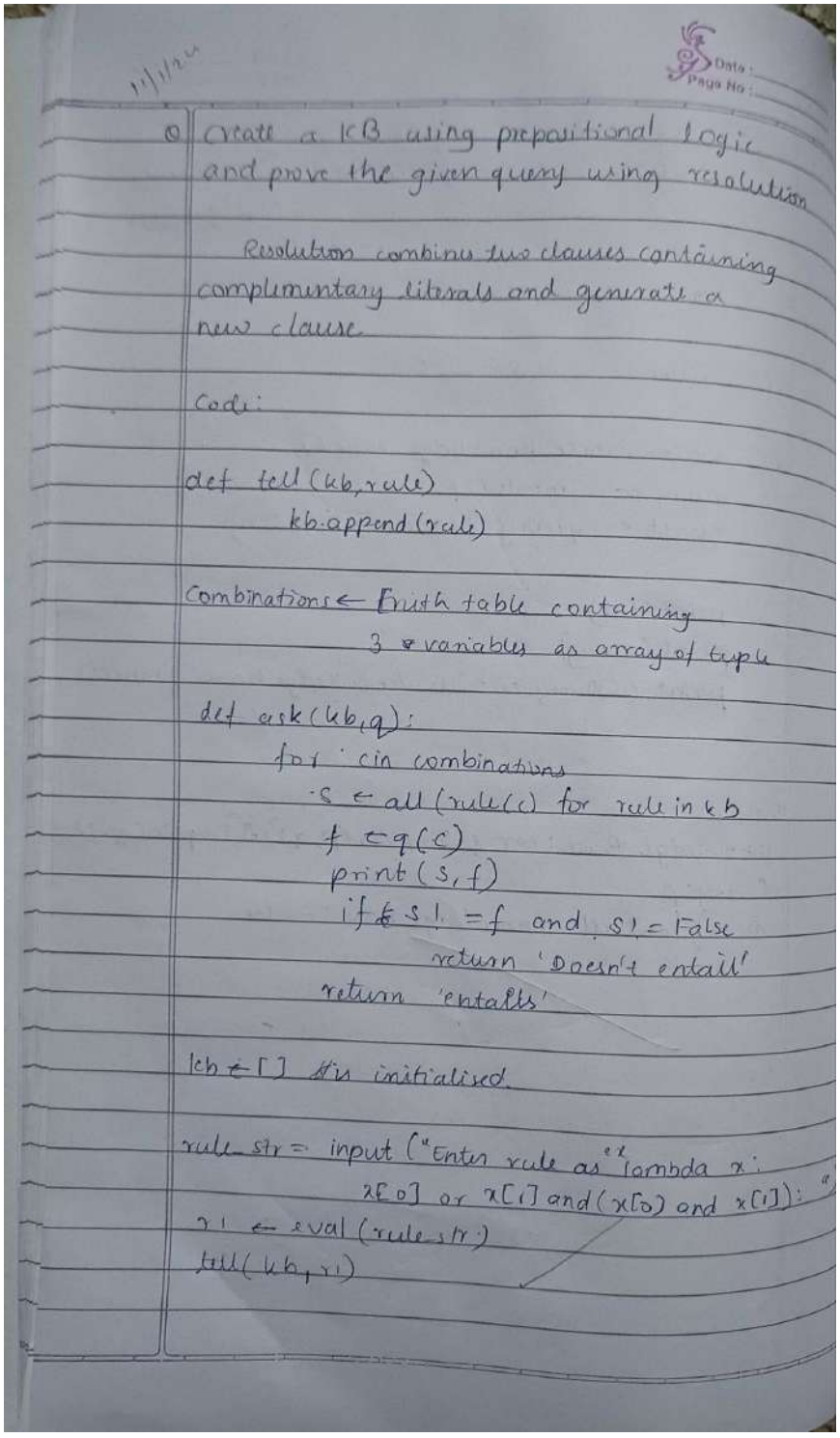
```
Knowledge Base: ~r & (Implies(p, q)) & (Implies(q, r))
Query: p
Query entails Knowledge Base: False
```

Program 7 : Knowledge Base Resolution

Code:

```
def tell(kb, rule):
   kb.append(rule)

combinations = [(True, True, True), (True, True, False),
                (True, False, True), (True, False, False),
                (False, True, True), (False, True, False),
                (False, False, True), (False, False, False)]



def ask(kb, q):
   for c in combinations:
      s = all(rule(c) for rule in kb)
      f = q(c)
      print(s, f)
      if s != f and s != False:
         return 'Does not entail'
   return 'Entails'



kb = []

# Get user input for Rule 1
rule_str = input("Enter Rule 1 as a lambda function (e.g., lambda x: x[0] or x[1] and (x[0] and
x[1]): ")
r1 = eval(rule_str)
tell(kb, r1)

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

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

Observation:

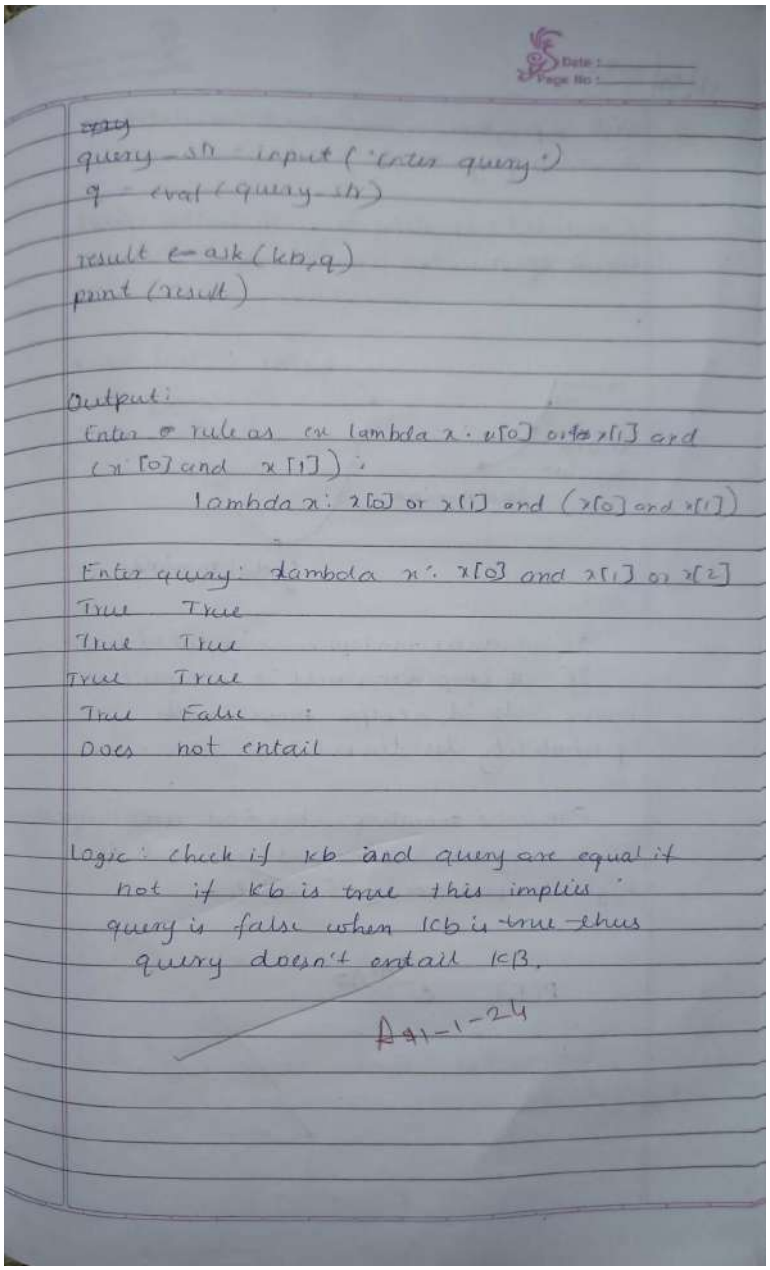


Create a KB using propositional Logic and prove the given query using resolution

Resolution combines two clauses containing complimentary literals and generate a new clause

Code:

```
def tell(kb,rule)
    kb.append(rule)

Combinations ← Truth table containing
                3 variables as array of tuple

def ask(kb,q):
    for c in combinations
        s ← all(rule(c) for rule in kb
        f ← q(c)
        print(s,f)
        if s != f and s != False
            return 'Doesn't entail'
    return 'entails'

kb ← [] is initialised.

rule_str = input("Enter rule as lambda x: x[0] or x[1] and (x[0] and x[1]): ")
r1 ← eval(rule_str)
tell(kb,r1)
```



Output:

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

Program 8. Simulated Annealing

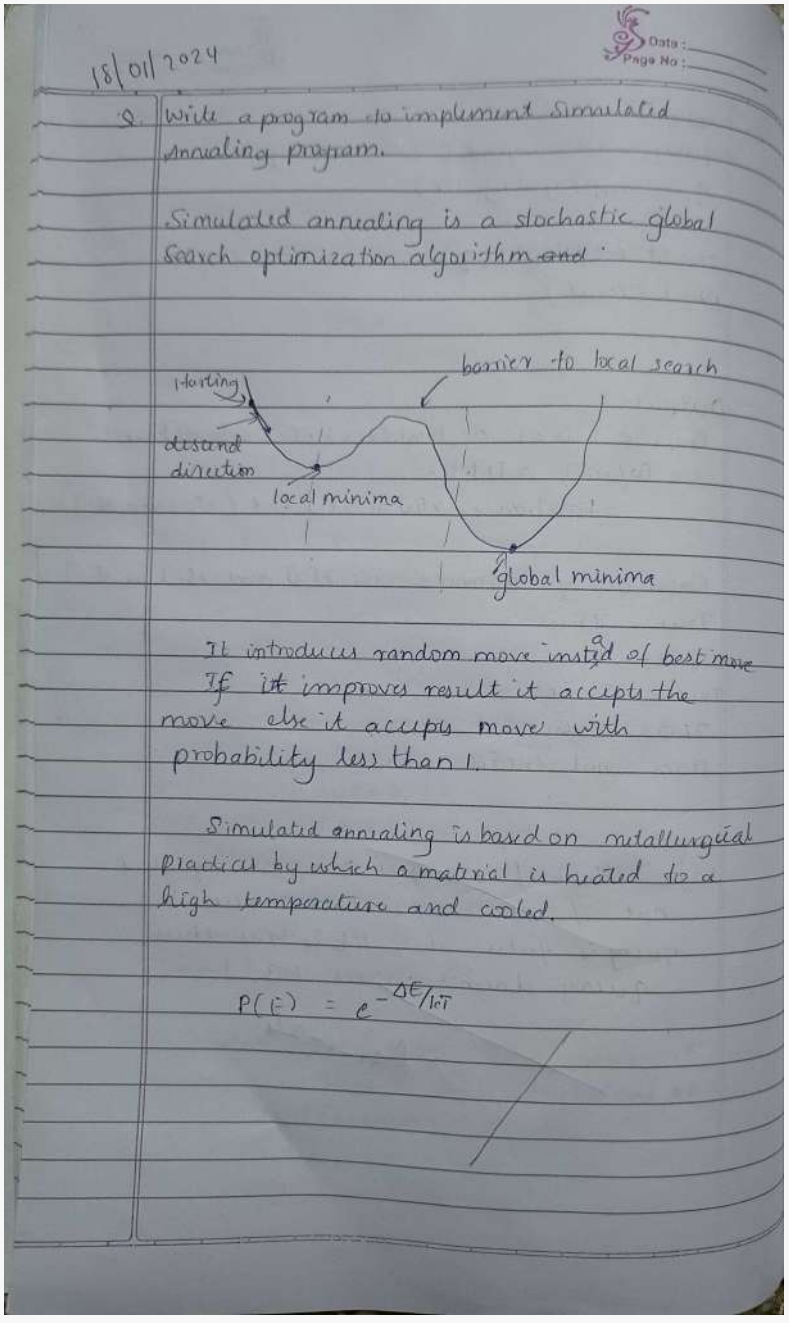
Code:

```
import random
import math

class Solution:
    def __init__(self, CVRMSE, configuration):
        self.CVRMSE = CVRMSE
        self.config = configuration

# Function prototype
def gen_rand_sol():
    a = [1, 2, 3, 4, 5]
    return Solution(-1.0, a)

# global variables
T = 1
Tmin = 0.0001
alpha = 0.9
num_iterations = 100
M = 5
N = 5
source_array = [['X' for _ in range(N)] for _ in range(M)]
temp = []
mini = Solution(float('inf'), temp)
current_sol = gen_rand_sol()

def neighbor(current_sol):
    return current_sol
```

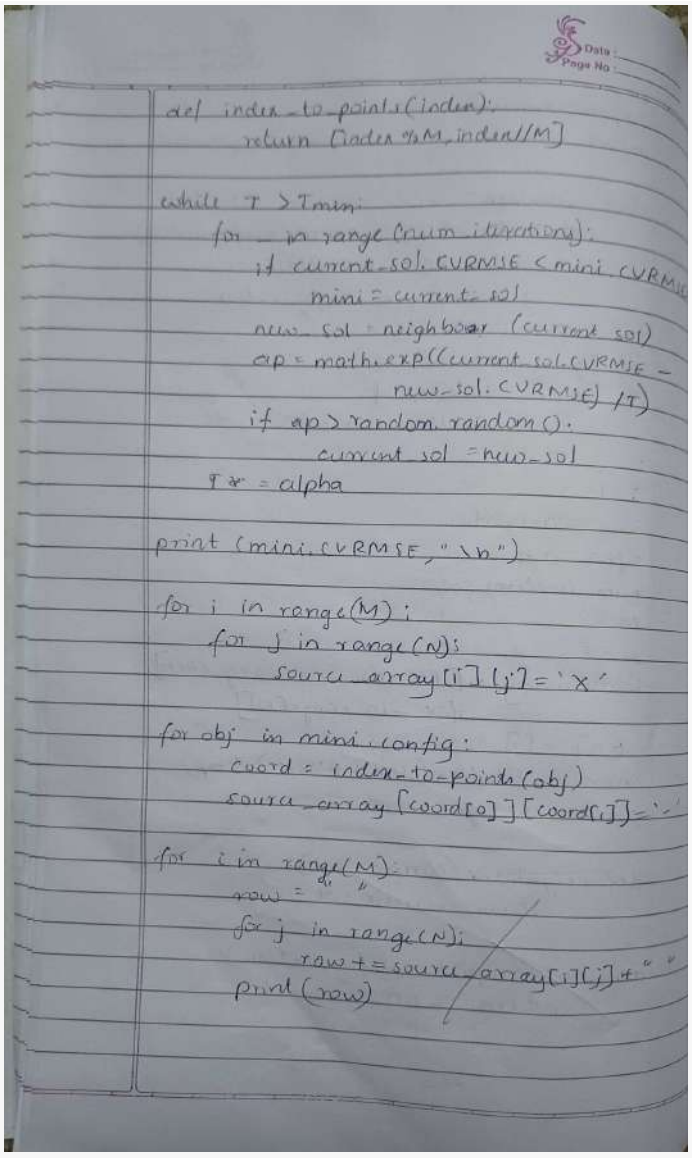
```
def cost(input_configuration):
    return -1.0

# Mapping from [0, M*N] --> [0, M]x[0, N]
def index_to_points(index):
    return [index % M, index // M]

# Returns minimum value based on optimization
while T > Tmin:
    for _ in range(num_iterations):
        # Reassigns global minimum accordingly
        if current_sol.CVRMSE < mini.CVRMSE:
            mini = current_sol
        new_sol = neighbor(current_sol)
        ap = math.exp((current_sol.CVRMSE - new_sol.CVRMSE) / T)
        if ap > random.random():
            current_sol = new_sol
    T *= alpha  # Decreases T, cooling phase

print(mini.CVRMSE, "\n")

for i in range(M):
    for j in range(N):
        source_array[i][j] = 'X'

# Displays
for obj in mini.config:
    coord = index_to_points(obj)
    source_array[coord[0]][coord[1]] = '-'
```

```
# Displays optimal location
for i in range(M):
    row = ""
    for j in range(N):
        row += source_array[i][j] + " "
    print(row)
```

Observation:



```
import random
import math

class Solution:
    def __init__(self, CVRMSE, configuration):
        self.CVRMSE = CVRMSE
        self.config = configuration

def gen_rand_sol():
    a = [1, 2, 3, 4, 5]
    return Solution(-1.0, a)

T = 1
Tmin = 0.0001
alpha = 0.9
num_iterations = 100
M = 5
N = 5
source_array = [['X' for _ in range(N)]
                for _ in range(M)]
temp = []
mini = Solution(float('inf'), temp)
current_sol = gen_rand_sol()

def neighbour(current_sol):
    return current_sol

def cost(input_configuration):
    return -1.0
```



```
def index_to_point(index):
    return [index%M, index//M]

while T > Tmin:
    for _ in range(num_iterations):
        if current_sol.CVRMSE < mini.CVRMSE:
            mini = current_sol
        new_sol = neighbour(current_sol)
        ap = math.exp((current_sol.CVRMSE -
                       new_sol.CVRMSE) /T)
        if ap > random.random():
            current_sol = new_sol
    T = alpha

print(mini.CVRMSE, "\n")

for i in range(M):
    for j in range(N):
        source_array[i][j] = 'X'

for obj in mini.config:
    coord = index_to_point(obj)
    source_array[coord[0]][coord[1]] = '-'

for i in range(M):
    row = ""
    for j in range(N):
        row += source_array[i][j] + " "
    print(row)
```

Output:

```
-1.0

X - X X X
- X X X X
- X X X X
- X X X X
- X X X X
```

Program 9 : Unification

Code:

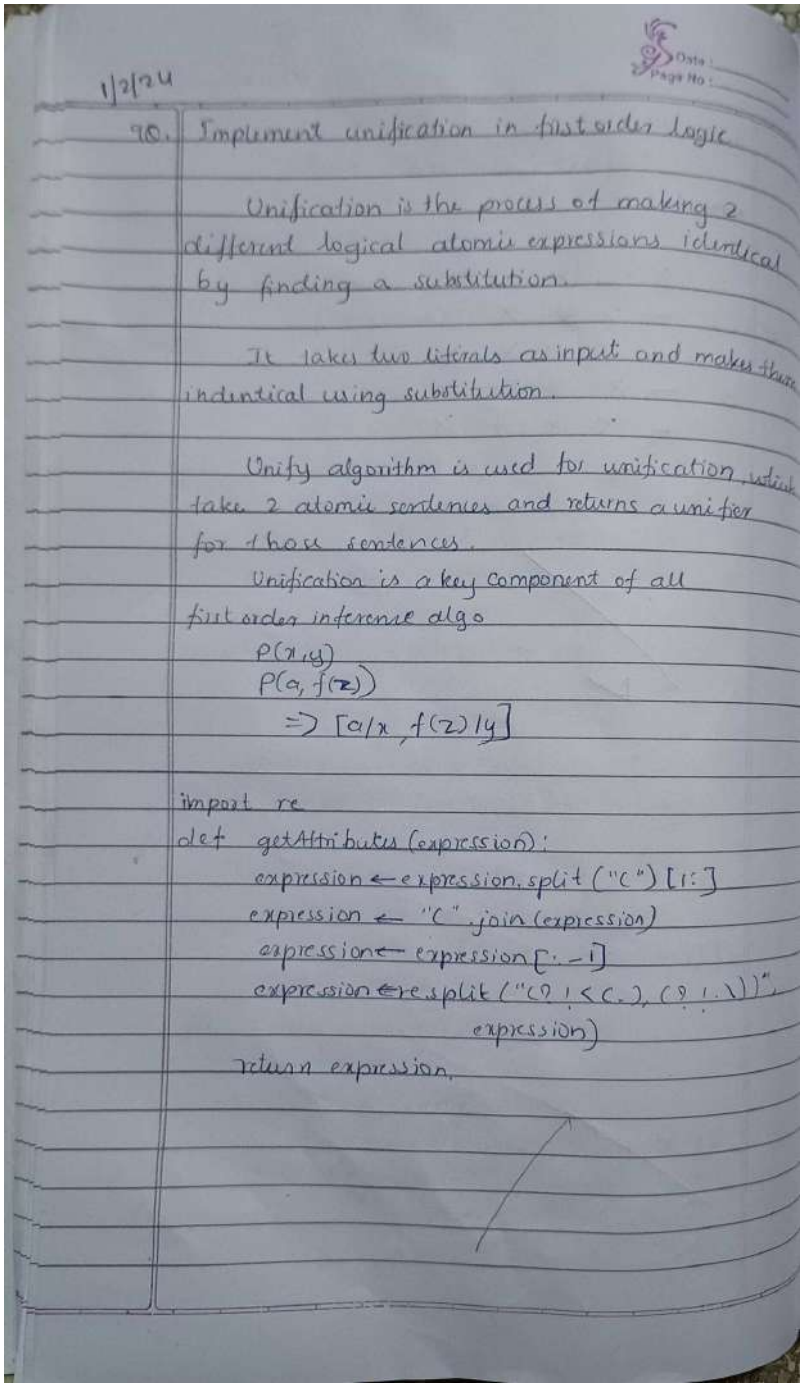
```
import re

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

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

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

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

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

def apply(exp, substitutions):
    for substitution in substitutions:
        new, old = substitution
        exp = replaceAttributes(exp, old, new)
    return exp
def checkOccurs(var, exp):
    if exp.find(var) == -1:
        return False
    return True
```

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


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

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

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

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

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

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

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

    attributeCount1 = len(getAttributes(exp1))
    attributeCount2 = len(getAttributes(exp2))
    if attributeCount1 != attributeCount2:
        return False

    head1 = getFirstPart(exp1)
    head2 = getFirstPart(exp2)
    initialSubstitution = unify(head1, head2)
    if not initialSubstitution:
        return False
    if attributeCount1 == 1:
        return initialSubstitution

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

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

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

    initialSubstitution.extend(remainingSubstitution)
    return initialSubstitution
exp1 = "knows(X)"
exp2 = "knows(Richard)"
substitutions = unify(exp1, exp2)

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

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

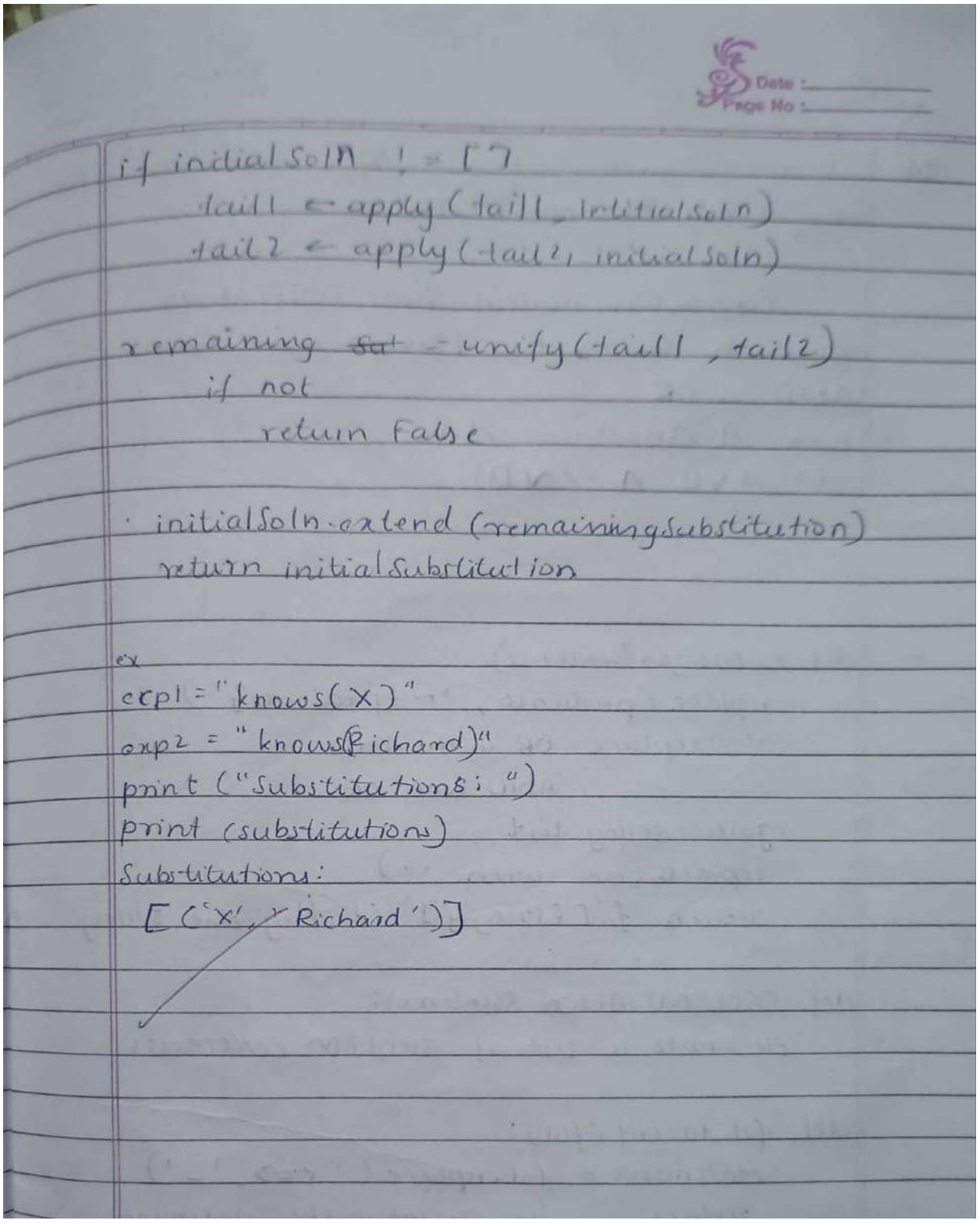
Observation :



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

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

def isVariable(char):
    return true if its lower and length is 1

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

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

def checkOccurs(var, exp):
    check if var is present in x

def getFirstPart(expression)
    return the first attribute in the expression.

def getRemainingPart(expression)
    get attribut from initial predicate
    return predicate + "(" + ",".join attributes[1:] + ")"
```

Date :
Page No :

```
def unify(exp1, exp2)
    if both are same return []
    if both are constant return false.
    if exp1 is constant
        return [(exp1, exp2)]
    if exp2 is constant
        return [(exp2, exp1)]
    if exp1 is variable
        if exp1 occurs in exp2
            return false
        else:
            return [(exp2, exp1)]
    if exp2 is variable
        if exp2 occurs in exp1
            return false
        else
            return [(exp1, exp2)]

    if initialPredicates don't match
        return false
    if length of attributes of exp1 & exp2 don't match
        return false

    initialSoln ← unify(firstpart of exp1 and exp2)
    if not initialSoln
        return False
    If attributeCount1 == 1
        return initial soln
    tail1 ← GetRemainingPart(exp1)
    tail2 ← GetRemainingPart(exp2)
```


Date :
Page No :
if initialSoln != []
tail1 ← apply(tail1, initialSoln)
tail2 ← apply(tail2, initialSoln)
remaining ~~Set~~ = unify(tail1, tail2)
if not
return False
initialSoln.extend(remainingSubstitution)
return initialSubstitution
ex
exp1 = "knows(X)"
exp2 = "knows(Richard)"
print("Substitutions:")
print(substitutions)
Substitutions:
[('X', 'Richard')]

Output:

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

```
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')]
```

Program 10 : FOL to CNF

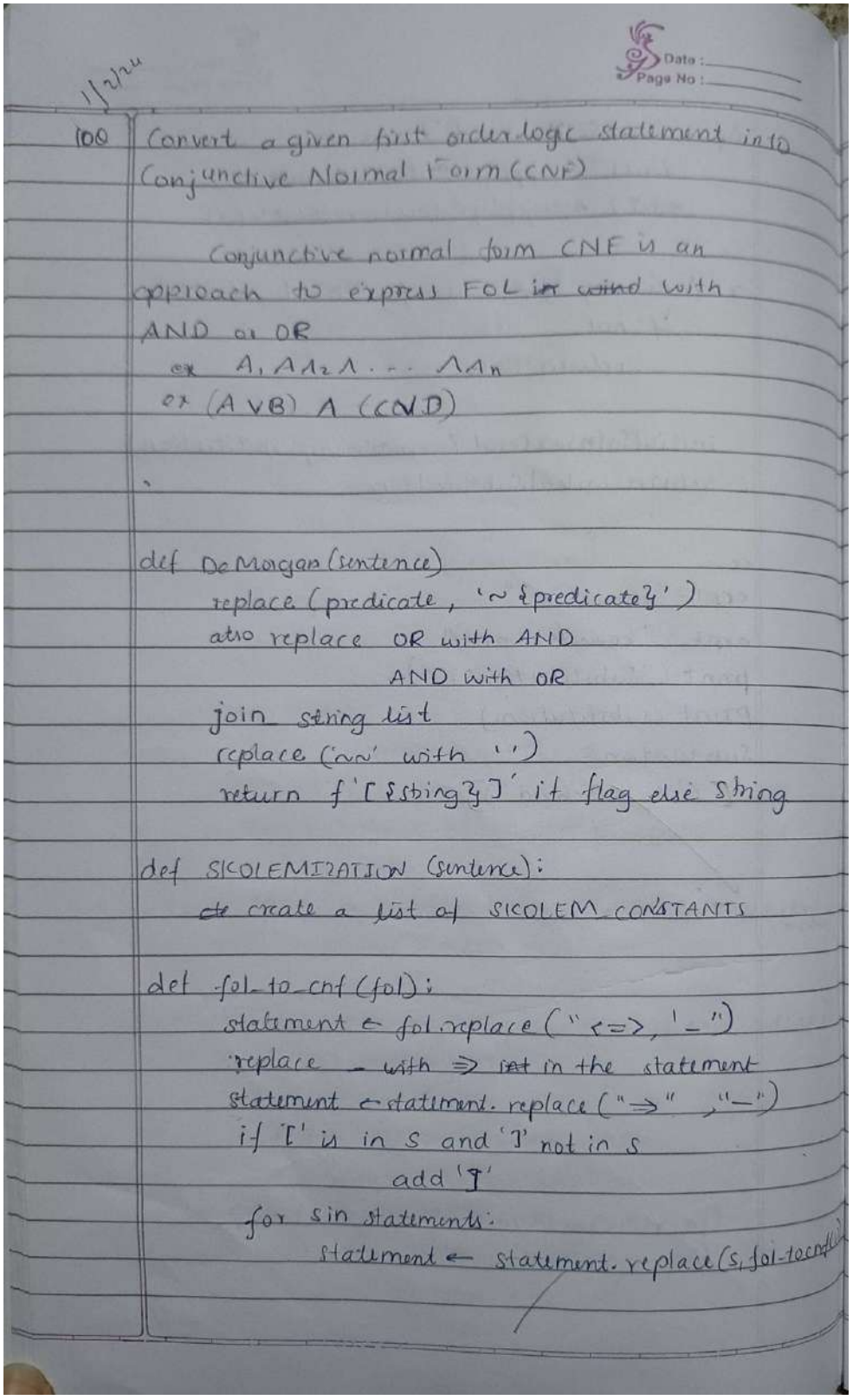
Code:

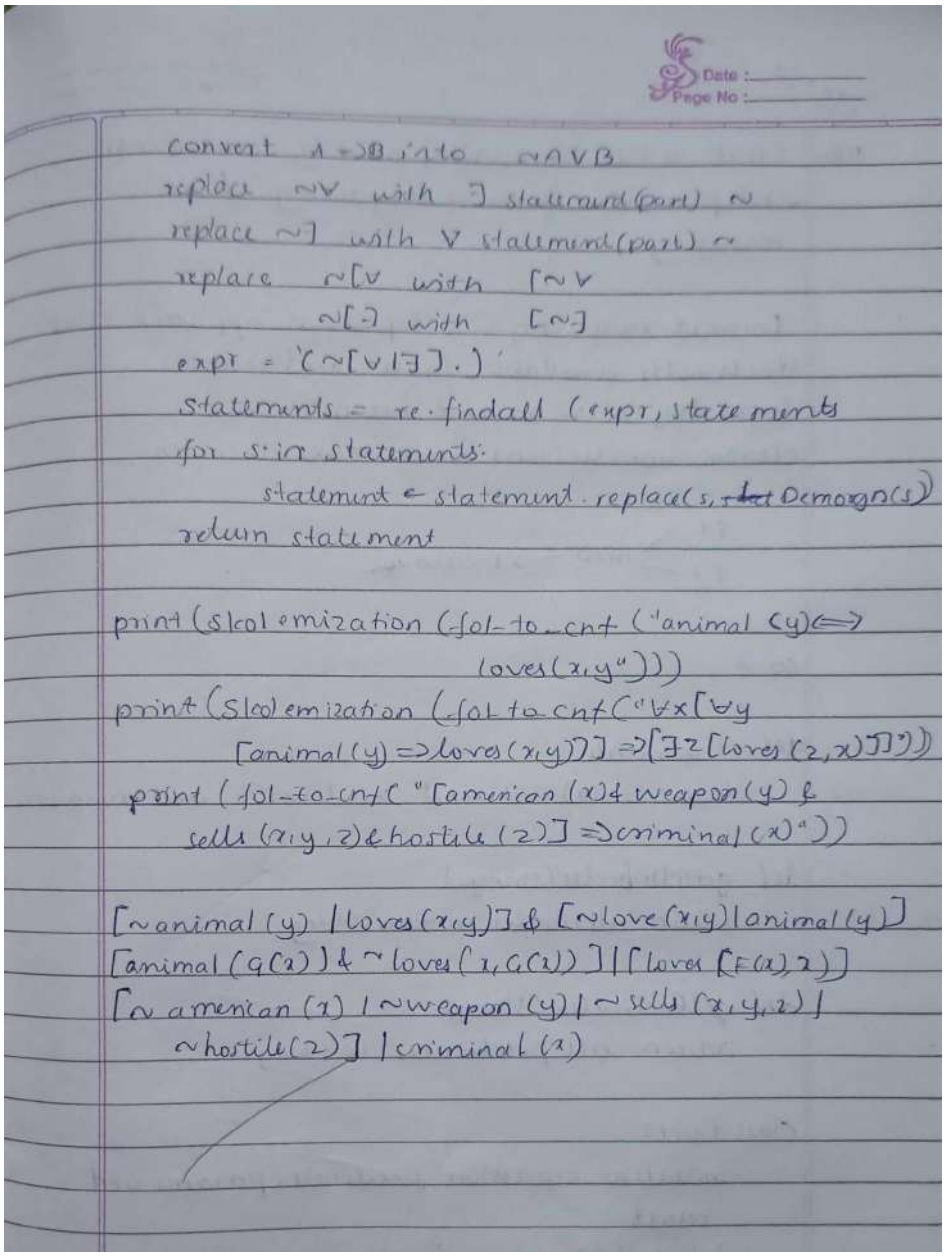
```
def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return [m for m in str(matches) if m.isalpha()]

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

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





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)
```

Program 11 : Forward Reasoning

Code:

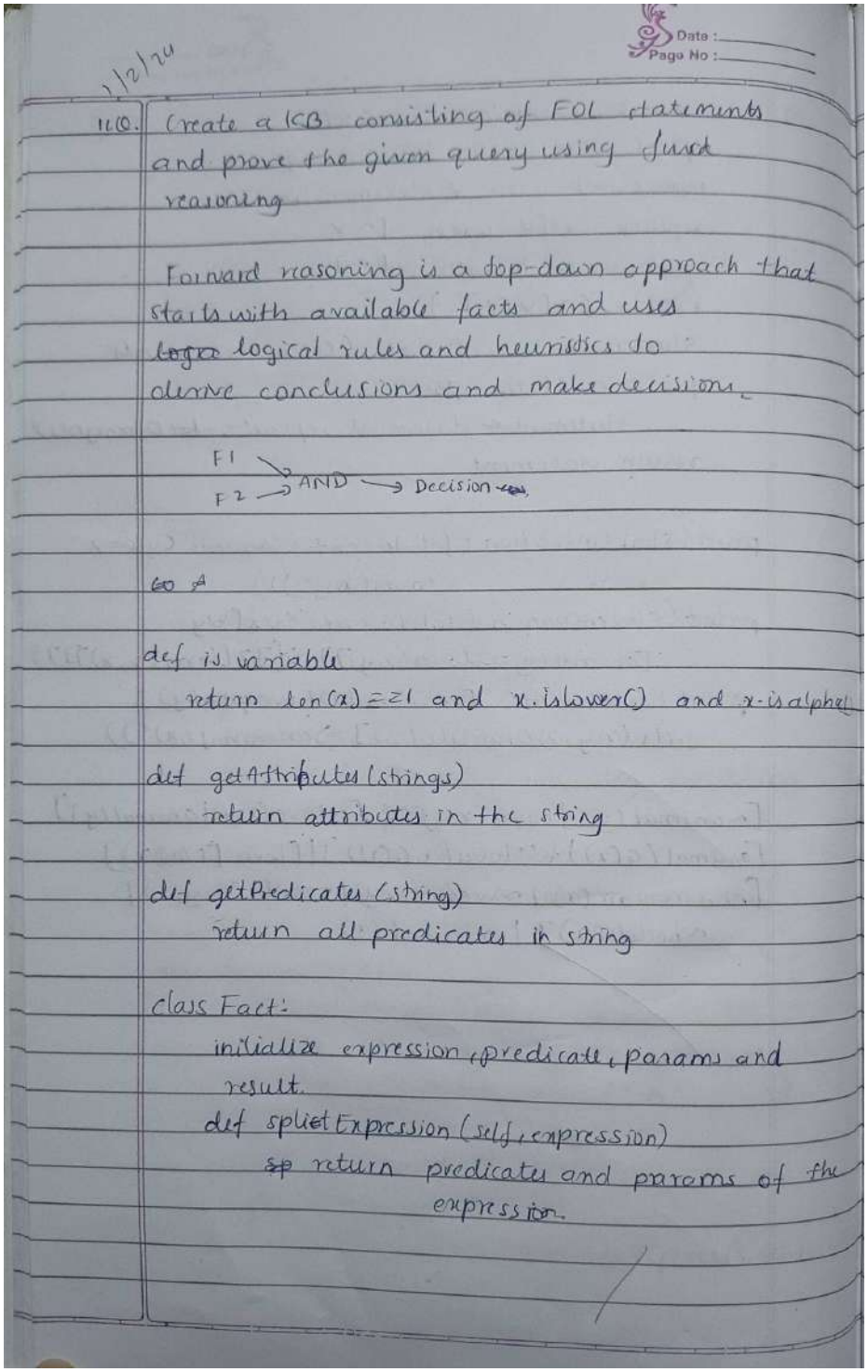
```
import re

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

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

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



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

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

    def getResult(self):
        return self.result

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

    def getVariables(self):
```

```
        return [v if isVariable(v) else None for v in self.params]

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

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

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

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

    def tell(self, e):
```

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

    def query(self, e):
        facts = set([f.expression for f in self.facts])
        i = 1
        print(f'Querying {e}:')
        for f in facts:
            if Fact(f).predicate == Fact(e).predicate:
                print(f'\t{i}. {f}')
                    i += 1

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

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()


kb_ = KB()
kb_.tell('king(x)&greedy(x)=>evil(x)')
kb_.tell('king(John)')
```

kb_.tell('greedy(John)')
kb_.tell('king(Richard)')
kb_.query('evil(x)')

Observation:



```
def getResults(self)
        return self.result.

def getConstants(self)
    return constants in params

def getVariables(self)
        return variables in params

    def substitute(self, constants):
        return the Facts.

class Implication:
        initialize variables
        in lhs if val.predicate == fact.predicate
                  constants[v] = fact.getConstants
        predicate, attributes = getPredicates(),
                                str(getattributes())
        return Fact(expr) if (new_lhs) and f.getResults

Create a KB

exi: kb = KB()
    kb.tell('king(x) & greedy(x) => evil(x)')
    kb.tell('king(John)')
    kb.tell('greedy(John)')
    kb.tell('king(Richard)')
    kb.query('evil(x)')

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

1-2-24

Output:

```
            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()
```

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

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

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