Ex No:01 IMPLEMENT RSA ASYMMETRIC (SECRET KEY ENCRYPTION) ALGORITHM

Date:

AIM:

To execute RSA Algorithm Using python and encrypt and decrypt.

ALGORITHM:

1. Start.
2. **Key Generation:**
   a. Choose two distinct prime numbers, p and q.
   b. Compute n = p*q.
   c. Compute Φ (n)=(p-1)*(q-1).where Φ is Eucler’s totient function.
   d. Choose an integer e such that 1 < e < Φ (n) and e is coprime to Φ (n).
   e. Compute the integer d such that d*e ≡1(modΦ (n)), i.e., d is the modular multiplicative inverse of e modulo Φ (n).
   f. The public key is (n,e) and the private key is (n,d).
3. Encryption:
   a. Encrypt the message M using public key(n,e).
      i. Compute $C \equiv M^e$ (mad n).
4. Decryption:
   a. Decrypt the ciphertext C using the private key (n, d).
      i. Compute $M \equiv c^d$ (mod N).
5. Stop

PROGRAM:

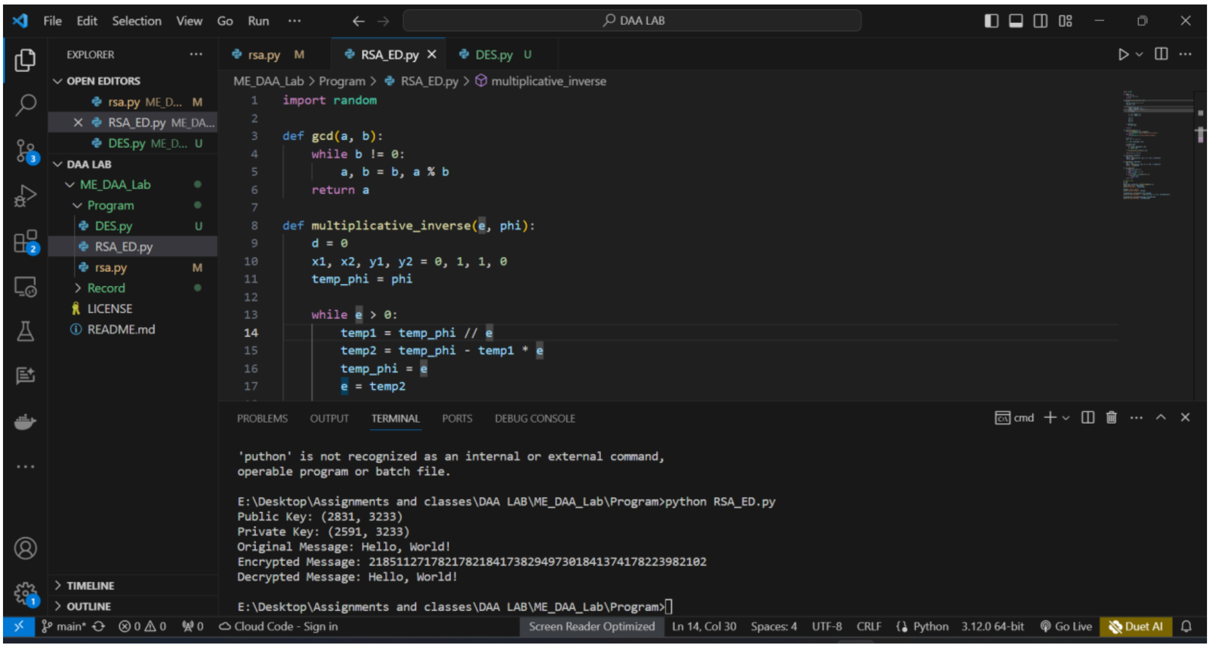
```
import random


def gcd(a, b):

   while b != 0:

      a, b = b, a % b

   return a


def multiplicative_inverse(e, phi):

   d = 0

   x1, x2, y1, y2 = 0, 1, 1, 0

   temp_phi = phi

   while e > 0:

      temp1 = temp_phi // e

      temp2 = temp_phi - temp1 * e

      temp_phi = e
```

```
        e = temp2

        x = x2 - temp1 * x1
        y = y2 - temp1 * y1

        x2 = x1
        x1 = x
        y2 = y1
        y1 = y

    if temp_phi == 1:
        d = y2 + phi

    return d

def generate_keypair(p, q):
    if not (is_prime(p) and is_prime(q)):
        raise ValueError("Both numbers must be prime.")
    elif p == q:
        raise ValueError("p and q cannot be equal")

    n = p * q
    phi = (p - 1) * (q - 1)

    e = random.randrange(1, phi)

    g = gcd(e, phi)
    while g != 1:
        e = random.randrange(1, phi)
        g = gcd(e, phi)

    d = multiplicative_inverse(e, phi)
```

```
    return ((e, n), (d, n))

def encrypt(pk, plaintext):
    key, n = pk
    cipher = [pow(ord(char), key, n) for char in plaintext]
    return cipher

def decrypt(pk, ciphertext):
    key, n = pk
    plain = [chr(pow(char, key, n)) for char in ciphertext]
    return ''.join(plain)

def is_prime(num):
    if num == 2 or num == 3:
        return True
    if num < 2 or num % 2 == 0:
        return False
    for n in range(3, int(num**0.5)+2, 2):
        if num % n == 0:
            return False
    return True

# Example usage:
p = 61
q = 53
public_key, private_key = generate_keypair(p, q)
print("Public Key:", public_key)
print("Private Key:", private_key)

message = "Hello, World!"
print("Original Message:", message)
```

```
encrypted_msg = encrypt(public_key, message)
print("Encrypted Message:", ".join(map(lambda x: str(x), encrypted_msg)))


decrypted_msg = decrypt(private_key, encrypted_msg)
print("Decrypted Message:", decrypted_msg)
```

OUTPUT:



RESULT:

This RSA algorithm was executed successfully.

Ex No:02 IMPLEMENT DATA ENCRYPTION STANDARD (DES) A SYMMETRIC ENCRYPTION ALGORITHM

Date:

AIM:

To implement DES to encode and decode a plain text using key in python.

ALGORITHM:

1. Start.
2. Get the values of Li, Ri, Ci, Di in hex format from the user.
3. Perform left circular shift of Ci Di with respective to the round with table values.
4. Using PC2 table arrange the elements in the same order.
5. Compute expansion permutation of ith round (Ri) and arrange elements in 6x8 matrix.
6. Convert PC2 matrix in 8x6 order.
7. Perform A=PC2 EX-OR E/P(Ri)
8. Find the value of ‘A’ in S-Box Table.
9. Arrange the ‘A’ Matrix in permutation Function table order.
10. Li+1=Ri Ri+1=Li EX-OR P32.
11. To decrypt, apply the same algorithm with subkey used in reverse order.
12. Stop.

PROGRAM:

```
def main():

    print()

    # Taking inputs from the user

    plaintext = input("Enter the message to be encrypted : ")

    key = input("Enter a key of 8 length (64-bits) (characters or numbers only) : ")

    print()


    # Checking if key is valid or not

    if len(key) != 8:

        print("Invalid Key. Key should be of 8 length (8 bytes).")

        return


    # Determining if padding is required

    isPaddingRequired = (len(plaintext) % 8 != 0)


    # Encryption

    ciphertext = DESEncryption(key, plaintext, isPaddingRequired)
```

```
    # Decryption
    plaintext = DESDecryption(key, ciphertext, isPaddingRequired)

    # Printing result
    print()
    print("Encrypted Ciphertext is : %r " % ciphertext)
    print("Decrypted plaintext is  : ", plaintext)
    print()

# Permutation Matrix used after each SBox substitution for each round
eachRoundPermutationMatrix = [
    16, 7, 20, 21, 29, 12, 28, 17,
    1, 15, 23, 26, 5, 18, 31, 10,
    2, 8, 24, 14, 32, 27, 3, 9,
    19, 13, 30, 6, 22, 11, 4, 25
]

# Final Permutation Matrix for data after 16 rounds
finalPermutationMatrix = [
    40, 8, 48, 16, 56, 24, 64, 32,
    39, 7, 47, 15, 55, 23, 63, 31,
    38, 6, 46, 14, 54, 22, 62, 30,
    37, 5, 45, 13, 53, 21, 61, 29,
    36, 4, 44, 12, 52, 20, 60, 28,
    35, 3, 43, 11, 51, 19, 59, 27,
    34, 2, 42, 10, 50, 18, 58, 26,
    33, 1, 41, 9, 49, 17, 57, 25
]


def DESEncryption(key, text, padding):
    """Function for DES Encryption."""
```

```
    # Adding padding if required
    if padding == True:
        text = addPadding(text)

    # Encryption
    ciphertext = DES(text, key, padding, True)

    # Returning ciphertext
    return ciphertext

def DESDecryption(key, text, padding):
    """Function for DES Decryption."""

    # Decryption
    plaintext = DES(text, key, padding, False)

    # Removing padding if required
    if padding == True:
        # Removing padding and returning plaintext
        return removePadding(plaintext)

    # Returning plaintext
    return plaintext

# Initial Permutation Matrix for data
initialPermutationMatrix = [
    58, 50, 42, 34, 26, 18, 10, 2,
    60, 52, 44, 36, 28, 20, 12, 4,
    62, 54, 46, 38, 30, 22, 14, 6,
    64, 56, 48, 40, 32, 24, 16, 8,
    57, 49, 41, 33, 25, 17, 9, 1,
```

```
    59, 51, 43, 35, 27, 19, 11, 3,
    61, 53, 45, 37, 29, 21, 13, 5,
    63, 55, 47, 39, 31, 23, 15, 7
]

#Expand matrix to get a 48bits matrix of datas to apply the xor with Ki
expandMatrix = [
    32, 1, 2, 3, 4, 5,
    4, 5, 6, 7, 8, 9,
    8, 9, 10, 11, 12, 13,
    12, 13, 14, 15, 16, 17,
    16, 17, 18, 19, 20, 21,
    20, 21, 22, 23, 24, 25,
    24, 25, 26, 27, 28, 29,
    28, 29, 30, 31, 32, 1
]



def DES(text, key, padding, isEncrypt):
    """Function to implement DES Algorithm."""

    # Initializing variables required
    isDecrypt = not isEncrypt
    # Generating keys
    keys = generateKeys(key)

    # Splitting text into 8 byte blocks
    plaintext8byteBlocks = nSplit(text, 8)
    result = []

    # For all 8-byte blocks of text
    for block in plaintext8byteBlocks:
```

```
# Convert the block into bit array
block = stringToBitArray(block)

# Do the initial permutation
block = permutation(block, initialPermutationMatrix)

# Splitting block into two 4 byte (32 bit) sized blocks
leftBlock, rightBlock = nSplit(block, 32)

temp = None

# Running 16 identical DES Rounds for each block of text
for i in range(16):
    # Expand rightBlock to match round key size(48-bit)
    expandedRightBlock = expand(rightBlock, expandMatrix)

    # Xor right block with appropriate key
    if isEncrypt == True:
        # For encryption, starting from first key in normal order
        temp = xor(keys[i], expandedRightBlock)
    elif isDecrypt == True:
        # For decryption, starting from last key in reverse order
        temp = xor(keys[15 - i], expandedRightBlock)
    # Sbox substitution Step
    temp = SboxSubstitution(temp)
    # Permutation Step
    temp = permutation(temp, eachRoundPermutationMatrix)
    # XOR Step with leftBlock
    temp = xor(leftBlock, temp)

    # Blocks swapping
```

```
            leftBlock = rightBlock
            rightBlock = temp

        # Final permutation then appending result
        result += permutation(rightBlock + leftBlock, finalPermutationMatrix)

    # Converting bit array to string
    finalResult = bitArrayToString(result)

    return finalResult

# Matrix used for shifting after each round of keys
SHIFT = [1, 1, 2, 2, 2, 2, 2, 2, 1, 2, 2, 2, 2, 2, 2, 1]

# Permutation matrix for key
keyPermutationMatrix1 = [
    57, 49, 41, 33, 25, 17, 9,
    1, 58, 50, 42, 34, 26, 18,
    10, 2, 59, 51, 43, 35, 27,
    19, 11, 3, 60, 52, 44, 36,
    63, 55, 47, 39, 31, 23, 15,
    7, 62, 54, 46, 38, 30, 22,
    14, 6, 61, 53, 45, 37, 29,
    21, 13, 5, 28, 20, 12, 4
]

# Permutation matrix for shifted key to get next key
keyPermutationMatrix2 = [
    14, 17, 11, 24, 1, 5, 3, 28,
    15, 6, 21, 10, 23, 19, 12, 4,
    26, 8, 16, 7, 27, 20, 13, 2,
    41, 52, 31, 37, 47, 55, 30, 40,
```

```
    51, 45, 33, 48, 44, 49, 39, 56,
    34, 53, 46, 42, 50, 36, 29, 32
]

def generateKeys(key):
    """Function to generate keys for different rounds of DES."""

    # Inititalizing variables required
    keys = []
    key = stringToBitArray(key)

    # Initial permutation on key
    key = permutation(key, keyPermutationMatrix1)

    # Split key in to (leftBlock->LEFT), (rightBlock->RIGHT)
    leftBlock, rightBlock = nSplit(key, 28)

    # 16 rounds of keys
    for i in range(16):
        # Do left shifting (different for different rounds)
        leftBlock, rightBlock = leftShift(leftBlock, rightBlock, SHIFT[i])
        # Merge them
        temp = leftBlock + rightBlock
        # Permutation on shifted key to get next key
        keys.append(permutation(temp, keyPermutationMatrix2))

    # Return generated keys
    return keys

# Sboxes used in the DES Algorithm
SboxesArray = [
    [
```

```
    [14, 4, 13, 1, 2, 15, 11, 8, 3, 10, 6, 12, 5, 9, 0, 7],
    [0, 15, 7, 4, 14, 2, 13, 1, 10, 6, 12, 11, 9, 5, 3, 8],
    [4, 1, 14, 8, 13, 6, 2, 11, 15, 12, 9, 7, 3, 10, 5, 0],
    [15, 12, 8, 2, 4, 9, 1, 7, 5, 11, 3, 14, 10, 0, 6, 13],
],

[
    [15, 1, 8, 14, 6, 11, 3, 4, 9, 7, 2, 13, 12, 0, 5, 10],
    [3, 13, 4, 7, 15, 2, 8, 14, 12, 0, 1, 10, 6, 9, 11, 5],
    [0, 14, 7, 11, 10, 4, 13, 1, 5, 8, 12, 6, 9, 3, 2, 15],
    [13, 8, 10, 1, 3, 15, 4, 2, 11, 6, 7, 12, 0, 5, 14, 9],
],

[
    [10, 0, 9, 14, 6, 3, 15, 5, 1, 13, 12, 7, 11, 4, 2, 8],
    [13, 7, 0, 9, 3, 4, 6, 10, 2, 8, 5, 14, 12, 11, 15, 1],
    [13, 6, 4, 9, 8, 15, 3, 0, 11, 1, 2, 12, 5, 10, 14, 7],
    [1, 10, 13, 0, 6, 9, 8, 7, 4, 15, 14, 3, 11, 5, 2, 12],
],

[
    [7, 13, 14, 3, 0, 6, 9, 10, 1, 2, 8, 5, 11, 12, 4, 15],
    [13, 8, 11, 5, 6, 15, 0, 3, 4, 7, 2, 12, 1, 10, 14, 9],
    [10, 6, 9, 0, 12, 11, 7, 13, 15, 1, 3, 14, 5, 2, 8, 4],
    [3, 15, 0, 6, 10, 1, 13, 8, 9, 4, 5, 11, 12, 7, 2, 14],
],

[
    [2, 12, 4, 1, 7, 10, 11, 6, 8, 5, 3, 15, 13, 0, 14, 9],
    [14, 11, 2, 12, 4, 7, 13, 1, 5, 0, 15, 10, 3, 9, 8, 6],
    [4, 2, 1, 11, 10, 13, 7, 8, 15, 9, 12, 5, 6, 3, 0, 14],
    [11, 8, 12, 7, 1, 14, 2, 13, 6, 15, 0, 9, 10, 4, 5, 3],
```

```
    ],

    [
        [12, 1, 10, 15, 9, 2, 6, 8, 0, 13, 3, 4, 14, 7, 5, 11],
        [10, 15, 4, 2, 7, 12, 9, 5, 6, 1, 13, 14, 0, 11, 3, 8],
        [9, 14, 15, 5, 2, 8, 12, 3, 7, 0, 4, 10, 1, 13, 11, 6],
        [4, 3, 2, 12, 9, 5, 15, 10, 11, 14, 1, 7, 6, 0, 8, 13],
    ],

    [
        [4, 11, 2, 14, 15, 0, 8, 13, 3, 12, 9, 7, 5, 10, 6, 1],
        [13, 0, 11, 7, 4, 9, 1, 10, 14, 3, 5, 12, 2, 15, 8, 6],
        [1, 4, 11, 13, 12, 3, 7, 14, 10, 15, 6, 8, 0, 5, 9, 2],
        [6, 11, 13, 8, 1, 4, 10, 7, 9, 5, 0, 15, 14, 2, 3, 12],
    ],

    [
        [13, 2, 8, 4, 6, 15, 11, 1, 10, 9, 3, 14, 5, 0, 12, 7],
        [1, 15, 13, 8, 10, 3, 7, 4, 12, 5, 6, 11, 0, 14, 9, 2],
        [7, 11, 4, 1, 9, 12, 14, 2, 0, 6, 10, 13, 15, 3, 5, 8],
        [2, 1, 14, 7, 4, 10, 8, 13, 15, 12, 9, 0, 3, 5, 6, 11],
    ]
]

def SboxSubstitution(bitArray):
    """Function to substitute all the bytes using Sbox."""

    # Split bit array into 6 sized chunks
    # For Sbox indexing
    blocks = nSplit(bitArray, 6)
    result = []
```

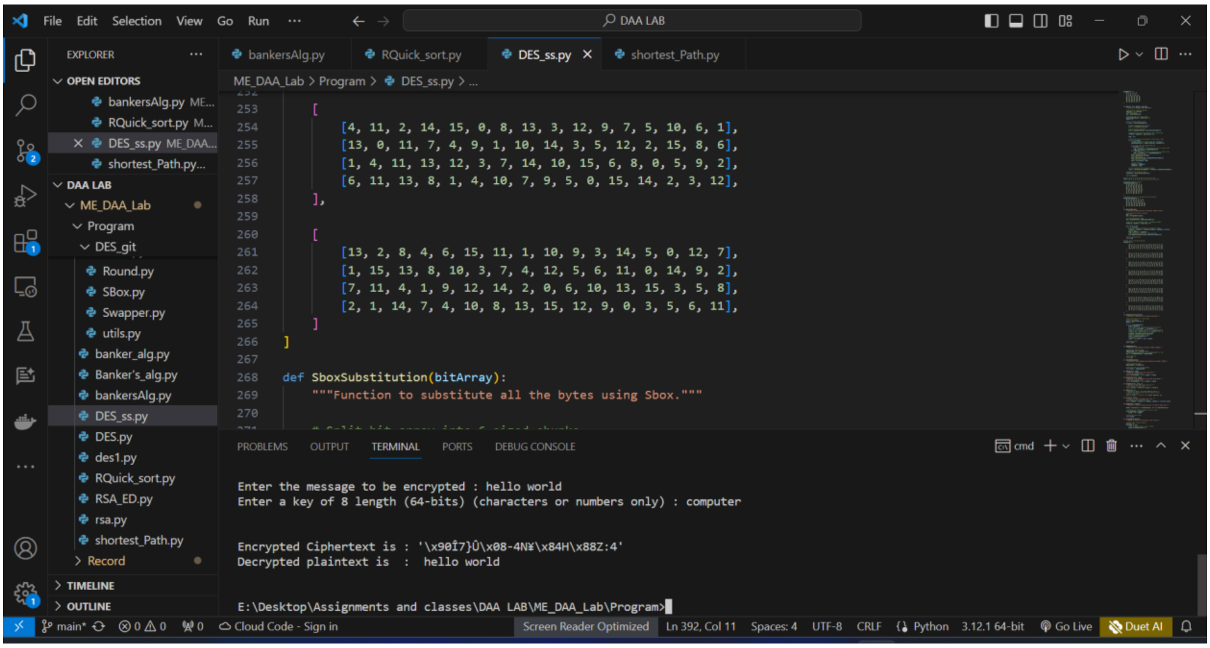
```
    for i in range(len(blocks)):
        block = blocks[i]
        # Row number to be obtained from first and last bit
        row = int( str(block[0]) + str(block[5]), 2 )
        # Getting column number from the 2,3,4,5 position bits
        column = int(''.join([str(x) for x in block[1:-1]]), 2)
        # Taking value from ith Sbox in ith round
        sboxValue = SboxesArray[i][row][column]
        # Convert the sbox value to binary
        binVal = binValue(sboxValue, 4)
        # Appending to result
        result += [int(bit) for bit in binVal]

    # Returning result
    return result



def addPadding(text):
    """Function to add padding according to PKCS5 standard."""

    # Determining padding length
    paddingLength = 8 - (len(text) % 8)
    # Adding paddingLength number of chr(paddingLength) to text
    text += chr(paddingLength) * paddingLength

    # Returning text
    return text

def removePadding(data):
    """Function to remove padding from plaintext according to PKCS5."""

    # Getting padding length
```

```
    paddingLength = ord(data[-1])

    # Returning data with removed padding
    return data[ : -paddingLength]

def expand(array, table):
    """Function to expand the array using table."""
    # Returning expanded result
    return [array[element - 1] for element in table]

def permutation(array, table):
    """Function to do permutation on the array using table."""
    # Returning permuted result
    return [array[element - 1] for element in table]

def leftShift(list1, list2, n):
    """Function to left shift the arrays by n."""
    # Left shifting the two arrays
    return list1[n:] + list1[:n], list2[n:] + list2[:n]

def nSplit(list, n):
    """Function to split a list into chunks of size n."""
    # Chunking and returning the array of chunks of size n
    # and last remainder
    return [ list[i : i + n] for i in range(0, len(list), n)]

def xor(list1, list2):
    """Function to return the XOR of two lists."""
    # Returning the xor of the two lists
    return [element1 ^ element2 for element1, element2 in zip(list1,list2)]

def binValue(val, bitSize):
```

```
    """Function to return the binary value as a string of given size."""

    binVal = bin(val)[2:] if isinstance(val, int) else bin(ord(val))[2:]

    # Appending with required number of zeros in front
    while len(binVal) < bitSize:
        binVal = "0" + binVal

    # Returning binary value
    return binVal

def stringToBitArray(text):
    """Funtion to convert a string into a list of bits."""

    # Initializing variable required
    bitArray = []
    for letter in text:
        # Getting binary (8-bit) value of letter
        binVal = binValue(letter, 8)
        # Making list of the bits
        binValArr = [int(x) for x in list(binVal)]
        # Apending the bits to array
        bitArray += binValArr

    # Returning answer
    return bitArray

def bitArrayToString(array):
    """Function to convert a list of bits to string."""

    # Chunking array of bits to 8 sized bytes
    byteChunks = nSplit(array, 8)
```

```
    # Initializing variables required
    stringBytesList = []
    stringResult = ''
    # For each byte
    for byte in byteChunks:
        bitsList = []
        for bit in byte:
            bitsList += str(bit)
        stringBytesList.append(''.join(bitsList))
    result = ''.join([chr(int(stringByte, 2)) for stringByte in stringBytesList])
    return result
if __name__ == '__main__':
    main()
```

OUTPUT:



RESULT:

Thus implementation of DES algorithm was completed successfully.

Ex No:03 IMPLEMENTATION OF BANKER'S ALGORITHM FOR DEADLOCK AVOIDANCE

Date:

AIM:

To implement Banker's algorithm for deadlock avoidance using python.

ALGORITHM:

1. Start.
2. Get the input from the user.
3. If request<=need, go to step 4, else it shows an error.
4. If request<=available, go to step 5, else it must wait as the resource it requires is not
5. available.
6. If the resulting resource allocation is safe, the process is allocated to resources.
7. If it is unsafe, the old state process is restored.
8. Stop .

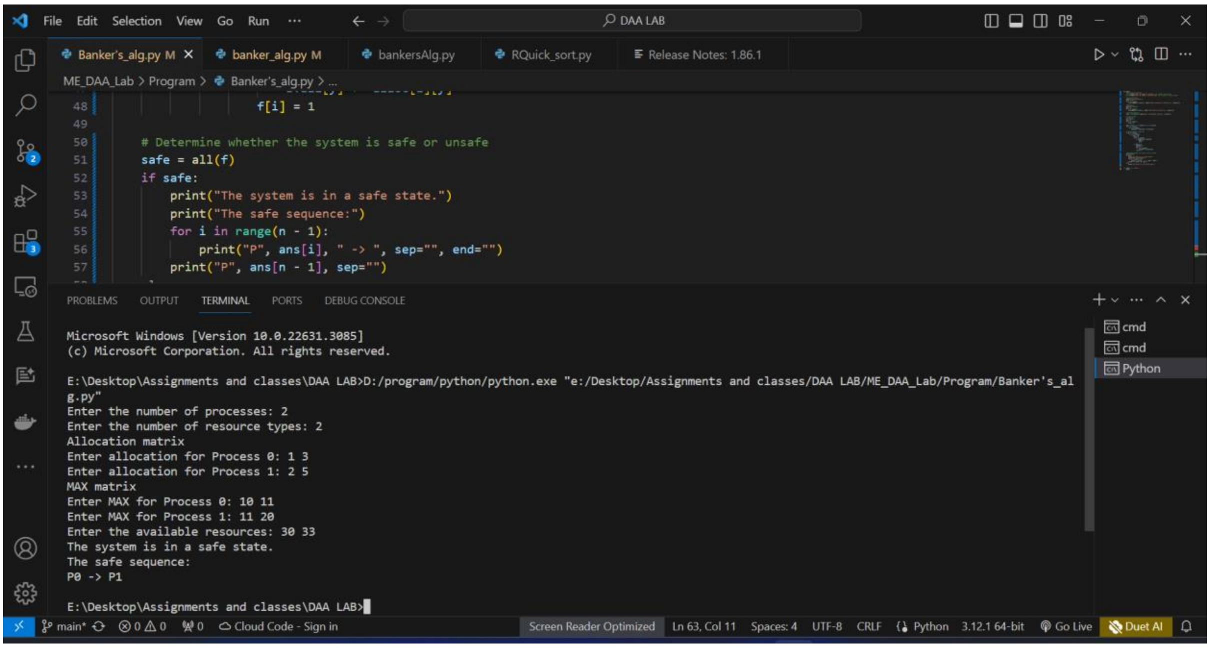
PROGRAM:

```
def main():
    # Get input from the user
    n = int(input("Enter the number of processes: "))  # Number of processes
    m = int(input("Enter the number of resource types: "))  # Number of resource types

    # Allocation Matrix
    print("Allocation matrix")
    alloc = []
    for i in range(n):
        alloc.append(list(map(int, input(f"Enter allocation for Process {i}: ").split())))

    # MAX Matrix
    print("MAX matrix")
    max = []
    for i in range(n):
        max.append(list(map(int, input(f"Enter MAX for Process {i}: ").split())))
    # Available Resources
    avail = list(map(int, input("Enter the available resources: ").split()))

    # Initialization
    f = [0] * n
```

```python
ans = [0] * n
ind = 0
for k in range(n):
    f[k] = 0

need = [[0 for i in range(m)] for i in range(n)]
for i in range(n):
    for j in range(m):
        need[i][j] = max[i][j] - alloc[i][j]

# Applying Banker's Algorithm
for k in range(n):
    for i in range(n):
        if f[i] == 0:
            flag = 0
            for j in range(m):
                if need[i][j] > avail[j]:
                    flag = 1
                    break

            if flag == 0:
                ans[ind] = i
                ind += 1
                for y in range(m):
                    avail[y] += alloc[i][y]
                f[i] = 1

# Determine whether the system is safe or unsafe
safe = all(f)
if safe:
    print("The system is in a safe state.")
    print("The safe sequence:")
```

```
        for i in range(n - 1):
            print("P", ans[i], " -> ", sep="", end="")
        print("P", ans[n - 1], sep="")
    else:
        print("The system is in an unsafe state.")



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

OUTPUT:



RESULT:

Thus implementation of bancker’s algorithm was completes successfully.

Ex No:04 IMPLEMENTATION OF RANDOMIZED QUICK SORT USING DIVIDE AND CONQUER STRATEGY

Date:

AIM:

To implement randomized quick sort using divide and conquer strategy.

ALGORITHM:

1. Start the program.
2. Read an input array.
3. Select a pivot randomly, then swap it with the right most position of the array.
4. Fix two pointers i.e., pivot element and the left most element.
5. Pivot is now compared with all other elements, if any number smaller than pivot is found, swap that element with the greatest number found.
6. Repeat step 5 until it reaches the end of the array, then swap the pivot element with the second pointer.
7. Pivot elements are again chosen for the left and right sub arrays separately.
8. Repeat steps from 3 to 6.
9. Print the sorted array.
10. Stop the program.

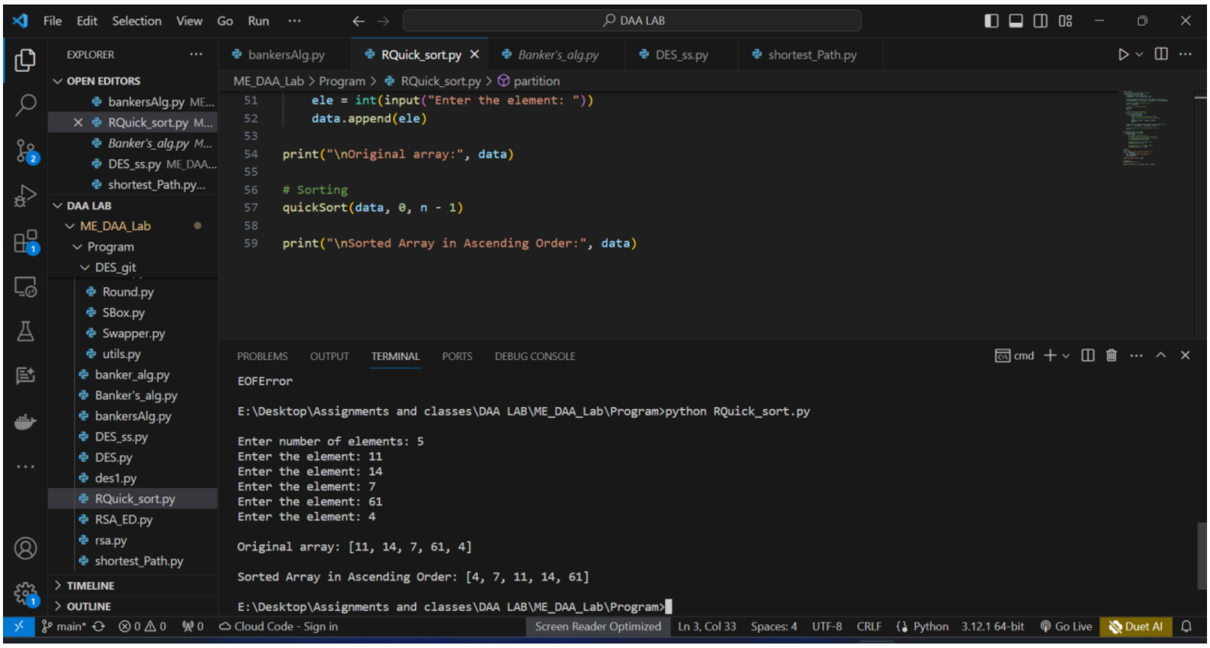
PROGRAM:

```
import random

# Function to find the partition position

def partition(array, low, high):

    # Choose a random pivot position

    randomNumber = random.randint(low, high)


    # Swap the pivot element with the last element of the array

    array[randomNumber], array[high] = array[high], array[randomNumber]


    # Choose the rightmost element as pivot

    pivot = array[high]

    # Pointer for the greater element

    i = low - 1

    swap = 0


    # Traverse through all elements

    # Compare each element with pivot

    for j in range(low, high):
```

```
        if array[j] <= pivot:
            # If element smaller than pivot is found
            # Swap it with the greater element pointed by i
            i += 1
            array[i], array[j] = array[j], array[i]
            swap += 1

    # Swap the pivot element with the greater element specified by i
    array[i + 1], array[high] = array[high], array[i + 1]

    # Return the position from where partition is done
    return i + 1

# Function to perform quicksort
def quickSort(array, low, high):
    if low < high:
        # Find pivot element such that
        # elements smaller than pivot are on the left
        # elements greater than pivot are on the right
        pi = partition(array, low, high)

        # Recursive call on the left of pivot
        quickSort(array, low, pi - 1)

        # Recursive call on the right of pivot
        quickSort(array, pi + 1, high)

# Input
data = []
n = int(input("\nEnter number of elements: "))
for i in range(n):
    ele = int(input("Enter the element: "))
```

```
    data.append(ele)

print("\nOriginal array:", data)

# Sorting
quickSort(data, 0, n - 1)

print("\nSorted Array in Ascending Order:", data)
```

OUTPUT:



RESULT:

Thus, the implementation of randomized quick sort using divide and conquer strategy in python was executed and verified successfully.

Ex No : **IMPLEMENT SHORTEST PATH USING DYNAMIC PROGRAMMING IN A MULTI-STAGED GRAPH**

DATE:

AIM:

To implement shortest path using dynamic programming in a multi staged graph using python.

ALGORITHM:

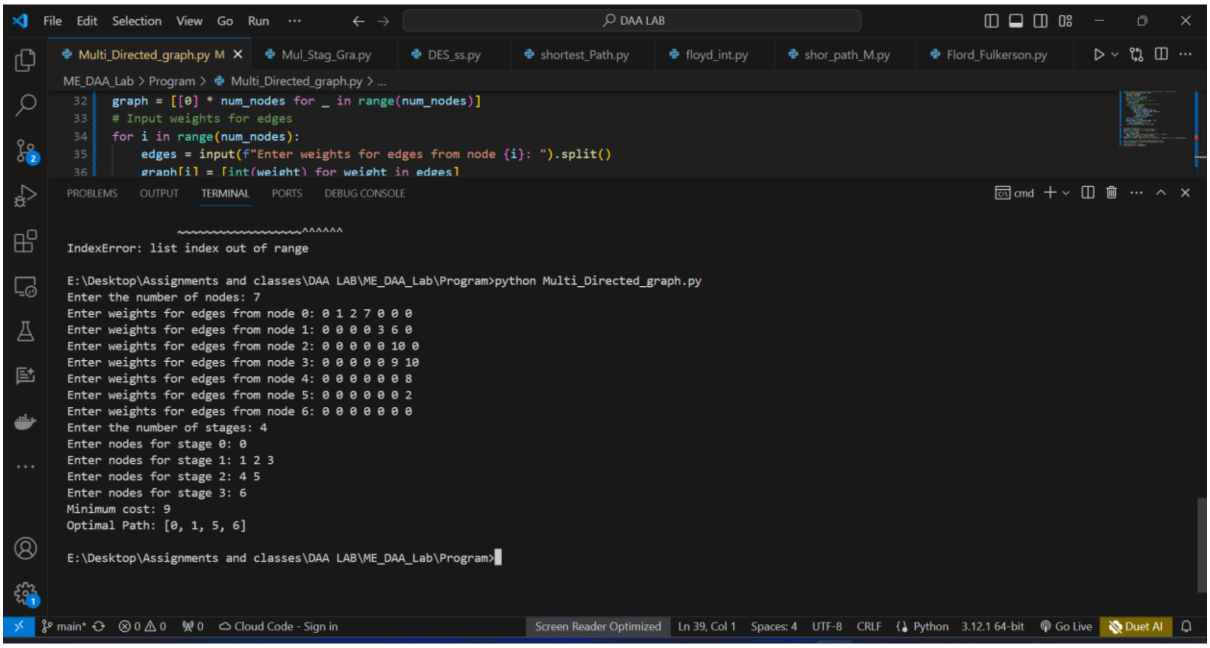
1. Start.
2. Create a cast table with dimensions (num stages+1)*min-nodes.
3. Initialize all entries to positive infinity except for the destination node in the last stage which is initialize to 0.
4. Iterate through each stage starting from the second-to last stage down to the first.
5. For each node in the current stage starting.
    a. Calculate the minimum cost to reach each neighbor in the next stage.
    b. Update the cost table with the minimum cost to reach each node.
6. The entry at position (0,0) in the cost table represents the shortest path cost from source node to the destination node..
7. Return the shortest path cost.
8. Stop.

PROGRAM:

```
# Define a function to find the minimum cost and optimal path in a multistage graph

def min_cost_multistage_graph(graph, stages):

    num_stages = len(stages)

    num_nodes = len(graph)

    # Initialize cost and parent arrays

    cost = [float('inf')] * num_nodes

    parent = [None] * num_nodes

    # Set costs for nodes in the first stage to 0

    for node in stages[0]:

        cost[node] = 0

    # Dynamic Programming approach to calculate minimum cost

    for i in range(1, num_stages):

        for node in stages[i]:

            min_cost = float('inf')

            for parent_node in stages[i - 1]:

                edge_cost = graph[parent_node][node]

                total_cost = cost[parent_node] + edge_cost
```

```
            if total_cost < min_cost:
                min_cost = total_cost
                parent[node] = parent_node
            cost[node] = min_cost
    # Reconstruct the shortest path
    path = [None] * num_stages
    path[num_stages - 1] = stages[num_stages - 1][0]
    for i in range(num_stages - 2, -1, -1):
        path[i] = parent[path[i + 1]]
    return cost[stages[num_stages - 1][0]], path


# Get input from the user
num_nodes = int(input("Enter the number of nodes: "))
graph = [[0] * num_nodes for _ in range(num_nodes)]
# Input weights for edges
for i in range(num_nodes):
    edges = input(f"Enter weights for edges from node {i}: ").split()
    graph[i] = [int(weight) for weight in edges]
num_stages = int(input("Enter the number of stages: "))
stages = [list(map(int, input(f"Enter nodes for stage {i}: ").split())) for i in range(num_stages)]

# Call the min_cost_multistage_graph function with user input
min_cost, optimal_path = min_cost_multistage_graph(graph, stages)
# Print the results
print(f"Minimum cost: {min_cost}")
print("Optimal Path:", optimal_path)
```

OUTPUT:



RESULT:

Thus, the implementation of shortest path using dynamic programming in a multistage graph using python was executed and verified successfully.

Ex No :

DATE:

IMPLEMENTATION OF FORD FULKERSON ALGORITHM TO COMPUTE THE MAXIMUM FLOW IN A GRAPH

AIM:

To implement Ford Fulkerson algorithm to compute the maximum flow in a graph using python.

ALGORITHM:

1. Start.
2. Initialize the flow in all the edges to 0.
3. While there is an augmenting path between the source and the sink and add this path to the flow.
4. Repeat search for an s-t path p while it exists.
5. Find if there is a path from s to t using breadth first search. A path exists if f(e) <c(e) for every edge e on the path.
6. If no path found, return max flow.
7. Else find minimum edge value for path p.
8. Flow=min(c(e)-f(e)) for path p, max_flow+=flow.
9. For all edge e of path incremented flow, f(e)+=flow.
10. Update the residual graph.
11. Stop.

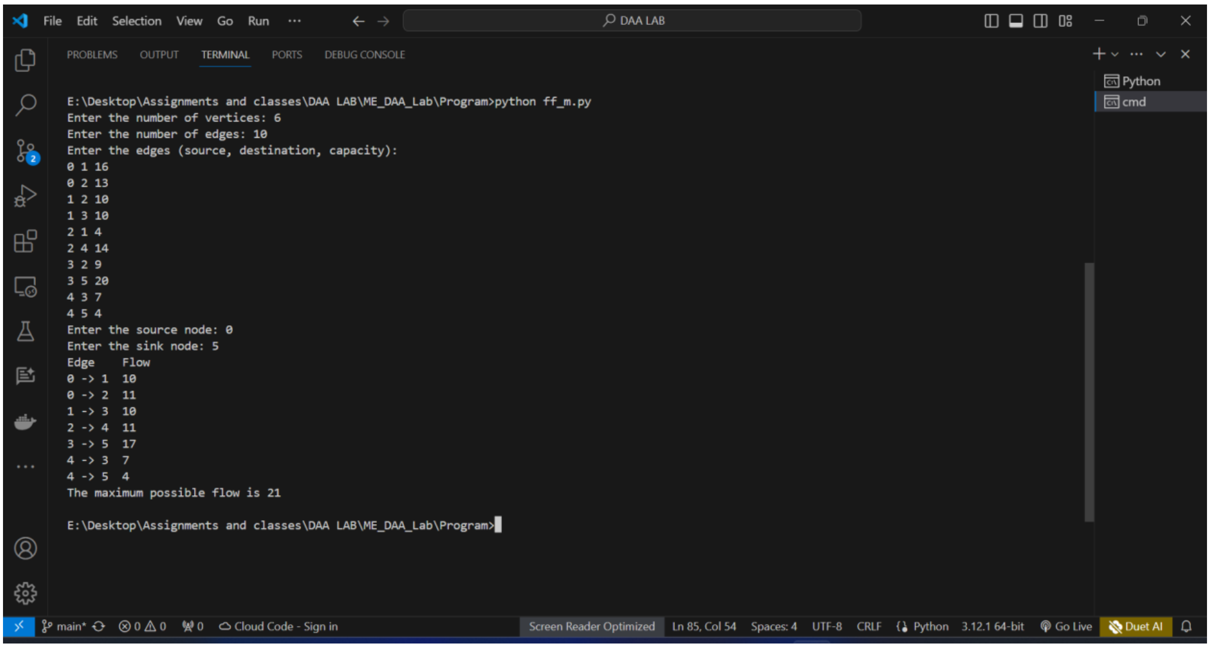
PROGRAM:

```
class Graph:

    def __init__(self, vertices):

        self.V = vertices

        self.graph = [[0] * vertices for _ in range(vertices)]

    def is_valid_edge(self, u, v, capacity):

        return 0 <= u < self.V and 0 <= v < self.V and capacity >= 0

    def add_edge(self, u, v, capacity):

        if self.is_valid_edge(u, v, capacity):

            self.graph[u][v] = capacity

    def print_solution(self, flow):

        print("Edge\tFlow")

        for i in range(self.V):

            for j in range(self.V):

                if flow[i][j] > 0:

                    print(f"{i} -> {j}\t{flow[i][j]}")

    def ford_fulkerson(self, source, sink):

        parent = [-1] * self.V
```

```
        max_flow = 0
        flow = [[0] * self.V for _ in range(self.V)]
        while self.bfs(source, sink, parent):
            path_flow = float("inf")
            s = sink
            while s != source:
                path_flow = min(path_flow, self.graph[parent[s]][s])
                s = parent[s]
        max_flow += path_flow
        v = sink
        while v != source:
            u = parent[v]
            flow[u][v] += path_flow
            flow[v][u] -= path_flow
            v = parent[v]
        # Update the residual capacities of edges along the path
        v = sink
        while v != source:
            u = parent[v]
            self.graph[u][v] -= path_flow
            self.graph[v][u] += path_flow
            v = parent[v]
        # Reset parent array for next BFS
        parent = [-1] * self.V
        self.print_solution(flow)
        return max_flow
    def bfs(self, source, sink, parent):
        visited = [False] * self.V
        queue = [source]
        visited[source] = True
        while queue:
            u = queue.pop(0)
```

```
            for ind, val in enumerate(self.graph[u]):
                if not visited[ind] and val > 0:
                    queue.append(ind)
                    visited[ind] = True
                parent[ind] = u
        return visited[sink]
if __name__ == "__main__":
    vertices = int(input("Enter the number of vertices: "))
    g = Graph(vertices)
    edges = int(input("Enter the number of edges: "))
    print("Enter the edges (source, destination, capacity): ")
    for _ in range(edges):
        u, v, capacity = map(int, input().split())
        g.add_edge(u, v, capacity)
    source = int(input("Enter the source node: "))
    sink = int(input("Enter the sink node: "))
    max_flow = g.ford_fulkerson(source, sink)
    print(f"The maximum flow is {max_flow}")
```

OUTPUT:



RESULT:

Thus, the implementation of Ford Fulkerson algorithm to compute maximum flow in a graph using python was executed and verified successfully.

Ex No : **IMPLEMENTATION OF BOYER-MOORE ALGORITHM FOR PATTERN SEARCHING**

DATE:

AIM:

Implementation of boyer-moore algorithm for pattern searching

ALGORITHM:

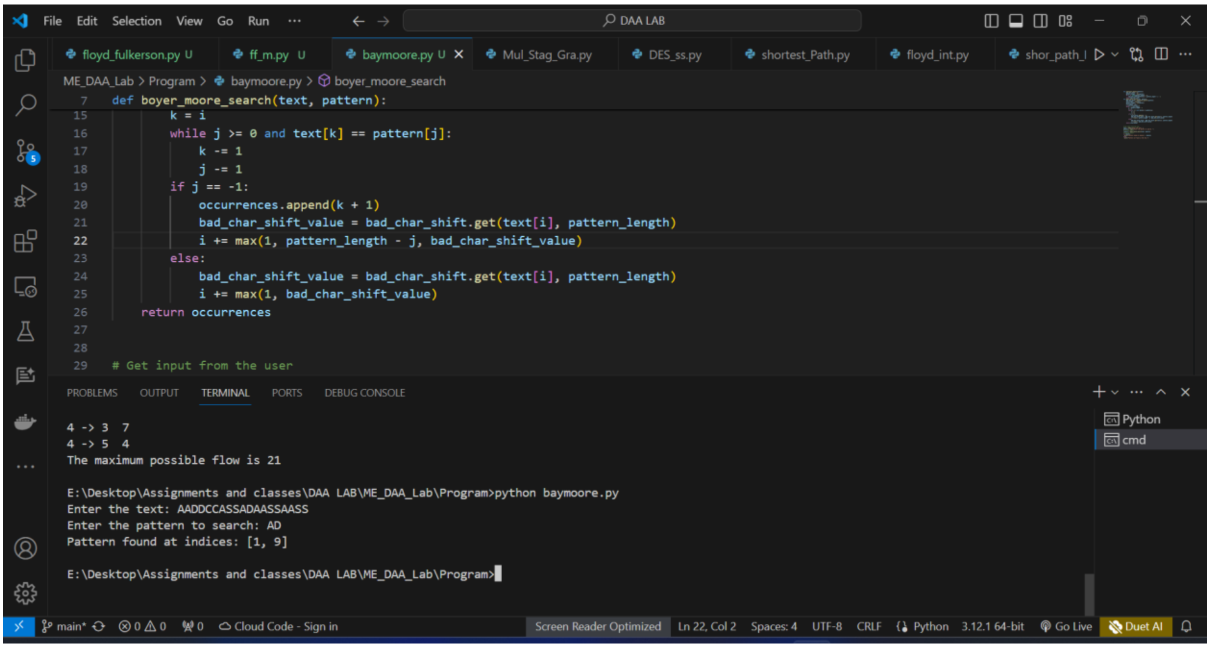
1. Start.
2. Create Bad Character Shift table for pattern characters.
3. Create Good Suffix Shift table.
4. Start matching from the right end of the pattern.
5. If a mismatch occurs:
    a. Use Bad Character Shift to calculate the shift based on the mismatched character.
    b. Use Good Suffix Shift for additional shifts.
    c. Shift the pattern by the maximum of the calculated values.
6. Continue matching until a match is found or the end of the text is reached.
7. Return the starting index of the first occurrence if found, otherwise, return -1.
8. Stop.

PROGRAM:

```
def preprocess_pattern(pattern):
    bad_char_shift = {}
    pattern_length = len(pattern)
    for i in range(pattern_length - 1):
        bad_char_shift[pattern[i]] = pattern_length - i - 1
    return bad_char_shift
def boyer_moore_search(text, pattern):
    bad_char_shift = preprocess_pattern(pattern)
    text_length = len(text)
    pattern_length = len(pattern)
    occurrences = []
    i = pattern_length - 1
    while i < text_length:
        j = pattern_length - 1
        k = i
        while j >= 0 and text[k] == pattern[j]:
            k -= 1
            j -= 1
        if j == -1:
```

```
            occurrences.append(k + 1)
            bad_char_shift_value = bad_char_shift.get(text[i], pattern_length)
            i += max(1, pattern_length - j, bad_char_shift_value)
        else:
            bad_char_shift_value = bad_char_shift.get(text[i], pattern_length)
            i += max(1, bad_char_shift_value)
    return occurrences


# Get input from the user
text = input("Enter the text: ")
pattern = input("Enter the pattern to search: ")
# Perform search
results = boyer_moore_search(text, pattern)
# Display result
if results:
 print("Pattern found at indices:", results)
else:
 print("Pattern not found in the text.")
```

OUTPUT:



RESULT:

Thus, the implementation of Boyer-Moore algorithm for pattern searching was executed and verified successfully.

Ex No :

DATE:

SOLVE THE GRAPH COLORING PROBLEM BY BACKTRACKING AND CONSTRAINT PROPAGATION (USING HEURISTICS)

AIM:

To solve the graph colouring problem by backtracking and constraint propagation using heuristics in python.

ALGORITHM:

1. Start.
2. Get the number of vertices and edges from the user.
3. If the nearby edge is adjacent, colour the edge with different colour.
4. Else nearby edge is not adjacent, colour the edge with same colour.
5. Create a recursive function that takes the graph, current index, number of vertices and output colour array.
6. If the current index is equal to the number of vertices, print the colour configuration in the output array.
7. Assign a colour to vertex (1 to m).
8. For every assigned colour, check if the configuration is safe.
9. If any recursive function returns the true, break the loop and return true.
10. If no recursive function returns true, then return false.
11. Stop.

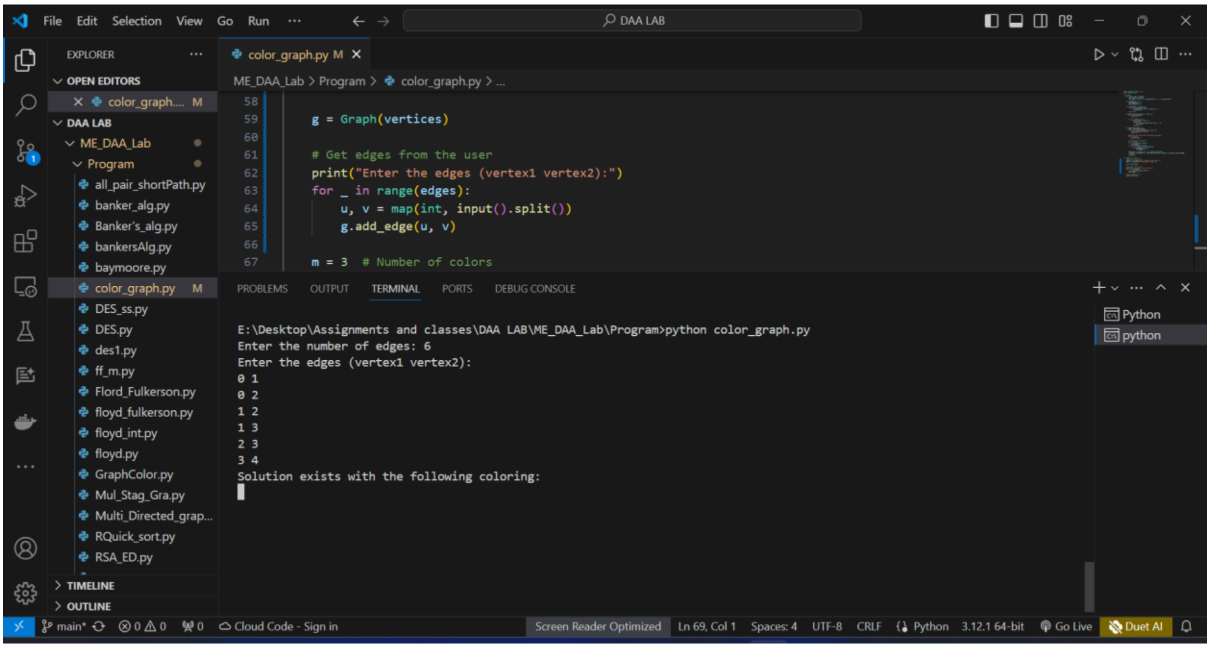
PROGRAM:

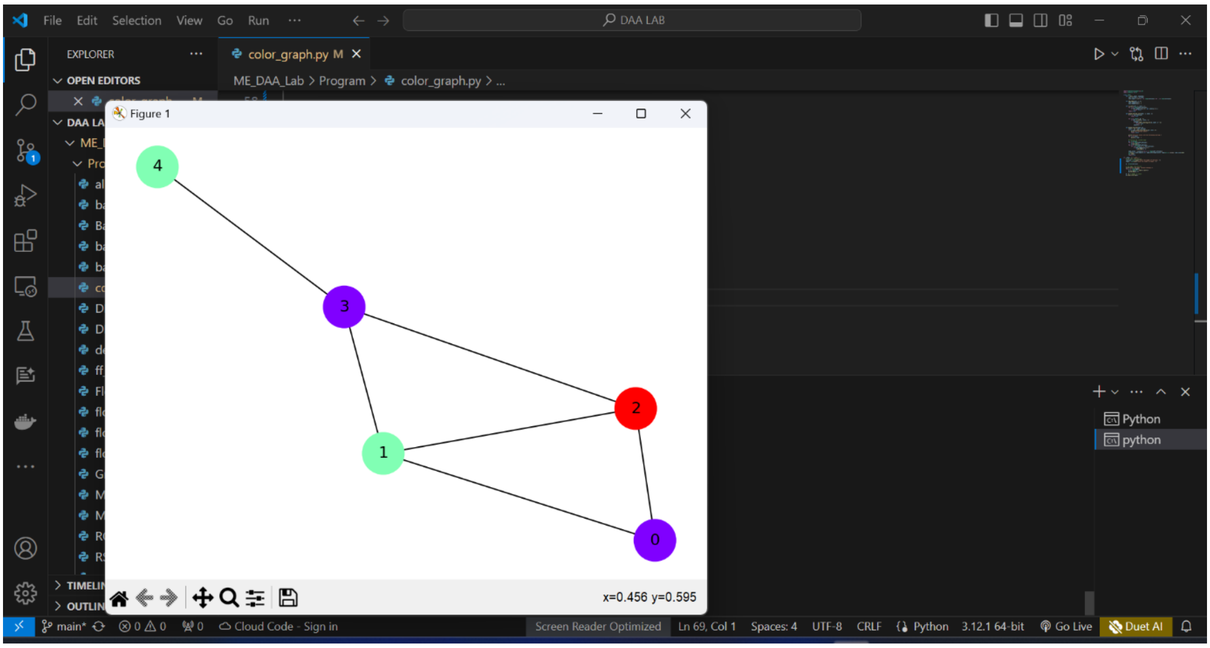
```
import matplotlib.pyplot as plt

import networkx as nx


class Graph:

    def __init__(self, vertices):

        self.vertices = vertices

        self.graph = [[0 for _ in range(vertices)] for _ in range(vertices)]


    def add_edge(self, u, v):

        self.graph[u][v] = 1

        self.graph[v][u] = 1


    def is_safe(self, v, color, c):

        for i in range(self.vertices):

            if self.graph[v][i] == 1 and color[i] == c:

                return False

        return True
```

```
def graph_coloring_util(self, m, color, v):
    if v == self.vertices:
        return True

    for c in range(1, m + 1):
        if self.is_safe(v, color, c):
            color[v] = c
            if self.graph_coloring_util(m, color, v + 1):
                return True
            color[v] = 0

def graph_coloring(self, m):
    color = [0] * self.vertices
    if not self.graph_coloring_util(m, color, 0):
        print("No solution exists")
        return False

    print("Solution exists with the following coloring:")
    for c in color:
        print(c, end=" ")

    # Plotting the colored graph
    G = nx.Graph()
    for i in range(self.vertices):
        G.add_node(i)
    for i in range(self.vertices):
        for j in range(i + 1, self.vertices):
            if self.graph[i][j] == 1:
                G.add_edge(i, j)

    node_colors = [color[i] for i in range(self.vertices)]
```

```python
        nx.draw(G, with_labels=True, node_color=node_colors, cmap=plt.cm.rainbow, node_size=1000)
        plt.show()
        return True

if __name__ == "__main__":
    # Get input from the user
    vertices = int(input("Enter the number of vertices: "))
    edges = int(input("Enter the number of edges: "))

    g = Graph(vertices)

    # Get edges from the user
    print("Enter the edges (vertex1 vertex2):")
    for _ in range(edges):
        u, v = map(int, input().split())
        g.add_edge(u, v)

    m = 3  # Number of colors
    g.graph_coloring(m)
```

OUTPUT:





RESULT:

Thus, the graph colouring problem by backtracking and constraint propagation using heuristics in python was executed and verified successfully.

Ex No : 9

DATE:

IMPLEMENTATION OF MAXIMUM CLIQUES PROBLEM USING THE BRANCH AND CUT ALGORITHM

AIM:

To implementation of maximum cliques problem using the branch and cut algorithm.

ALGORITHM:

1. Start.
2. Selection an undirected graph which consists of vertices and edges.
3. Use a heuristics or algorithm to find lower bound on the maximum clique size
4. Choose a vertex from the graph and branch in to subproblem.
    a. In one subproblem, Include the chosen vertex in the clique and remove all vertices adjacent to it.
    b. In other subproblem, exclude the chosen vertex form the cliques and remove it from the graph.
5. Solve each sub problem using relaxation techniques i.e. finding maximum cliques in the reduced graph.
6. Repeat the steps 4 and 5 for each subproblem until an optimal clique is found or the maximum cliques size equals the lower bound .
7. Stop.

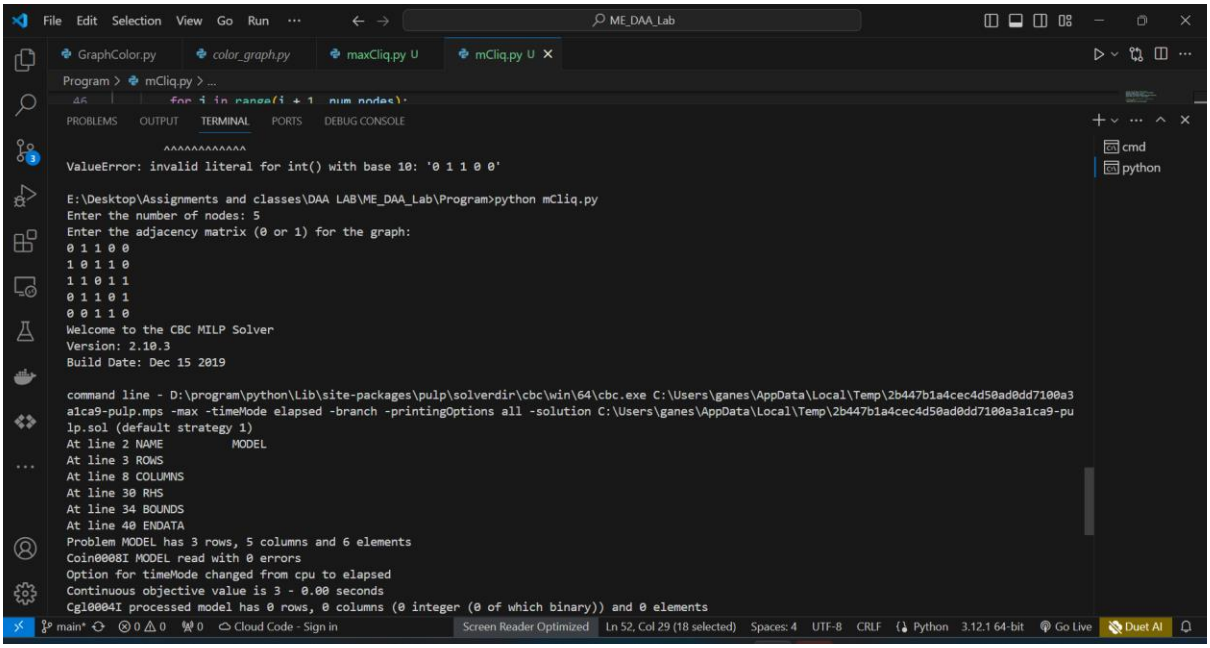
PROGRAM:

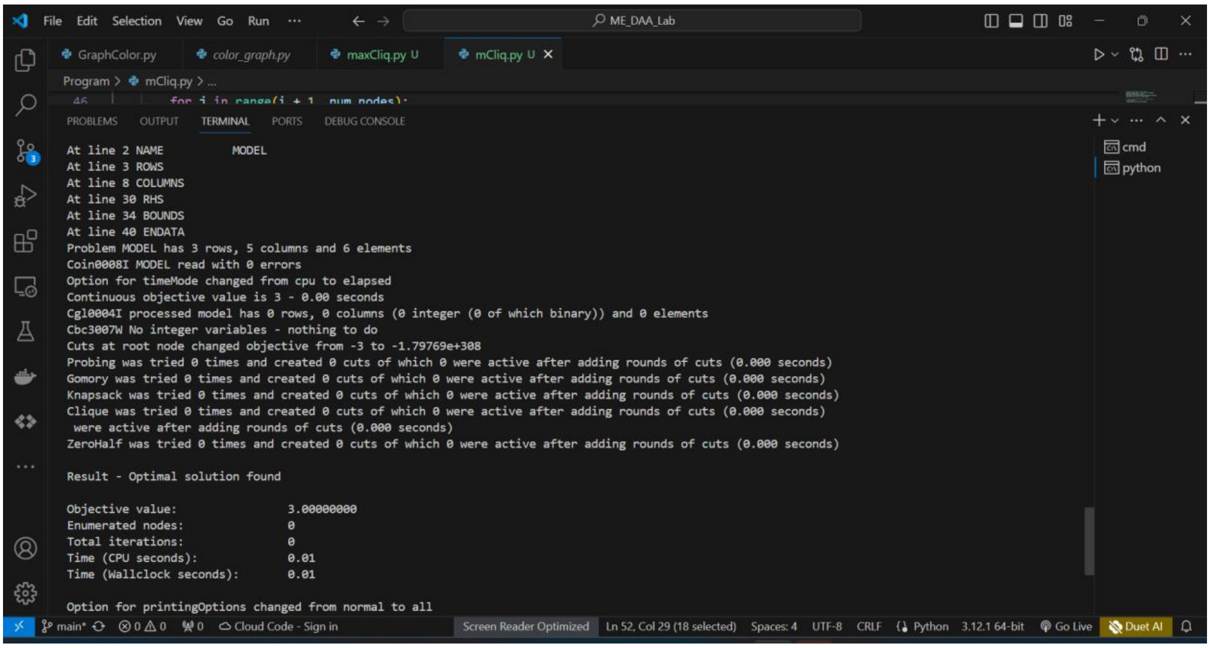
```
from itertools import combinations

from pulp import LpMaximize, LpProblem, LpVariable, lpSum

import networkx as nx

import matplotlib.pyplot as plt


class MaximumClique:

    def __init__(self, graph):

        self.graph = graph

        self.nodes = range(len(graph))

        self.model = LpProblem(name="maximum_clique", sense=LpMaximize)

        self.x = LpVariable.dicts("x", self.nodes, cat="Binary")


    def add_constraints(self):

        for i, j in combinations(self.nodes, 2):

            if not self.graph[i][j]:

                self.model += self.x[i] + self.x[j] <= 1


    def solve(self):
```

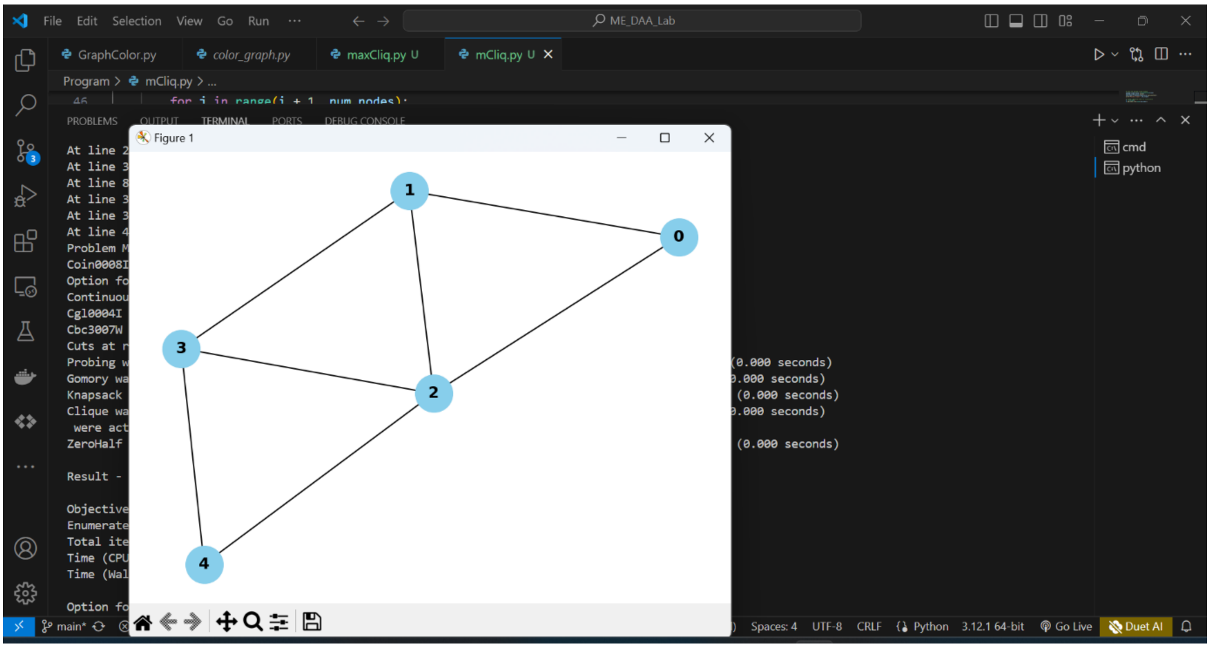
```
        self.model += lpSum(self.x)
        self.add_constraints()
        self.model.solve()

    def get_solution(self):
        return [i for i in self.nodes if self.x[i].value() == 1]

if __name__ == "__main__":
    # Get input from the user
    num_nodes = int(input("Enter the number of nodes: "))
    print("Enter the adjacency matrix (0 or 1) for the graph:")
    graph = [[int(x) for x in input().split()] for _ in range(num_nodes)]

    # Solve the maximum clique problem
    maximum_clique_solver = MaximumClique(graph)
    maximum_clique_solver.solve()
    max_clique = maximum_clique_solver.get_solution()
    print("Maximum clique:", max_clique)

    # Create a NetworkX graph for visualization
    G = nx.Graph()
    G.add_nodes_from(range(num_nodes))
    for i in range(num_nodes):
        for j in range(i + 1, num_nodes):
            if graph[i][j] == 1:
                G.add_edge(i, j)

    # Color the nodes in the maximum clique differently
    node_colors = ['skyblue' if node not in max_clique else 'orange' for node in G.nodes()]

    # Plot the graph
    nx.draw(G, with_labels=True, node_color=node_colors, node_size=800, font_size=12,
font_weight='bold')
```

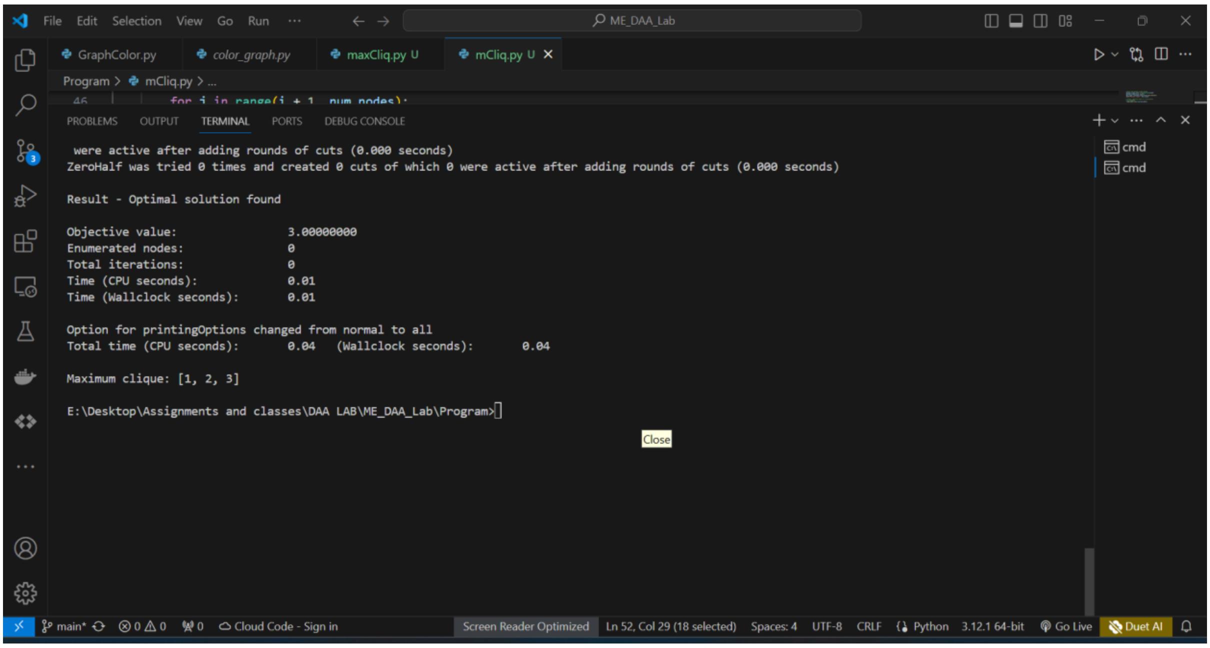
```
plt.title("Input Graph with Maximum Clique Highlighted")

plt.show()
```

OUTPUT:









RESULT:

Thus an implementation of maximum clique problem using branch and cut method was executed and verified successfully.