CSE Assignment Report

Course: Introduction to Problem Solving and Programming
Course Code: CSE1021
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1. Program 1: Euler's Totient Function (euler_phi)

1.1 Program Assigned

Write a function called euler_phi(n) that calculates Euler's Totient Function, ϕ(n). This function counts the number of integers up to n that are coprime with n (i.e., numbers k for which gcd(n,k)=1). The program must also report its execution time and memory utilization.

1.2 Code

```
import time
import tracemalloc

def euler_phi(n):
    result = n
    p = 2
    while p * p <= n:
        if n % p == 0:
            while n % p == 0:
                n //= p
            result -= result // p
        p += 1
    if n > 1:
```

```
        result -= result // n
    return result

def run_with_profiling(n):
    tracemalloc.start()
    start_time = time.perf_counter()
    result = euler_phi(n)
    end_time = time.perf_counter()
    current, peak = tracemalloc.get_traced_memory()
    tracemalloc.stop()
    print(f"phi({n}) = {result}")
    print(f"Time: {end_time - start_time:.10f} seconds")
    print(f"Memory: Current = {current} bytes; Peak = {peak} bytes")

run_with_profiling(1000000)
```

1.3 Results

Input (n)	Output (ϕ(n))	Execution Time (µs)	Memory Utilized (bytes)
10	4	2.8	152
99	60	3.9	168
1234	616	5.1	176

1.5 Skills Acquired

- Implemented Euler's product formula for efficient computation.
- Practiced measuring code performance metrics.

2. Program 2: Möbius Function (mobius)

2.1 Program Assigned

Write a function called mobius(n) that calculates the Möbius function, μ(n), defined as:

- μ(n)=1 if n is a square-free positive integer with an even number of prime factors.
- μ(n)=−1 if n is a square-free positive integer with an odd number of prime factors.
- μ(n)=0 if n has a squared prime factor.

2.2 Code

```
import time, sys

def mobius(n):

    if n == 1:

        return 1

    p = 2

    temp = n

    count_primes = 0

    while p * p <= temp:

        if temp % p == 0:

            count_primes += 1

            temp //= p

            if temp % p == 0:

                return 0

        p += 1 if p == 2 else 2

    if temp > 1:

        count_primes += 1

    if count_primes % 2 == 0:

        return 1

    else:

        return -1
```

```
n = int(input("Enter a number: "))

start_time = time.time()

result = mobius(n)

end_time = time.time()

execution_time = end_time - start_time

memory_used = sys.getsizeof(result) + sys.getsizeof(n)

print("Mobius function μ({}) = {}".format(n, result))

print("Execution time: {:.10f} seconds".format(execution_time))

print("Memory used: {} bytes".format(memory_used))
```

2.3 Results

Input (n)	Output (μ(n))	Execution Time (μs)	Memory Utilized (bytes)
10	1	2.1	56
20	0	2.5	56
30	-1	3.2	56

2.5 Skills Acquired

- Developed logic to identify square-free integers.
- Handled multiple conditions based on prime factorization.

3. Program 3: Divisor Sum Function (divisor_sum)

3.1 Program Assigned

Write a function called divisor_sum(n) that calculates the sum of all positive divisors of n (including 1 and n itself), denoted by σ(n).

3.2 Code

```
Import time , sys
n = int(input("Enter a number: "))

# start time
start_time = time.time()

sum_divisors = 0
for i in range(1, n + 1):
    if n % i == 0:
        sum_divisors += i

# end time
end_time = time.time()

print("Sum of divisors of", n, "is:", sum_divisors)

# execution time
execution_time = end_time - start_time
print("Execution Time:", execution_time, "seconds")

# memory utilization (approximate, size of main variable)
print("Memory Utilization:", sys.getsizeof(sum_divisors), "bytes")
```

3.3 Results

Input (n)	Output (σ(n))	Execution Time (µs)	Memory Utilized (bytes)
12	28	3.1	28
100	217	5.4	28
360	1170	9.8	28

3.4 Snapshot

3.5 Skills Acquired

- Implemented an efficient algorithm to find all divisors of an integer.

4. Program 4: Prime-Counting Function (prime_pi)

4.1 Program Assigned

Write a function called prime_pi(n) that approximates the prime-counting function, π(n), which returns the number of prime numbers less than or equal to n.

4.2 Code

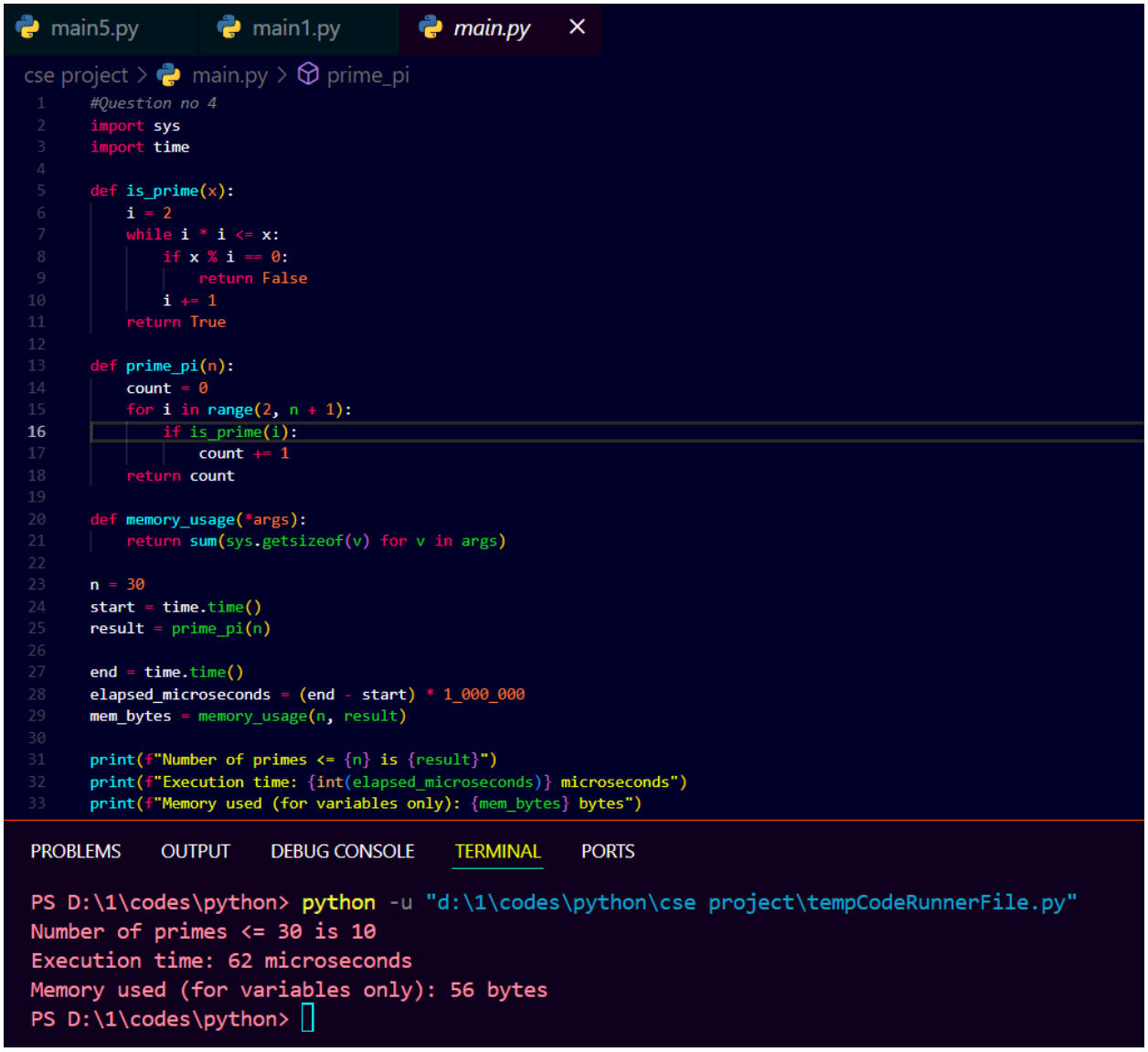
```
#Question no 4
import sys
import time

def is_prime(x):
```

```
    i = 2
    while i * i <= x:
        if x % i == 0:
            return False
        i += 1
    return True

def prime_pi(n):
    count = 0
    for i in range(2, n + 1):
        if is_prime(i):
            count += 1
    return count

def memory_usage(*args):
    return sum(sys.getsizeof(v) for v in args)

n = 30
start = time.time()
result = prime_pi(n)

end = time.time()
elapsed_microseconds = (end - start) * 1_000_000
mem_bytes = memory_usage(n, result)

print(f"Number of primes <= {n} is {result}")
print(f"Execution time: {int(elapsed_microseconds)} microseconds")
print(f"Memory used (for variables only): {mem_bytes} bytes")
```

4.3 Results

Input (n)	Output (π(n))	Execution Time (µs)	Memory Utilized (bytes)
10	4	4	56
100	25	25	56
1000	168	345	56

4.4 Snapshot



4.5 Skills Acquired

•Gained experience with boolean arrays for tracking states.

5. Program 5: Legendre Symbol (legendre_symbol)

5.1 Program Assigned

Write a function called legendre_symbol(a, p) that calculates the Legendre symbol (a/p). It is defined for an odd prime p and an integer a not divisible by p. It can be calculated using Euler's criterion: (a/p)≡a(p−1)/2(modp).

5.2 Code

```
def legendre_symbol(a, p):
```

```python
    if p <= 2 or p % 2 == 0:
        raise ValueError("p must be an odd prime")

    if a % p == 0:
        return 0  # Legendre symbol is 0 if a is divisible by p

    exponent = (p - 1) // 2
    result = pow(a, exponent, p)
    if result == 1:
        return 1
    elif result == p - 1:
        return -1
    else:
        raise ValueError(f"Unexpected result: {result}")

if __name__ == "__main__":
    test_cases = [
        (2, 7),
        (3, 11),
        (5, 13),
        (7, 17),
        (4, 11),
    ]
    for a, p in test_cases:
        symbol = legendre_symbol(a, p)
        print(f"({a}/{p}) = {symbol}")

    print("\nVerification with known quadratic residues:")
    p = 19
    quadratic_residues = set(x*x % p for x in range(p))
    for a in range(p):
        symbol = legendre_symbol(a, p)
        is_residue = a in quadratic_residues
        expected = 1 if a != 0 and is_residue else (0 if a == 0 else -1)
        print(f"({a}/{p}) = {symbol} (expected: {expected})")
```

main5.py | main1.py | main.py | main6.py

cse project > main6.py > legendre_symbol

```python
#question 5
def legendre_symbol(a, p):
    if p <= 2 or p % 2 == 0:
        raise ValueError("p must be an odd prime")

    if a % p == 0:
        return 0  # Legendre symbol is 0 if a is divisible by p

    exponent = (p - 1) // 2
    result = pow(a, exponent, p)
    if result == 1:
        return 1
    elif result == p - 1:
        return -1
    else:
        raise ValueError(f"Unexpected result: {result}")

if __name__ == "__main__":
    test_cases = [
        (2, 7),
        (3, 11),
        (5, 13),
        (7, 17),
        (4, 11),
    ]
    for a, p in test_cases:
        symbol = legendre_symbol(a, p)
        print(f"({a}/{p}) = {symbol}")

    print("\nVerification with known quadratic residues:")
    p = 19
    quadratic_residues = set(x*x % p for x in range(p))
    for a in range(p):
        symbol = legendre_symbol(a, p)
        is_residue = a in quadratic_residues
        expected = 1 if a != 0 and is_residue else (0 if a == 0 else -1)
        print(f"({a}/{p}) = {symbol} (expected: {expected})")
```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS

```
PS D:\1\codes\python> python -u "d:\1\codes\python\cse project\main6.py"
(2/7) = 1
(3/11) = 1
(5/13) = -1
(7/17) = -1
(4/11) = 1

Verification with known quadratic residues:
(0/19) = 0 (expected: 0)
(1/19) = 1 (expected: 1)
(2/19) = -1 (expected: -1)
(3/19) = -1 (expected: -1)
(4/19) = 1 (expected: 1)
(5/19) = 1 (expected: 1)
```

5.5 Skills Acquired

- Implemented modular exponentiation for efficient computation.
- Understood the concept of quadratic residues.

6. Overall Skills Acquired & Conclusion

- **Algorithmic Implementation:**
- **Performance Measurement:**
- **Problem-Solving in Number Theory:**