Subject: Mathematics

Investigating patterns in the product of Euler's totient function φ and the sum of divisors function σ

Research Question: What gives rise to the patterns and bounds in the graph of $f(n) = \varphi(n) \cdot \sigma(x)$, and how does this relate to the Riemann zeta function and the Basel problem?

March 31, 2025

Word count: 1729

1 Presentation to the Class

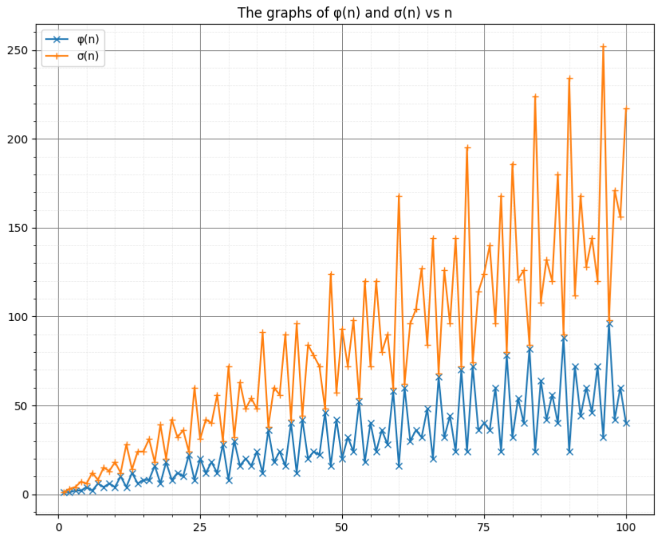
This paper aims to investigate patterns in the graph of $f(n) = \varphi(n) \cdot \sigma(n)$.

1.1 What are the functions

$\varphi(n)$ is the "number of positive integers $\leq n$ and coprime to n." $\sigma(n)$ is the "sum of the positive divisors of n."

Examples:

n	$\varphi(n)$	numbers	$\sigma(n)$	numbers
1	1	1	1 =	1
2	1	1	3 =	1+2
3	2	1,2	4 =	1+3
4	2	1,3	7 =	1+2+4
5	4	1,2,3,4	6 =	1+5
6	2	1,5	12 =	1+2+3+6
7	6	1,2,3,4,5,6	8 =	1+7
8	4	1,3,5,7	15 =	1+2+4+8
9	6	1,2,4,5,7,8	13 =	1+3+9
10	4	1,3,7,9	18 =	1+2+5+10



There are nice patterns in this graph, and we will explore them more closely.

Some properties of these functions:

2 Abstract

Contents

3 Introduction

Broadly speaking, number theory is the branch of mathematics concerned with the properties of integers. In a school setting, this often includes topics such as divisibility rules, prime factorization, and, most importantly, the **Fundamental Theorem of Arithmetic**.

Theorem 1 (Fundamental Theorem of Arithmetic) *Every integer $n > 1$ can be represented as a product of prime factors in precisely one way, up to the order of the factors.*

This theorem asserts that for any integer n, there exists a unique set of distinct prime numbers $p_1, p_2, ..., p_k$, along with their respective exponents $\alpha_1, \alpha_2, ..., \alpha_k$, such that

$$n = p_1^{\alpha_1} p_2^{\alpha_2} ... p_k^{\alpha_k}.$$

This form of writing numbers as a product of primes is the key to the proofs delivered in this paper. For example, we can construct all the factors (positive divisors) of a number when given its prime factorization. Namely, they are precisely the numbers of the form

$$d = p_1^{\beta_1} p_2^{\beta_2} ... p_k^{\beta_k},$$

where $\beta_i \leq \alpha_i$ for all $1 \leq i \leq k$.

4 The zeta function

hello [**basel**] hello!!

5 An Explanation for the Patterns

6 Appendices