

Some remarks on the coefficients of cyclotomic polynomials

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Abstract: Some recent advances related to the coefficients of cyclotomic polynomials, including a recurrence formula for their calculation and some numerical simulations are presented.

Keywords: cyclotomic polynomial, coefficients, recurrence formula, Möbius function, Ramanujan sums, partition function

1 Introduction

For an integer $n \geq 1$, an n th root ζ of the unity is called primitive if $\zeta^n = 1$, but $\zeta^d \neq 1$ for all $1 \leq d < n$. Denoting by $\zeta_n = \cos \frac{2\pi}{n} + i \sin \frac{2\pi}{n}$ the first root of order n of the unity, the n -th cyclotomic polynomial Φ_n is defined by

$$\Phi_n(z) = \prod_{\substack{1 \leq k \leq n-1 \\ \gcd(k,n)=1}} (z - \zeta_n^k) = \sum_{j=0}^{\varphi(n)} c_j^{(n)} z^j, \quad (1)$$

where φ is Euler's totient function, also the degree of the polynomial. The term cyclotomic comes from the property of the n th roots of unity to divide the unit circle into n equal arcs, forming a regular polygon inscribed in the unit circle.

The first few cyclotomic polynomials are

$$\Phi_1(z) = z - 1, \Phi_2(z) = z + 1, \Phi_3(z) = z^2 + z + 1, \Phi_4(z) = z^2 + 1,$$

$$\Phi_5(z) = z^4 + z^3 + z^2 + z + 1, \Phi_6(z) = z^2 - z + 1,$$

$$\Phi_7(z) = z^6 + z^5 + z^4 + z^3 + z^2 + z + 1, \Phi_8(z) = z^4 + 1,$$

$$\Phi_9(z) = z^6 + z^3 + 1, \Phi_{10}(z) = z^4 - z^3 + z^2 - z + 1,$$

$$\Phi_{12}(z) = z^4 - z^2 + 1, \Phi_{14}(z) = z^6 - z^5 + z^4 - z^3 + z^2 - z + 1,$$

$$\Phi_{15}(z) = z^8 - z^7 + z^5 - z^4 + z^2 - z + 1, \Phi_{16}(z) = z^8 + 1,$$

$$\Phi_{18}(z) = z^6 - z^3 + 1, \Phi_{20}(z) = z^8 - z^6 + z^4 - z^2 + 1,$$

$$\Phi_{21}(z) = z^{12} - z^{11} + z^9 - z^8 + z^6 - z^4 + z^3 - z^1 + 1,$$

$$\Phi_{22}(z) = z^{10} - z^9 + z^8 - z^7 + z^6 - z^5 + z^4 - z^3 + z^2 - z + 1.$$

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Rachel S Tattersall



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