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VOLUME 1

INVESTIGATIONS ON PURE MATHEMATICS, FINANCE MATHEMATICS AND OPTICS

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$$\varphi_1(x, y, z) = z$$

$$\pi_1 = \begin{pmatrix} x & y & z \\ y & z & x \end{pmatrix}$$

$$z' = x^2 + y^2 + z^2 + 2yz$$

$$\pi_1 \vee_1 \pi_1 = \vee_{17}$$



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Investigations on Pure Mathematics, Finance Mathematics and Optics

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ON THE ELEMENTARY CHARACTERIZATION OF PRIMES IN PRIMALITY TESTS: TWO SHORT STUDIES.

Kee Md. Rafique Zainal Abidin
Prof. Dr. Nasir Ganikhodjaev

Abstract. *This project proposes to study two elementary but interesting characterizations of the primes that may be used in primality testing algorithms. The first characterization to be studied comes from a fully justified, deterministic, polynomial time algorithm known as the AKS algorithm. The second characterization is a project under development and is also a suggestion for further investigation into the use of radix expansions as a primality test. This work is a reflection on the importance of seeking arithmetic characterizations of the primes that do not go beyond integer relationships and their structure.*

1 The characterization of primes in the AKS algorithm

The AKS algorithm is a combination of both elementary and very deep notions. As stated previously, we will only look at the identity upon which the entire algorithm is based. Like most primality tests that go beyond the level of sophistication of Trial Division, the AKS test is based upon a congruence relation. More explicitly, it involves a congruence between polynomials,

$$(x + 1)^n \equiv_n x^n + 1 \quad (1)$$

where n would have to be prime for the above congruence to hold. The congruence relation (1) is well-known and should be familiar to most students of number theory who have studied Fermat's little theorem. Before we go into the theorem that validates AKS as a primality test, we will relate (1) with Fermat's little theorem.

2 Fermat's Little Theorem

One of the most important statements about congruence in primality testing is this,

Theorem (Fermat). If p is a prime, suppose that $p \nmid a$. Then $a^{p-1} \equiv_p 1$

We will not prove the above theorem as its proof is rather ubiquitous, especially in number theory textbooks. To see how (1) is related to Fermat's little theorem, we will derive (1) from it. To start this off, consider the following corollary of Fermat's little theorem,

Corollary. If p is a prime then for any integer a , $a^p \equiv_p a$

Multiply Fermat's little theorem by $a \equiv_p a$. The corollary holds when $p|a$ as well as $p \nmid a$. Obviously, since when $p|a$ the corollary is true, that is $a|a(a^{p-1} - 1)$. When $p \nmid a$, the divisibility relation still holds by Euclid's lemma (see next section for proof of this lemma). Using the above corollary, we will derive (1). By using the binomial theorem on $(a + 1)^p$ we get the following equality,

$$(a + 1)^p = a^p + \binom{p}{1} a^{p-1} + \dots + \binom{p}{k} a^{p-k} + \dots + \binom{p}{p-k} a + 1$$