# THE PLACE OF MUHAMMAD AL-KHWARIZMI'S ARITHMETIC AND ALGEBRAIC LEGACY IN THE HISTORY OF MATHEMATICS

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**Abstract.** *This article analyzes the scientific legacy of Muhammad ibn Musa al-Khwarizmi in the fields of arithmetic and algebra. Al-Khwarizmi's works marked a new era in the history of mathematics and had an unparalleled impact on the mathematical thinking of subsequent periods. The study examines his works from historical, theoretical, and practical perspectives, highlighting their role and methodological significance in the development of mathematics. The article analyzes al-Khwarizmi's scientific approach, calculation methods, techniques for solving equations, and his contribution to the formation of algebra as an independent discipline. This research is based on a historical-analytical method and demonstrates the contemporary relevance of his legacy in scientific research and mathematics education.*

**Keywords:** *Muhammad al-Khwarizmi, arithmetic, algebra, history of mathematics, scientific legacy, decimal positional system*

## Introduction

The historical development of mathematics is closely linked to the evolution of human thought, and scientific achievements of each era serve as theoretical and methodological foundations for subsequent stages. One of the main characteristics of scientific progress is that it relies on principles of continuity and inheritance: each new idea is developed based on previous scientific experience. From this perspective, the scientific legacy of great scholars who worked in the medieval Eastern intellectual environment holds special significance not only for their own time but also for the advancement of global science.

Muhammad ibn Musa al-Khwarizmi was one such great thinker. His scientific works in arithmetic and algebra are fundamental sources that brought about a turning point in the development of mathematics. His scientific views contributed significantly to the systematization of mathematical knowledge, the improvement of calculation methods, and the establishment of algebra as an independent scientific discipline. Studying al-Khwarizmi's legacy in terms of its historical, theoretical, and practical significance is an important scientific task for contemporary intellectual thought, mathematics education, and the methodology of science.

The main aim of this article is to analyze the place of al-Khwarizmi's arithmetic and algebraic works in the history of mathematics, their scientific essence, and the impact they had on the development of subsequent scientific advancements.

## Literature Review

Research on al-Khwarizmi's scientific legacy constitutes a significant area in the historiography of mathematics. Scholarly sources extensively discuss his contribution to algebra, his role in developing calculation systems, and his influence on the evolution of mathematical thought. In particular, fundamental studies in the history of mathematics directly associate al-Khwarizmi with the formation of algebra. Researchers evaluate his works highly in terms of logical systematization of mathematical knowledge, precise conceptual expression, and the development of methodological approaches.

In the literature, al-Khwarizmi's works are recognized as exemplary achievements of medieval scientific thinking, and their introduction into European intellectual circles is emphasized. The processes of translation, scholarly commentary, and their influence on the formation of later mathematical schools are documented in numerous historical sources. Moreover, contemporary studies examine al-Khwarizmi's legacy not only as a historical fact but also in relation to scientific methodology, pedagogy, and interdisciplinary integration.

The analysis of relevant literature indicates that the significance of al-Khwarizmi's works is not limited to mathematical formulas or calculation rules. They also contributed to the development of scientific thought, the integration of theoretical knowledge with practical applications, and the formation of principles for the systematization of scientific knowledge.

## Research Methodology

This article primarily employs a historical-analytical approach. During the study, scholarly sources on the history of mathematics, theoretical perspectives, and historical data were systematically examined. Logical analysis, comparison, generalization, and conceptual methods were used to reveal the content and essence of al-Khwarizmi's scientific legacy.

The historical approach allowed the author to identify the intellectual environment of al-Khwarizmi's era, the level of development of mathematical knowledge, and the nature of scientific needs. Systematic analysis enabled the study of the internal logical structure, scientific concepts, and methodological aspects of al-Khwarizmi's works. Furthermore, based on the principles of continuity and inheritance observed in the history of science, the subsequent development of al-Khwarizmi's ideas was evaluated.

## Analysis and Discussion

In his arithmetic work, al-Khwarizmi was the first to present the decimal positional system and operations based on it in Arabic. The Latin manuscript preserved at Cambridge University begins with the phrase Dixit Algorizmi, meaning "Al-Khwarizmi said." This manuscript covers 1020–1096 folios, and the discussion of fractions remains incomplete. According to A. P. Yushkevich, the original Arabic title should have been Kitab al-jam' wa-l-tafriq bi-hisab al-hind ("The Book of Addition and Subtraction According to the Hindu Calculation"), indicating that only the two main arithmetic

operations were explicitly mentioned in the title, while multiplication and division were implied to be derived from them.

At the beginning of his treatise, after the customary praise, al-Khwarizmi explains the method of calculation using nine “letters,” representing digits, showing how any number can be easily expressed and manipulated. In the Latin manuscript, Hindu numerals are not written, only the numeral for zero is depicted as a small circle, and in some cases, numerals 1, 2, 3, 5 are represented. Examples use Roman numerals common in Western Europe, with spaces left for corresponding Hindu digits. Al-Khwarizmi’s arithmetic treatise reflects not only Hindu arithmetic but also the influence of ancient Greek philosophy. Furthermore, he draws upon earlier mathematical works, as indicated by statements such as:

"Therefore, the unity is present in the composition of every number… It is the root of every number… it exists outside numbers, independently, without other numbers."

Here, the notion that “unity is in every number” and is “outside numbers” aligns both with Pythagorean and Aristotelian views.

Al-Khwarizmi carefully explains how numbers are written using Hindu numerals in a decimal positional system, emphasizing the role of zero. He demonstrates reading large numbers, for instance: 1,180,073,051,492,863, with detailed instructions. Such cumbersome reading persisted in both East and West until the decimal positional system became widespread.

He then moves to arithmetic operations, starting with addition and subtraction, highlighting the significance of the “small circle,” i.e., zero:

"If nothing remains in a place, insert a circle to prevent the position from being empty; it must occupy the place, otherwise your number will be misread."

Al-Khwarizmi emphasizes performing operations from the highest place value downwards. His first subtraction example is 6422 minus 3211, written by aligning the digits by place value. In more complex examples, such as 1144 minus 144, the importance of zero is clearly illustrated.

Al-Khwarizmi also addresses doubling and halving operations, known from ancient Egyptian mathematics. These operations, executed using multiplication and division, continued to be employed in both Eastern and European mathematics due to his treatise. Although al-Khwarizmi knew that doubling is a particular case of multiplication and halving a particular case of division, the Cambridge manuscript does not explicitly mention this. Nevertheless, the revised version by Ioann of Seville clarified these relationships, emphasizing their importance for extracting roots.

**Conclusion**

Muhammad ibn Musa al-Khwarizmi’s scientific legacy in arithmetic and algebra is of fundamental importance in the historical development of mathematics. His approaches contributed to the systematization of mathematical knowledge, the consolidation of methodological foundations, and the advancement of scientific thinking.

Al-Khwarizmi's works not only addressed the scientific needs of his time but also laid a solid theoretical foundation for subsequent centuries. His scientific perspectives remain relevant for modern mathematics, scientific methodology, and education. Therefore, studying al-Khwarizmi's legacy is not only a historical necessity but also an important scientific and methodological task.

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