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Ancient Indian Contributions to Mathematics

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Abstract- This paper explores the significant contributions of ancient Indian mathematicians from the Indus Valley civilization (3500 BCE) through the Islamic conquest, emphasizing their pioneering work in areas such as the decimal system, geometry, algebra, and trigonometry. Despite facing historical Eurocentric biases that have often overshadowed their achievements, ancient Indian scholars made invaluable contributions, including the invention of zero, early concepts of infinity, and significant advancements in astronomy and linguistic theories. Highlighting the need for a fresh and objective assessment, this paper aims to shed light on the profound impact of ancient Indian mathematics on the development of global mathematical knowledge.

Mathematics is a vast adventure of ideas. Its history reflects some of the noblest thoughts of countless generations. The civilizations of India and China are of greater antiquity than those of Greece and Rome, although not older than those in the Nile and Mesopotamian valleys.

Archaeological excavations at Mohenjo-daro and Harappa gave evidence of a highly cultured civilization in India earlier to and during the times of the building of pyramids in Egypt. Some (mathematical) writings were partly deciphered therein.

Sathapatha Brahmana, a part of *Shukla Yajurveda*, contains a detailed description of the geometry required for the construction of altars for the purpose of sacrifices. Sophisticated astronomical work is to be found in the text *Vedanga Jyothisha* of Lagada (12th Century BCE). The study of astronomy necessitated considerable development of mathematics in general and trigonometry, in particular.

In India, like Egypt, there were "rope stretchers," and the geometric knowledge acquired in connection with the construction of temples and altars for rituals and sacrifices took the form of a body of knowledge known widely as *Sulvasutras* or Rules of the Cord. Baudhayana, Manava, Apasthamba, and Katyayana were some of the famous *Sulvasutrakars* of the Sutra period stretching from 800 to 200 BCE. Baudhayana's works contain the well-known theorem attributed to Pythagoras of the fifth Century BCE. It is amazing to note that Baudhayana dealt with irrational numbers also.

The great teacher Buddha was active in India about the fifth Century BCE. Carl B. Boyer, a well-known historian of mathematics, writes that Pythagoras visited India during the times of Buddha and "learned his theorem from the Hindus." By the dawn of the fifth Century BCE, Jain mathematicians started their marvelous works. The concept of "Infinity" in mathematics found in Jaina mathematical works is very interesting, and they were evolved largely due to their ideas of cosmology. In the *Lalitha Visthara* (Sanskrit Buddhist text — 1st Century CE), mention is made of large numbers as found in Vedic lore also. It is hard to imagine that without a sound knowledge of the place value system, it would be impossible to think of such large numbers.

The importance of the place value decimal system of numeration was highlighted in the most befitting manner by the great mathematician of France, Laplace, in the following words: "It is India that gave us the ingenious method of expressing all numbers by means of ten symbols, each symbol receiving a value of position as well as an absolute value; a profound and important idea which appears so simple to us now that we ignore its true merit. But its very simplicity and the great ease which has lent to computations put the arithmetic in the first rank of useful inventions; and we shall appreciate the grandeur of the achievement the more when we remember that it escaped the genius of Archimedes and Apollonius, two of the greatest men produced by antiquity."

The next milestone after the sutra period is the Siddhanta period, the highlight of which was the *Panchasiddhantika* of Varahamihira (7th Century CE), which is a valuable compendium of the five Siddhantas: Surya, Romaka, Paulisa, Vasishta, and Paitamaha, a blend of Indian and Western astronomical thought. The Siddhanta period concludes with the seminal work *Mahasiddhanta* of Aryabhata II (10th Century).

A few of the leaders during the ancient and medieval periods were Aryabhata (5th and 6th Centuries), Varahmihira, Brahmagupta (7th Century), Bhaskara I (7th Century), Aryabhata II, Mahavira (9th Century), Bhaskaracharya (12th Century), and Madhava (14th Century) who contributed to the development of mathematics in a big way. Some of the famous centers which nourished the growth of the subject were Kusumapura, near present Patna, Ujjain, Manyakheta, and Mysore of Karnataka, and Sangamagrama of Kerala.

Starting from the Bakshali manuscript, the oldest extant mathematical document that was discovered in the year 1881, many manuscripts were unearthed. Even a small study of these leaves one with a sense of wonder at the depth and breadth of ancient Indian thoughts on mathematics. There is much that one can do in the field of ancient Indian mathematics.

The challenges are two-fold. First, there is the task of locating and identifying the manuscripts and of translating them into a language that is more familiar to present-day scholars. Second, there is the difficult task of interpreting the significance of these works vis a vis modern mathematics. Since much of the earlier work in this area was done with a Eurocentric perspective and interpretation, it is necessary to take a fresh and objective look.

The ancient Indian mathematicians enriched the subject over the ages by their outstanding contributions. From the times of the Indus Valley civilization (3500 B.C.E.) up to the times of Islamic conquest, Indian scientists and mathematicians were leaders in many different areas of knowledge. They stood singularly apart in mathematics. India takes a comfortable and secure place of legitimate pride with other ancient civilizations of the world: Egypt, China, Mesopotamia, and Greece.

It is surprising that in our universities and colleges, students, and teachers too in some cases, are not aware of the many notable achievements of our ancestors in the field of science in general and of mathematics in particular. The historians of science should share the blame as well, because of their reluctance to properly assess the quantum of contributions to science made by the ancient scholars of India. Perhaps, we are still haunted by the ghost of T.B. Macaulay (1800-1859), who designed a pattern of education for the British India to train "a class of persons, Indian in blood and color but English in taste, in opinion, in morals, and in intellect." Many a time, injustice has been meted out to and harm is perpetrated against the wisdom of our ancient scientists.

We can cite a number of instances; one would be enough for the present. Take, for example, the decimal system of numerals originated in India. In fact, when Arab scholars came to know about this system of numerals, they hailed them as the numbers from India. The Father of Algebra, al Khwarizme, in 825 C.E., wrote an essay on *The Calculation with Hindu Numerals*. Al Khwarizmi was the coordinating link between India and Arabic mathematics, one of those "irreplaceable men capable of facing in two directions at once." Abul Hasan Ahmed ibn Ibrahim al Uqlidisi (920-980 C.E.), an Arab mathematician, whose *Kitab al-fusul fi ah-hisab al-Hindi* (Chapters in Indian Mathematics) is an important known Arabic work discussing the positional use of the decimal system of numerals that the Arabs got from India.

Giving credit to India for inventing and to the Arabs for popularizing, historians started calling these numerals as Hindu-Arabic Numerals. In spite of the fact that the world acknowledges and recognizes the origins of the decimal system, there are scholars who still call these numbers as Arabic numerals, and a few in recent times went to the extent of labeling them as "eurobic" numerals. The world knows that during the 12th Century C.E., an enterprising Italian merchant and scholar, Fibonacci, took these numerals to Italy from Arab countries and popularized them in the whole of Europe. Therefore, should they be called "eurobic" numerals? It should be recalled what Fibonacci wrote: "compared to the method of Indians, all other methods are a mistake." This method of Indians is none other than our very simple arithmetic of addition, subtraction, multiplication, and division.

Famous scientists and men of letters hailed these decimal numerals as the greatest contribution by India to the onward march of human civilization. Laplace (1749-1827 C.E.), France, wrote: "It is India that gave us the ingenious method of expressing all numbers by the means of ten symbols, each symbol receiving a value of position, as well as an absolute value; a profound and important idea which appears so simple to us now that we ignore its true merit, but its very simplicity, the great ease which it has lent to all computations, puts our arithmetic in the first rank of useful inventions, and we shall appreciate the grandeur of this achievement when we remember that it escaped the genius of Archimedes and Apollonius, two of the greatest minds produced by antiquity."

Irfah (1992), France, said, "the measure of genius of Indian civilization to which we owe our modern [number] system, is all the greater in that it was the only one in all history to have achieved this triumph." He (1994) also wrote, "A thousand years ahead of Europeans, Indian Savants knew that zero and infinity were mutually inverse notions.” Bourbaki (1998), France, wrote, “modern mathematics was known during the medieval times as *Modus Indorium* or method of the Indians.” Bourbaki further added, “our decimal system which [by the agency of the Arabs] is derived from Hindu mathematics, where its use is attested already from the first century to our era.”

Famous historian of mathematics, F. Cajori wrote that he and others “suspect that Diophantus got his first glimpse of algebraic knowledge from India.” Albert Einstein (1879-1955 C.E.), U.S.A., said, “we owe a lot to Indians who taught us how to count, without which no worthwhile scientific discovery could have been made.” A.L. Basham (20th Century), Australia, said, “… the world owes most to India in the realm of mathematics… which was developed in the Gupta period, to a shape more advanced than that reached by other nations of antiquity.” Voltaire (18th Century), France, speaking on Indian mathematics and spiritualism said, “I am convinced that everything has come down to us from the banks of Ganga; Astronomy, Astrology, and Spiritualism. It is very important to note that 2500 years ago, at the least, Pythagoras went from Samos to the Ganga to learn Geometry.”

T. Dantzig (1884 – 1956), U.S.A, wrote, “the invention of zero will always stand out as one of the greatest simple achievements of the human race.” He further added, “Long period of nearly five thousand years…the history of reckoning presents a peculiar picture of desolate stagnation. When viewed in this light, the achievements of the unknown Hindu, who some time in the first centuries of our era discovered the principle of position, assumes the importance of a world event.”

The Indian place-system of numerals might have spread first to the nearby Persia and from there to the Arab land. In 662 CE, a Nestorian bishop living in what is now called Iraq said, “I will omit all discussion of the science of the Indians ... of their subtle discoveries in astronomy - discoveries that are more ingenious than those of the Greeks and the Babylonians - and of their valuable methods of calculation which surpass description. I wish only to say that this computation is done by means of nine signs. If those who believe that because they speak Greek they have arrived at the limits of science would read the Indian texts, they would be convinced even if a little late in the day that there are others who know something of value.”

G. Halstead said, “the importance of the creation of zero mark can never be exaggerated, giving to airy nothing, not merely a local habitation and a name, a picture, a symbol, but helpful power is the characteristic power of the Hindu race from whence it sprang. No single mathematical creation has been more potent for the general on go of intelligence and power.”

Indian mathematics has its roots in Vedic literature, which is about 4,000 years old. For example, in the anuvaka section of *Taittiriya Upanishad* of *Yajurveda*, we find a precise sequence of multiplication of numbers by 100. It shows without doubt that the Vedic scholars were comfortable with the usage of very large numbers. The earliest concept of a heliocentric model of the solar system, in which the sun is at the center of the system with the earth orbiting the sun, is found in the Vedic text.

The *Aithareya Brahmana* (8th Century BCE) states, “The sun never sets nor rises. When people think the sun is setting, it is not so, they are mistaken.”

The oldest mathematical manuscript written in Buddhist hybrid Sanskrit timed as belonging to early centuries of the common era, was discovered in 1881 in the village of Bakshali, now in Pakistan. The Bakshali manuscript also “employs a decimal place value system with a dot for zero.”

G.G. Joseph (1995), said that Indian contributions to mathematics in particular and other secular branches of knowledge in general have not been duly acknowledged by the historians by science. It is unfortunate that many discoveries and inventions of ancient Indian mathematicians were made known to Indian scholars through the writings of the western scholars! The Eurocentrism of our historians of science blinded their vision, and this has resulted in great injustice meted out to the scholars of India who were forerunners and trendsetters in a commendable way.

Jaina scholars of ancient India in the second half of the first millennium before the Christian era made signal contributions to science in general. They carry credit because they freed Indian mathematics from religion and rituals, a significant development indeed. In particular, their fascination with enumeration of very large numbers and various levels of infinity was marvelous. They classified the numbers as enumerable, innumerable, and infinity. They could conceive five different kinds of infinities, 2000 years before Cantor.

The theorem now known as the Pythagoras Theorem (500 B.C.E.) is recorded in the writings of Baudhayana (800 B.C.E.) in his *Sulba Sutras*. Baudhayana gave a value for $\sqrt{2}$ as: $\sqrt{2} = 1 + (1/3) + (1/3.4) - (1/3.4.34) \approx 1.4142156\ldots$

Pingala (300-2000 B.C.E) stumbled upon both the binomial coefficients and the Pascal triangle (*Meruprastara*). His work *Chandahsastra* contains basic ideas of Fibonacci (12th Century C.E.) numbers called *Maatrameru*. We find in Pingala a system of binary enumeration. Pingala used binary numbers to classify Vedic metres. Barend Van Nooten (1993) has shown that the binary numbers were known at the time of Pingala’s *Chandahsastra*.

Panini (400 B.C.E.) in his *Ashtadyayi* discussed most scientifically the linguistic theories found by modern linguists, and this was just based on his 4,000 sutras or aphorisms. He raised the whole structure of the Sanskrit language by making use of highly sophisticated scientific notation. His grammar includes early use of “Boolean logic, of the null operators and of context-free grammars and includes a precursor of the Backus – Naur form, now used in processing languages,” in computer technology.

The mathematical world knows that Aryabhata I (499 C.E.) gave a value for π as 3.1416. He did not agree with the widely held doctrines of his contemporary times about eclipses and also about the Geocentric Theory. He did not subscribe to the view that eclipses were caused by Rahu. They are caused by the Earth’s shadow over the moon or the moon’s shadow over the Earth. As early as the 6th Century, he wrote about the diurnal motion of the Earth and the relative motion of the sun, many centuries before Copernicus (1473-1543).

Hugh Thurston wrote, “Not only did Aryabhata believe that the Earth rotates, but there are glimmerings in his system of a possible underlying theory in which the Earth (and the planets) orbits the sun rather than the sun orbiting the Earth." That Aryabhata was aware of the relative motion is clear from the following passage taken from his writings: "Just as a man in a boat sees the trees on the bank moving backwards, so an observer on the Earth sees the fixed stars moving westwards."

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