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Ancient Indian Mathematicians and Their Contributions

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Abstract:

Indian mathematics emerged in the Indian subcontinent from 1200 BC until the end of the 18th century. In the classical period of Indian mathematics (400 AD to 1200 AD), important contributions were made by scholars like Aryabhata, Brahmagupta, Bhaskara II, Ramanujan, and Shakuntaladevi. The decimal number system in use today was first recorded in Indian mathematics. Indian mathematicians made early contributions to the study of the concept of zero as a number, negative numbers, arithmetic, and algebra. In addition, trigonometry was further advanced in India, and, in particular, the modern definitions of sine and cosine were developed there. These mathematical concepts were transmitted to the Middle East, China, and Europe and led to further developments that now form the foundations of many areas of mathematics.

Many of the Vedic texts give details about some of the geometric constructions which were used during the Vedic Age. Besides the Vedic texts and the Sulabasutras also gave enough details about the geometric constructions those were used in the ancient age. Although during this period mathematics was mostly used for solving practical problems but at the same time there was a little development in the field of algebra.

Many of the developments of Indian mathematics remain almost completely ignored, or worse, attributed to scholars of other nationalities, often European. However a few historians (mainly European) are reluctant to acknowledge the contributions of Indian mathematicians. They believe Indians borrowed the knowledge of mathematics from Greeks. In this article author has written the significant of Indian mathematicians' brief

history and their contributions.

APASTAMBA (About 600 BC - about 540 BC)

- Āpastamba is from a family of Brahmins of the Taittirīya branch Vedic school dedicated to the study of the Black Yajurveda. It is believed that the entire Kalpasūtra was written by Āpastamba
- The Dharmasūtra was written (approximate date) between 450-350 BC
- The Dharmasutra of Āpastamba forms a part of the larger Kalpasūtra of Āpastamba. It contains thirty praśnas, which literally means 'questions' or books. These praśanas consist of the Śrautasūtra followed by Mantrapāṭha which is used in domestic rites and is a collection of ritual formulas, the Gṛhyasūtra which deals with domestic rituals and lastly the Śulvasūtra which are principles of geometry needed for Vedic Rituals.

BAUDHAYANA (About 800 BC - about 740 BC)

He was neither a mathematician in the sense that we would understand it today, nor a scribe who simply copied manuscripts like Ahmes. He would certainly have been a man of very considerable learning but probably not interested in mathematics for its own sake, merely interested in using it for religious purposes. Undoubtedly he wrote the Sulbasutra to provide rules for religious rites and it would appear an almost certainty that Baudhayana himself would be a Vedic priest.

The mathematics given in the Sulbasutras is there to enable the accurate construction of altars needed for sacrifices. It is clear from the writing that Baudhayana, as well as being a priest, must have been a skilled craftsman. He must have been himself skilled in the practical use of the mathematics he described as a craftsman who himself constructed sacrificial altars of the highest quality.

The Sulbasutras are discussed in detail in the article Indian Sulbasutras. Below we give one or two details of Baudhayana's Sulbasutra, which contained three chapters, which is the oldest which we possess and, it would be fair to say, one of the two most important.

The Sulbasutra of Baudhayana contains geometric solutions (but not algebraic ones) of a linear equation in a single unknown. Quadratic equations of the forms $ax^2 = c$

and $ax^2 + bx = c$ appear.

Several values of π occur in Baudhayana's Sulbasutra since when giving different constructions Baudhayana uses different approximations for constructing circular shapes. Constructions are given which are equivalent to taking π equal to $^{676}/_{225}$ (where $^{676}/_{225}$ = 3.004), $^{900}/_{289}$ (where $^{900}/_{289}$ = 3.114) and to $^{1156}/_{361}$ (where $^{1156}/_{361}$ = 3.202). None of these is particularly accurate but, in the context of constructing altars they would not lead to noticeable errors.

An interesting, and quite accurate, approximate value for √2 is given in Chapter 1 verse 61 of Baudhayana's Sulbasutra. The Sanskrit text gives in words what we would write in symbols as $\sqrt{2} = 1 + {}^{1}/_{3} + {}^{1}/_{(3\times4)} - {}^{1}/_{(3\times4\times34)} = {}^{577}/_{408}$

Which is, to nine places, 1.414215686. This gives √2 correct to five decimal places. This is surprising since, as we mentioned above, great mathematical accuracy did not seem necessary for the building work described. If the approximation was given as

$\sqrt{2} = 1 + {}^{1}/_{3} + {}^{1}/_{(3\times4)}$

Then the error is of the order of 0.002 which is still more accurate than any of the valuesof π.

ARYABHATA (476—550AD)

Aryabhata from ancient history was actually the first person to figure out that earth was spherical and revolved around the sun, thereby discovering the nine planets and calculating the correct number of days in a year were 365. Therefore it wouldn’t be wrong to call him a scientist and an astronomer as well, as far back as the time and mythology suggests. Aryabhatta was born in Kerala and lived from 476 AD to 550 AD, he completed his education from the ancient university of Nalanda and later he moved to Bihar and continued his studies in the great centre of learning located in close proximity to Kusumapura in Bihar and lived in Taregana District in Bihar in the late 5th and early 6th century.

His contribution to the astronomy

The astronomical calculations and deductions suggested by Aryabhatta are extraordinary by the fact that he didn’t have any modern equipment or instrument to do it. He had a very sharp brain and his dedication and hard work led him to solve the various mysteries of the solar system. He also deduced that the earth is round in shape and rotates along its own axis, which forms the existence of day and night. Many superstitious beliefs were challenged by him and he presented scientific reasons to prove them wrong.

He also said that the moon has no light and shines because it reflects light from the sun. He also proved wrong the false belief that eclipse is caused because of the shadows formed by the shadows cast by the earth and the moon. Aryabhatta used epicycles in a similar manner to the Greek Philosopher Ptolemy to illustrate the inconsistent movement of some planets. This great astronomer wrote the famous treatise Aryabhatiya, which was based on astronomy in 499 AD. This treatise was acknowledged as a masterpiece. In honour of this excellent work Aryabhatta was made head of the Nalanda University by the Gupta ruler Buddhagupta.

Aryabhatiya – a treatise that solved various mysteries related to astronomy Aryabhatiya is a treatise that includes various facts related to Hindu mathematics and astronomy that appeared during those times. The treatise comprises of four chapters that are concerned with sine tables and astronomical constants. It also comprises of rules to calculate the longitudes of the planets by utilizing epicycles and eccentrics and also the rules related to trigonometry and calculation of eclipses. There is a ganita section in the Aryabhatiya, which include various innovative methods for calculating the lengths of the chords of circles by using the half chord method unlike the Greekswho used the full chord method.

Contribution in the approximation of pi

Aryabhatta is among the mathematicians who brought new deductions and theories in mathematics and astronomy. His contribution to the mathematics is unmatched and cannot be ignored, as he was the one who deduced the approximate value of pi, which he found it to be 3.14. He also derived the correct formulas for calculating the areas of triangles and circles. He also played a very important role in the formation of the tableof Sines.

His role in the place value system

He also played a very major role in determining the place value system and discovering the zero. He also worked on the summation series of square roots and cube roots. He is also regarded as the first to use zero in the place value system. He also calculated the sidereal rotation, which is the rotation of the earth in relation to the fixed stars. His theories and deductions formed the base of the trigonometry and algebra.

For his extraordinary works and contributions to mathematics and astronomy, India's first satellite was named as Aryabhatta. Aryabhatta Research Institute of Observational Sciences near Nainital and the Aryabhatta Knowledge University in Patna, in India are also named after him.

Aryabhata given the formula for area of a triangle .He also discussed the concept of sine in his work by the name of ardhajya. If we use Aryabhata's table & calculate the value of $\sin 30^0$ which is 1719/3438=0.5.,the value is correct. His alphabetic code is commonly known as the Aryabhata cipher.

He gave the formula $(a+b)^2 = a^2 + b^2 + 2ab$.

He taught the method of solving the following problems:

$1+2+3+ \ldots\ldots\ldots + n = n(n+1)/2$

$1^2 + 2^2 + 3^2 + \ldots\ldots\ldots + n^2 = n(n+1)(2n+1)/6$

$1^3 + 2^3 + 3^3 + \ldots\ldots\ldots + n^3 = (n(n+1)/2)^2$

BRAHMAGUPT (598-668 AD)

Brahmagupta was an Indian mathematician, born in 598 AD in Bhinmal, a state of Rajhastan, India. He spent most of his life in Bhinmal which was under the rule of King Vyaghramukha. He was the head of the astronomical observatory at Ujjain which was the center of mathematics in India witnessing the work of many extraordinary mathematicians.

Brahmagupta wrote many textbooks for mathematics and astronomy while he was in Ujjain. These include 'Durkeamynarda' (672), 'Khandakhadyaka' (665), 'Brahmasphutasiddhanta' (628) and 'Cadamakela' (624). The 'Brahmasphutasiddhanta' meaning the 'Corrected Treatise of Brahma' is one of his well-known works. It contains a lot of criticism on the work of his rival mathematicians.

Brahmagupta had many discrepancies with his fellow mathematicians and most of the chapters of this book talked about the loopholes in their theories.

Contributions to Mathematics

One of the most significant input of Brahmagupta to mathematics was the introduction of 'zero' to the number system which stood for 'nothing'. His work the 'Brahmasphutasiddhanta' contained many mathematical findings written in verse form. It had many rules of arithmetic which is part of the mathematical solutions now. These are 'A positive number multiplied by a positive number is positive.', 'A positive number multiplied by a negative number is negative', 'A negative number multiplied by a positive number is negative' and 'A negative number multiplied by a negative number is positive'. The book also consisted of many geometrical theories like the 'Pythagorean Theorem' for a right angle triangle. Brahmagupta was the one to give the area of a triangle and the important rules of trigonometry such as values of the sin function. He introduced the formula for cyclic quadrilaterals. He also gave the value of 'Pi' as square root ten to be accurate and 3 as the practical value. Additionally he introduced the concept of negative numbers.

The major contribution of Brahmagupta in maths was -

How to use zero in mathematical calculations that is used as base to calculate every field. He has formed the set of rules in the mathematics for positive and negative number in addition to forming the rules for using zeros in calculations and that has become the basis of mathematics and rest of the field including economics, finance, physics, chemistry, astronomy etc.

Brahmagupta gave the solution of the general linear equation which is $bx + c = dx + e$ equivalent to

$x = (e-c)/ (b-d)$.

Contribution to Science and Astronomy

Brahmagupta argued that the Earth and the universe are round and not flat. He was the first to use mathematics to predict the positions of the planets, the timings of the lunar and solar eclipses. Though all this seems like obvious and simple solutions it was a major improvement in science at that time. He also calculated the length of the solar year which was 365 days, 5 minutes and 19 seconds which is quite accurate based on today's calculation of 365 days, 5 hours and 19 seconds. He also talked about 'gravity' in one of his statements saying: 'Bodies fall towards the earth as it is in the nature of the earth to attract bodies, just as it is in the nature of water to flow'.

BHASKARACHARYA (1114-1185 AD)

He was born in Bijapur in modern Karnataka. He & his work represent a significant contribution to mathematical & astronomical knowledge in the 12th century. His main work "Siddhanta Shiromani" is divided into four parts called Lilawati, Bijaganit, Grahaganita and Goladhyaya.

Bhaskaracharya otherwise known as Bhaskara II was one of the most powerful and creative mathematicians of ancient India. He was also known as Bhaskara the Learned. He was born in 1114 AD in Vijayapura. His father, Mahesvara, himself was a famous astrologer. In many ways Bhaskaracharya represents the peak of mathematical knowledge of 12th century. He was the head of the astronomical observatory at Ujjain.**Bhaskara – Books**

There are six well known works of Bhaskaracharya. They are

- Lilavathi – Mathematics
- Bijaganita – Algebra
- Siddhantasiromani – first part mathematical astronomy and second part sphere
- Vasanabhasya
- Karanakutuhala
- Vivarana

However, among the six works of Bhaskaracharya, the first three are more interesting from the point of view of mathematics.

1. Lilavathi contains 13 chapters and covers topics such as Définition, Mathematical terms, Interest, Arithmetical progression and Geometrical progression, Plane geometry, Solid geometry, Shadow of the gnomon, Kuttaka and combinations.
2. Bijaganita contains 12 chapters and covers topics like as Positive and negative numbers, Zero, Surds, the kuttaka , Indeterminate quadratic equation with more than one unknown, Quadratic equation with more than one unknown , Operations with products of several unknown.
3. Siddhantasironmani is a mathematical astronomy book compiled in two parts. First part contains twelve chapters dealing with topics such as Longitudes of the planets, True longitudes of the planets, 3 problems of decimal rotation, syzygies, Lunar eclipse, Solar eclipse, Latitudes of the planets, Rising and setting, Moon's crescent, Conjunction of the planets, The pates of sun and moon. Second part of siddhantasiromani contains 13 chapters on the sphere. The topics such as: Praise of study of the sphere, Nature of the sphere, Cosmography and geography, Planetary mean motion, Eccentric epicyclic model, The armillary sphere, Spherical trigonometry, Ellipse calculations, First visibilities of planets, Calculating the lunar crescents, Astronomical instruments, Problems of astronomical calculations

Contributions: Negative Numbers

- Bhaskaracharya was known for his treatment of negative numbers with he considered as debts or losses, and also for his treatise on arithmetic and measurement.
- Bhaskaracharya also handled efficiently arithmetic involving negative numbers.
- In Bijaganita placing a dot above them denotes negative numbers.

Infinity & Zero

- He for the first time brought the idea of infinity while dividing a number by zero.

Zero rules

- He was sound in addition, subtraction and multiplication involving zero but realized that there were problems with Brahmagupta's idea of dividing by zero.A + 0 = A
  A – 0 = AA x 0 = 0
- He understood about zero and negative numbers and he knew that $x^2 = 9$ had two solutions.

Progression

- He was aware of arithmetical and geometrical progression and explainsexamples.

Sphere

- He found formula for finding the area and volume of sphere given below: Area of sphere = 4 x area of a circle.
- Volume of a sphere = area of a sphere x 1/6 of its diameter.

Trigonometry

- He seems more interested in trigonometry. Among the many interesting results given by bhaskaracharya are: sin (a + b) = sin a cos b + cos a sin b
  And sin (a - b) = sin a cos b - cos a sin b.

Lilavati

- Bhaskaracharya gave two methods of multiplication in Lilavati.
- It is argued that zero used by bhaskaracharya, in his rule (a.0)/0 = a given in Lilavathi, is equivalent to the modern concept of a non-zero "infinitesimal".

Other works

- He has used the kuttaka method of solving indeterminate equations.

- He had explained the concepts of permutation combination with examples.
- In differential calculus he was the first mathematician who presented examples related to differential coefficient.
- He originated the fundamentals of Rolle's Theorem.
- He knew about inverse proportions and rule of the three.

Bhaskaracharya's innumerable contribution had earned him an outstanding position among the ancient Hindu mathematicians.

RAMANUJAN (1887-1920)

Ramanujan the mathematical genius taught himself math after he dropped out of high school due to his failure in the English subject. He is most famously known for his contribution in analytical theory of numbers, elliptic functions, continued fractions and infinite series. He was also invited to England on his set of 120 theorems that he sent to Cambridge. He further made many mathematical demonstrations in his lifetime, all of which are beyond the scope of this article. He taught a greater valuable lesson, that failure isn't permanent as he did not let his failure bring him down and continued to teach himself mathematics, which he was passionate about. He has been the inspiration of many mathematicians, not just in India but all over the world.

Ramanujan showed that any big number can be written as sum of not more than four prime numbers. He showed that how to divide the number into two or more squares or cubes, when Mr Litlewood came to see Ramanujan in taxi number 1729, Ramanujan said that 1729 is the smallest number which can be written in the form of sum of cubes of two numbers in two ways,

i.e. $1729 = 9^3 + 10^3 = 1^3 + 12^3$ since then the number 1729 is called Ramanujan'snumber.

In the third century B.C, Archimedes noted that the ratio of circumference of a circle to its diameter is constant. The ratio is now called 'pi (Π)' (the 16th letter in the Greek alphabet series) The largest numbers the Greeks and the Romans used were 106 whereas Hindus used numbers as big as 1053 with specific names as early as 5000 B.C.during the Vedic period.

Contribution to Mathematics

His chief contribution in mathematics lies mainly in analysis, game theory and infinite series. He made in depth analysis in order to solve various mathematical problems by bringing to light new and novel ideas that gave impetus to progress of game theory. Such was his mathematical genius that he discovered his own theorems. It was because of his keen insight and natural intelligence that he came up with infiniteseries for π

$$\frac{1}{\pi} = \frac{2\sqrt{2}}{9801} \sum_{k=0}^{\infty} \frac{(4k)!(1103 + 26390k)}{(k!)^4 396^{4k}}.$$

This series made up the basis of certain algorithms that are used today. One such remarkable instance is when he solved the bivariate problem of his roommate at spur of moment with a novel answer that solved the whole class of problems through continued fraction. Besides that he also led to draw some formerly unknown identities such as by linking coefficients of and providing identities for hyperbolic secant.

He also described in detail the mock theta function, a concept of mock modular form in mathematics. Initially, this concept remained an enigma but now it has been identified as holomorphic parts of mass forms. His numerous assertions in mathematics or concepts opened up new vistas of mathematical research for instance his conjecture of size of tau function that has distinct modular form in theory of modular forms. His papers became an inspiration with later mathematicians such as G. N. Watson, B. M. Wilson and Bruce Berndt to explore what Ramanujan discovered and to refine his work. His contribution towards development of mathematics particularly game theory remains unrivaled as it was based upon pure natural talent and enthusiasm. In recognition of his achievements, his birth date 22 December is celebrated in India as Mathematics Day. It would not be wrong to assume that he was first Indian mathematician who gained acknowledgment only because of his innate genius and talent.

His Publications

It was after his first publication in the "Journal of the Indian Mathematical Society" that he gained recognition as genius mathematician. With collaboration of English mathematician G. H. Hardy, with whom he came in contact with during his visit to England, he brought forward his divergent series that later stimulated research in that given area thus refining the contribution of Ramanujan. Both also worked on new asymptotic formula that gave rise to method of analytical number theory also calledas "Circle Method" in mathematics.

It was during his visit to England that he got worldwide recognition after publication of his mathematical work in European journals. He also achieved the distinction of becoming second Indian, who was elected as Fellow of Royal Society of London in 1918.

SHAKUNTALA DEVI

She was born in 1939. She is an Indian calculating prodigy. She was an Indian writer and mathematical genius popularly known as the "human computer". She was reputed to make complicated mathematical calculations in her head and effortlessly speak out the results! Born into an impoverished family in southern India as the daughter of a circus performer, she started displaying her skills at an early age. Her father recognized her as a child prodigy and took her on road shows where she displayed her ability at calculation. What was really amazing about the young girl's mathematical prowess was that she did not receive any formal education owing to her family's financial situation, yet emerged to be one of the most brilliant mathematical minds of her time. Her phenomenal ability to perform the most complicated mathematical calculations without the aid of any technological device gained her much fame and she eventually became an international phenomenon. Arthur Jensen, a professor of psychology at the University of California, Berkeley, tested and studied her abilities and published his findings in the academic journal 'Intelligence'. Her extraordinary abilities also earned her a place in the 1982 edition of 'The Guinness Book of World Records'. In addition, she was also a well-known author of children's books as well as works on mathematics, puzzles, and astrology.

With time she became an internationally known name and she moved to London with her father in 1944. She travelled widely all over the world and demonstrated her skills in several countries including the United States, Hong Kong, Japan, Sri Lanka, Italy, Canada, Russia, France, Spain, Mauritius, Indonesia and Malaysia.

In 1955, she appeared on a BBC show where the host Leslie Mitchell gave her a complex math problem to solve. She solved it in seconds but the host told her that her answer was incorrect as her answer was different from what the host and his team hadcalculated.

Mitchell then rechecked the answer and realized that Devi's answer was the correct one and the original answer was wrong. This news spread across the world and Shakuntala earned the title of the 'Human Computer'.

She was often invited by educational institutions and in 1977 she visited the Southern Methodist University in Dallas, USA. There she was asked to calculate the 23rd root of a 201-digit number, which she solved in 50 seconds. It had taken four minutes for a professor to write the problem on the board, and it took more than a minute for a Univac computer to solve it.

She was also a successful astrologer and authored several books on the subject. In addition she also wrote texts on mathematics for children and puzzles. One of her most significant books was ‘The World of Homosexuals’ (1977) which is the first comprehensive study of homosexuality in India. The realization that her husband was a homosexual had made her look at homosexuality more closely.

Major Works

Shakuntala Devi is best remembered for demonstrating the multiplication of two randomly picked 13-digit numbers—7,686,369,774,870 × 2,465,099,745,779 on 18 June 1980. She correctly gave the answer as 18,947,668,177,995,426,462,773,730 in 28 seconds. This unbelievable feat of hers earned her a place in the ‘Guinness Book ofRecords’ in 1982.

Awards & achievements

- In 1969 she was awarded the title of the 'Most Distinguished Woman of the Year' by the University of Philippines.
- She received the 'Ramanujan Mathematical Genius' Award in Washington D.C in 1988.

Dattatreya Ramchandra Kaprekar (1905–1986)

He was an Indian recreational mathematician who described several classes of natural numbers including the Kaprekar, Harshad and Self numbers and discovered the Kaprekar constant, named after him. Despite having no formal postgraduate training and working as a school teacher, he published extensively and became well known in recreational mathematics circles.

He attended the University of Mumbai, receiving his bachelor's degree in 1929. Having never received any formal postgraduate training, for his entire career (1930–1962) he was a school teacher at Nashik in Maharashtra, India. He published extensively, writing about such topics as recurring decimals, magic squares, and integers with special properties. He is also known as "Ganitanand".

Kaprekar constant

In 1949, Kaprekar discovered an interesting property of the number 6174, which was subsequently named the Kaprekar constant. He showed that 6174 is reached in the limit as one repeatedly subtracts the highest and lowest numbers that can be constructed from a set of four digits that are not all identical. Thus, starting with 1234, we have:

4321 − 1234 = 3087, then

8730 − 0378 = 8352, and

8532 − 2358 = 6174.

Repeating from this point onward leaves the same number (7641 − 1467 = 6174). In general, when the operation converges it does so in at most seven iterations.

A similar constant for 3 digits is 495. However, in base 10 a single such constant only exists for numbers of 3 or 4 digits; for other digit lengths or bases other than 10, the Kaprekar's routine algorithm described above may in general terminate in multiple different constants or repeated cycles, depending on the starting value.

Kaprekar number

Another class of numbers Kaprekar described are the Kaprekar numbers. A Kaprekar number is a positive integer with the property that if it is squared, then its representation can be partitioned into two positive integer parts whose sum is equal to the original number (e.g. 45, since 45^2=2025, and 20+25=45, also 9, 55, 99 etc.) However, note the restriction that the two numbers are positive; for example, 100 is not a Kaprekar number even though 100^2=10000, and 100+00 = 100. This operation, of taking the rightmost digits of a square, and adding it to the integer formed by the leftmost digits, is known as the Kaprekar operation.

Some examples of Kaprekar numbers in base 10, besides the numbers 9, 99, 999 … are (sequence A006886 in the OEIS):

Number	Square	Decomposition
703	703^2 = 494209	494+209 = 703
2728	2728^2 = 7441984	744+1984 = 2728
5292	5292^2 = 28005264	28+005264 = 5292
857143	857143^2 = 734694122449	734694+122449 = 857143

CONCLUSIONS:

The conclusion of Mathematicians of India or from outside is that the mathematicians had given a way to all of us to solve the mathematics by using their formulas, theorems, postulates and many more tricks. They had done many things for us to create our future with math because it is a straight way, if you go long you will reach early and safely.

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