A Brief History of Ancient Indian Mathematics (part II)

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(India's Romance with Numbers)

A Brief History of Ancient Indian Mathematics (part I)**?**

Bhaskar I continued where Aryabhatta left off, and discussed in further detail topics such as the longitudes of the planets; conjunctions of the planets with each other and with bright stars; risings and settings of the planets; and the lunar crescent. Again, these studies required still more advanced mathematics and Bhaskar I expanded on the trigonometric equations provided by Aryabhatta, and like Aryabhatta correctly assessed pi (pi) to be an irrational number. Amongst his most important contributions was his formula for calculating the sine function which was 99% accurate. He also did pioneering work on indeterminate equations and considered for the first time quadrilaterals with all the four sides unequal and none of the opposite sides parallel.

Another important astronomer/mathematician was Varahamira (6th C, Ujjain) who compiled previously written texts on astronomy and made important additions to Aryabhatta's trigonometric formulas. His works on permutations and combinations complemented what had been previously achieved by Jain mathematicians and provided a method of calculation of n-C-r that closely resembles the much more recent Pascal's Triangle. In the 7th century, Brahmagupta (born 598) did important work in enumerating the basic principles of algebra. In 628 he wrote his Brahma-sphuta-siddhanta ("The Revised System of Brahma"). In addition to listing the algebraic properties of zero, he also listed the algebraic properties of negative numbers and used these signs for addition, subtraction and multiplication (+, -, x). He was the first to postulate that, "The multiplication of a positive number with a negative number comes out to be a negative number. Further when a positive number is divided by a negative number or a negative number is divided by a positive number the result is a negative number."

His work on solutions to quadratic indeterminate equations anticipated the work of Euler and Lagrange. It is a sobering thought that even eight hundred years later European mathematics would be struggling to cope with the use of negative numbers and of zero. More than that, he made other major contributions to the understanding of integer solutions to indeterminate equations and to interpolation formulas invented to aid the computation of sine tables. Although almost all ancient countries used quantities of unknown values for solution of problems, the expansion of Algebra (Biz Ganit) became possible only when Indians realized that all the calculations of Numerical Mathematics could be done by notations, and for the first time used Sanskrit Alphabet to denote unknown quantities.

Brahmagupta is also credited with the following:

* To give the general solution to the quadratic equation $ax^{2}+bx+c=0$ in the form:

$$x=\frac{-b \pm \sqrt(b^{2}-4ac)}{2a}.$$

- To give an alternate proof of the Pythagorean Theorem by calculating the same area in two different ways and then canceling out terms to get a² + b² = c².

Developments also took place in applied mathematics such as in creation of trigonometric tables and measurement units. Yativrsabha's work Tiloyapannatti (6th C) gives various units for measuring distances and time and also describes the system of infinite time measures.

Aryabhatta's equations were elaborated on by Manjula (10th C) and Bhaskaracharya (12th C) who derived the differential of the sine function. Later mathematicians used their intuitive understanding of integration in deriving the areas of curved surfaces and the volumes enclosed by them.

Between the 7th C and the 11th C, Indian numerals developed into their modern form, and along with the symbols denoting various mathematical functions eventually became the foundation stones of modern mathematical notation.

The study of original mathematics in India slowed down after 8th century. This was also the time when Buddhism started to decline in India. The onslaught of the Islamic invasions in the twelfth century gave a great blow to Buddhism and basically expelled Buddhism out of India. Since that time, India may be said to undergo a period of Dark Age. During this period, secular studies in mathematics suffered greatly. During this time, the main center of studies in mathematics also gradually shifted to south India.

But this was also the time when Indian mathematical texts were increasingly being translated into Arabic and Persian. The last notable Indian mathematician may be said to be Bhaskaracharya who came from a long-line of mathematicians and was head of the astronomical observatory at Ujjain. He left several important mathematical texts including the Lilavati, Bijaganita and the Siddhanta Shiromani, an astronomical text. He is however more popularly known today for his book, Lilavati which is a unique book which shows how mathematics was brought to the reach of the common people. It is a collection of worked out examples of arithmetic, algebra, geometry, and mensuration. The language is written in Sanskrit verse, and the level of mathematics ranges between high school algebra to pre-Calculus. In its time, it represented the height of 12th-century mathematics. The problems are generally addressed to one Lilavati, traditionally taken to be either his wife or his daughter. Reading Lilavati, any reader will find that learning mathematics can be fun which also flourishes in wonder.

A typical problem reads, "O deer eyed one! Tell me if one sixth of the number of bees in a colony entered a jasmine flower tree, one-third went to kadamba tree, one fourth flew to a mango tree, one-fifth went to a tree blooming with sampaka flowers, one-thirtieth went to a beautiful bed of lotuses bloomed by the Sun's rays and if the remaining one bee was roving about, how many total bees were there in the colony?"

This is a problem of unknown quantity which is solved by now a days by assuming X for the unknown quantity. In this case, the problem resolves to

(X) – (X/6) – (X/3) – (X/4) – (X/5) – (X/30) = 1; or, (X/60) =1; or, X = 60

There were also problems that excite real passion for mathematics. Note the following verse:

Whilst making love, a necklace broke.

A row of pearls mislaid.

One third fell to the floor.

One fifth upon the bed.

The young woman saved one sixth of them.

One tenth were caught by her lover.

If six pearls remained upon the string

How many pearls were there altogether?

This is another problem of finding the unknown number. The modern way of solving is to assume X for the unknown number. Then the problem can be written as:

(X) - (X/3) – (X/5) – (X/6) – (X/10) = 6; or X (30-10-6-5-3) / 30 = 6; or (6X) / 30 = 6; or X = 30

Another problem describes as "A flock of swans contained total x^{2} members. As clouds gathered, (10x) of these went to Manasa lake, and (1/8 x^{2}) flew away to a garden. The remaining three couples played about in the water. O young woman, how many swans were there in that lake full of beautiful lotuses?"

This is a problem of quadratic equation which can be written as:

$(X^{2})-(10X)-(\frac{X^{2}}{8})=6$; the problem is solved for X = 31; which makes the number of swans to be $X^{2}=961.$

Another problem that deals higher mathematics runs like this: "Dear Lilavaty, Suppose different kinds of Chatnies are made by mixing 1, 2, 3, 4, 5 or 6 at a time from six substances which are respectively sweet, bitter, astringent, sour, salty and hot. O, my pretty mathematician, tell me how many different Chatnies can be prepared from these all?"

This is a problem of Combination which can be solved by the formula for Combination of n things taken 1, 2, 3 … r things at a time. The formula is: n-C-r = n! / [r! (n-r)!] (Where n is the total number of things taken r things at a time).

The solution is: = n!/0!(n!), n!/1!(n-1)!, n!/2!(n-2)!, n!/3!(n-3)!,….n!/n!(n-n)!

= 6!/0!(6!), 6!/1!(5!), 6!/2!(4!), 6!/3!(3!), 6!/4!(2!), 6!/5!(1!), 6!/6!(0!)

= 1, 6, 15, 20, 15, 6, 1 = 64, the total number of different chatnies that can be made.

[In the above, [n! is called factorial n; example, Factorial 3!=3.2.1=6] The answers also can be found from modern day Pascal's Triangle which was used by ancient Indian mathematicians and was known as Khandmeru.

The lucid, scholarly and literary presentation in Lilavaty has attracted several cultural areas. The graphic descriptions of a drove of swans; a flock of elephants; a colony of bees; the attack of a snake by a domesticated peacock; sinking of a lotus in water owing to strong wind; and many others were to train the students not only in mathematics but also in appreciation of nature. No wonder that Lilavati has not only been used widely in India in the medieval times as a standard base text-book for about 800 years, but it was commented and translated into several languages of the world.

Besides that, like poetry, mathematics has a beauty and truth, and can be enjoyed as such. Plato once said, "Arithmetic has a very great elevating effect, compelling the soul to reason about abstract numbers refusing to be satisfied visible and tangible objects." The joy of mathematics is similar to the experience of discovering something new for the first time. In Lilavaty, Bhaskara showed that he was not only a great mathematician but was also a great poet who may be compared to Omar Khayyam. His conclusion to Lilavati states: "Joy and happiness is indeed ever increasing in this world for those who have Lilavati clasped to their throats." Overall, Bhaskaracharya?s Lilavati proves the point that Indians had great romance with mathematics and that it is very much ingrained in the Indian culture. The creation of a book like Lilavaty was possible in India because of its long tradition of culture with mathematics; one will not find such book in any other civilization.

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[This article is contributed by our Adviser Mr. Rajen Barua. Rajen Barua is an engineer by profession and a writer by passion. Barua lives in Houston, Texas and can be reached through email: rajenbarua@gmail.com]

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