

Indian Contribution to Science and Technology- Ancient to Middle age periods : A glimpse

Prof. V. P. N. Nampoori

International School of Photonics

Cochin University of Science & Technology

I. Numbers – How Large and How Small?

Indian contributions to science and technology date back to antiquity. Human interactions with the external world necessitated the treatment of large and small numbers. For example duration of a yuga or the size of an atom demanded numbers of unimaginable magnitude. It was the time when the Greeks did not have number-names beyond myriad (10^4 – then thousand) while Romans did not go beyond Mille (thousand). Indians described numbers to the power of ten systematically attributing names to each. These names appear in old texts like Vedas, uanishads, puranas etc. Ofcourse there seems to have no unique names for some large numbers. Yajurveda, and thaittiriya upanishads describes following numbers in powers of ten:

Ekam	1	10^0
Dasam	10	10^1
Satham	100	10^2
Sahasram	1000	10^3
Ayutham	10,000	10^4
Niyutham	100,000	10^5
Prayutham	1000,000	10^6
Arbudam	10,000,000	10^7
Niarbudam	100,000,000	10^8
Samudram	1000,000,000	10^9
Madhyam	10,000,000,000	10^{10}
Anthyam	100,000,000,000	10^{11}

Pancavimsa Brahmana uses names nikharvam, vadavam and akshiti after niarbudam. Samkyana Sutra attributes names nikharvam, samudram, salilam, anthyam and anantham after niarbudam. In the Indian Epic Ramayana Suka, the spy of Ravana, describes the size of Rama's army as

$$10^{10} + 10^{14} + 10^{20} + 10^{24} + 10^{30} + 10^{34} + 10^{40} + 10^{44} + 10^{52} + 10^{57} + 10^{62} + 5 \text{ men !}$$

In Lalithavisthara, a Buddhist text , Bodhisatva recites numbers as powers of hundreds beyond koti (One crore , 10 million) as follows:

100 koti	=	1 ayutham
100 ayutham	=	1 niyutham
100 niyutham	=	1 kunkaram
100 kunkaram	=	1 vivaram
100 vivaram	=	1 kshobhyam
100 kshobhaym	=	1 vivaham

the number 1 vivaham will be 10^{19} or 19 zeros after 1! Lalithavisthara goes on giving names to still higher numbers beyond vivaham as ulsangam, bahulam, nagabalam, thidilambham, vyavasthanprajabdhi, hethuvila, kamahu, hethwindriyam, samapthalam, gamgagathi, thiravadyam, mudrabalam, sarvabalam, visajnagathi, sarvajnam, vibhuthangamam and thallakshanam. It can be seen that 1 thallakshanam will be 10^{53} or 53 zeros after the digit 1!

Anuyogadwarasutra mentions a number shirshaprahelika which is 10^{140} Sreedhara names the powers of ten as ekam, dasam, satham, sahasra, ayutham, laksham, prayutham, koti, arbudam, abjam, kharvam, nikharvam, mahasarojam, sanku, sarithapathi, anthyam, madhyam and parartham. Parardham is 10^{17}

According to Mahavira number names are ekam, dasam, satham, sahasram, dasasahasram, laksham, dasalaksham, koti, dasakoti, sathakoti, arbudam, niarbudam, kharvam, mahakharvam, padmam, mahapadmam, kshoni, mahakshoni, sankham , mahasankham, kshiti, mahakshiti, kshobham and mahakshobham. Mahakshobham is 10^{23} .

Famous textbook of Mathematics, Leelavathi, written by Bhaskaracharya gives the most popular names for the eighteen place values through the following quartet-

*Ekadasasatha sahasrayutha lakshaprayutha kotaya: kramasa:
Arbudamabjam kharvanikharva mahapadma sankuvasthamath
Jaladhischanthyam madhyam pararthamithi dasagunothara: sajna:
Samkhyaya: sthananam vyavahartham krutha: purvai:*

One of the problems in understanding the place values as described above is the nonuniformity in naming them. Sometimes this will create some hurdles in the proper description of the ancient texts. The classic example is the definition of the unit of distance yojana. Under various contexts, one yojana has different definitions like four, six, nine, ten, twelve kilometers.

The large numbers were used by our ancients to describe the cosmology and vastness of space and time. Jains and Buddhists were quite at home in handling large numbers. Jains have a measure of time called Purvis which is equal to 750×10^{11} days (or 750 niarbudam days). Then one sirsha prahelika = $(8400000)^{28}$ purvis which is number of 194 digits! The text Anuyogadwarasutra indicates the world population as 2^{96} which is a number of 29 digits.

What about small numbers? One does not have much information about it. However, Kerala had a system of description of small numbers which were in daily use till about two generations ago.

Ara (half) = $\frac{1}{2}$

kal (quarter) = $\frac{1}{4}$

arakkal (half quarter) = $\frac{1}{8}$

makani = $\frac{1}{16}$

mavu = $\frac{1}{20}$

kani = $\frac{1}{80}$

munthirika = $\frac{1}{320}$

keezhkal = $\frac{1}{320} (\frac{1}{4}) = \frac{1}{1280}$

keezhmavu = $\frac{1}{320}(\frac{1}{20}) = \frac{1}{6400}$

keezhkani = $\frac{1}{25600}$

keezhmunthirika = $\frac{1}{102400}$

Thus the prefix keezh will provide $\frac{1}{320}^{\text{th}}$ number like the modern use of milli which is $\frac{1}{1000}^{\text{th}}$ of a number.

Immi = $\frac{1}{21} (\frac{1}{102400})$

Anu = $\frac{1}{21}$ Immi

Thimirima = $\frac{1}{22}$ anu

Thalavaravu = $\frac{1}{22}$ anu

Chathuranu = 1/51 thalavaravu

One can see that one chathuranu is 10^{-12}

It is quite surprising that Indians were handling numbers of such a large dynamical range from 10^{-12} to 10^{140} that too with respective nomenclature. One need not wonder since our forefathers were contemplating on universe from micro to macro scales – from the size of an atom to the size of the whole universe !

II. Word – Numbers

It is said that while the Greek Mathematics originated from Geometry Indian Mathematics originated from literature. It has been the Indian custom to represent every thing in verses so that it will be easy to remember. For this numbers were represented using letters or words. In this section let us see how this was done.

Typical Sanskrit names for numbers are as follows.

- | | | |
|-----------------|-----|----------------|
| 1. ekam | 30 | thrimisathi |
| 2. dwe | 40 | chathwarimsath |
| 3. thrini | 50 | panchasata |
| 4. chathwari | 60 | shashti |
| 5. pancha | 70 | sapthathi |
| 6. shad | 80 | aseethi |
| 7. saptha | 90 | navathi |
| 8. nava | 100 | satham |
| 9. dasa | | |
| 10. ekadasa | | |
| 11. dwadasa | | |
| 12. thrayodasa | | |
| 13. chathurdasa | | |
| 14. panchadasa | | |
| 15. shodasa | | |
| 16. sapthadasa | | |
| 17. ashtadasa | | |
| 18. navadasa | | |

19. vimsathi

The numbers in words are useful in denoting arithmetical operations with a literary flavour. For example dwinavakam is 2×9 thrinavakam is 3×9 navavimsathi is $20 + 9$ ashtathrimisathi is $30 + 8$ More examples are as follows.

Ekonasatham = $100 - 1$ ekonavimsathi = $20 - 1$

sapthasathani vimsathi = $7 \times 100 + 20 = 720$

shashtimasahasra navathim nava = $60 \times 1000 + 90 + 9 = 60,099$

thrinisathani thrisahasrani thrimsachanavacha = $3 \times 100 + 3 \times 1000 + 30 + 9 = 3339$

chathuradhikam sathamashthagunam

dwashashtisthatha sahasranam = $(4 + 100) \times 8 + 1000 \times 62 = 62,832$

However, it is very difficult to represent large numbers using the above style. It is also difficult to decipher the number from the above style of representation. Indians invented ingenious technique to solve the problem by inventing word – numbers.

Bhoothasankhyas

One of the most popular types of word number is the bhoothasankhyas . Numbers are represented using objects which have unique values. For example nayana (eyes) is 2 nasika (nose) is 1 dantha (teeth) is 32 Rama is 3 .

Purna (complete) and akasha (Sky) are words for 0. There are more than one word to represent a number. Following list are examples.

0- sunya, kham, abhram, purnam, akasam etc

1- bhu (earth) , sasi (moon) etc.

2- nayanam (eyes), yugalam (twin), bahu (hands) etc

3- Rama, lokam , kalam etc

4- Veda, yuga, urushartham etc

5- Banam, bhutham, pandavas, indriya

The words are written from the left to right while number starts (lowest place) from right. Hence to represent a number using word combination we follow the rule Ankanam vamatho gathi (number moves towards the left).. The leftmost word will represent the number in the rightmost place (unit place).

Let us see what rama dantha represents? Literary meaning is the teeth of Rama

Rama dantha by the rule ankanam vamthogathi it is 323

3 32

purnaakasashtamuni ramanethra – purna, akasa, ashta, muni, rama, nethra corresponds to respectively 0,0,8, 7, 3, 2 so that the number will be 237800..

It is clear that one can represent large numbers using the above technique..

Letter Numbers- Katapayadi system of Kerala

It is believed that Vararuchi devised a number representation during the fifth century A D in Kerala. In this case each letter represents a number unlike in Bhootha sankhya method where numbers are represented by words.

Digits are represented as follows:

1	2	3	4	5	6	7	8	9	0
Ka	Kha	Ga	Gha	Gna	Cha	Chha	Ja	Jha	Nja
Ta	hTa	Da	Dha	Na	Tha	Htha	Had	Hdaha	
Pa	Pha	Ba	Bha	ma					
Ya	Ra	La	Va	S'a	Sha	S''	Ha	Lla	zha

Independent vowels have zero values. Semi letters do not have any values.

Eg: Raman - ra ma

2 5

by the rule ankanam vamatho gathi the number is 52

ayurarogyasoukhyam – a yu ra ro gya sau khyam

- a yu ra ro ya s'' ya

0 1 2 2 1 7 1

Number is 1712210

This is a line from the famous work Naraaneeyam . Literal meaning is prayer to God to provide us longevity, health and happiness.

The corresponding number is the day when the work was completed. It is 1712210 days after the kali era started. Kali era started at BC 3102 February 13. This gives the date as 4687 years and 9 months in Kali era or AD 1585 November. Date of death of a famous poet is on “divyam thava vijayam” or your success is divine. This gives the date as AD 1949 June 15. Numbers were appropriately chosen to get a poetical flavour. This will help us in remembering large numbers and formulae. For example a text book on Mathematics, sadratna mala gives value of pi correct to 17 decimals as

$$3.14159265358979324$$

using the following line: bhadrambudhissidha janmaganitha sradhasmayal bhupagi !!

Letter Numbers – Method of Aryabhata

Aryabhata was a mathematician, astronomer whose book Arabhatiya written in 499AD is a magnum opus which contains a number of original ideas in Mathematics and Astronomy. Since he had to handle large numbers Aryabhata devised an ingenious technique to represent numbers using letters. Details are given as follows.

Place values are classified into varga places (oja places) unit, hundred, ten thousand etc (note that these place values are perfect squares or varaga samkhyas)

and avarga places (yugma places) ten, thousand etc (these place values are avarga samkhyas or non-perfect squares)

Letters are also classified similarly:

vargaksharas or varga letters – consonants ka to ma – represents numbers 1 to 25

avargaksharas or avarga letters – 8 consonants ya to ha represents 30, 40, 50, 60, 70, 80, 90, 100 respectively.

Vowels a, i, uo, ru, lu, ae, ai, o, au are 100^0 , 100^1 , 100^2 , 100^9 respectively.

Aryabhata says

Varga letters and avarga letters should respectively denote varga and avarga place values in a given number.

Compound letters formed between consonants and vowels should represent the numbers obtained by multiplying the respective numbers.

Eg:

Ka k +a $1 \times 100^0 = 1$

$$\begin{array}{lll}
\text{Ma} & m+a & 25 \times 100^0 = 25 \\
\text{Ku} & k+uo & 1 \times 100^2 = 10,000 \\
\text{Kyu} & ku+yu = kXuo + yXuo = & 1 \times 100^2 + 30 \times 100^2 = 300,000
\end{array}$$

Let us see what does ngisibushkhrunlu represents:

$$\begin{aligned}
\text{Ngisibushkhrunlu} &= (ngXI) + (sXI) + (bXuo) + (shXru + khXru) + n+lu \\
&= 500 + 7000 + 2300000 + 82000000 + 1500000000 \\
&= 1582237500
\end{aligned}$$

Difficulty in pronunciation is a drawback of this method and hence nobody followed Aryabhata's method of number representation. However, one sees that Aryabhata could represent very large numbers using very few letters.

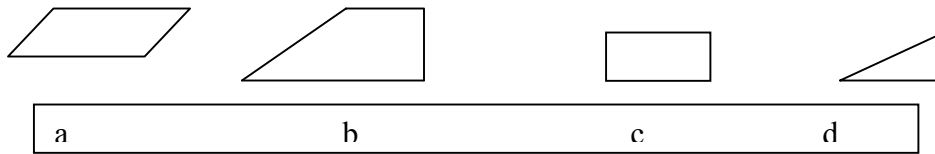
Sulba Sutras- Indian Contribution to Geometry

Indians were concentrated on higher studies of astronomy and algebra. They devised geometry to support astronomical calculations as well as the construction of Yaga alter. In ancient days geometrical constructions were made using thread (sulba) based on established sutras or formulae. This is the origin of the field Sulba Sutra. Later on it was changed to Rekha ganitham or diagrammatic mathematics. Essentially SS contains methods of constructing various types of yaga vedi or pooja alter with complicated patterns. SS is an important component of Yajurveda which describes the detailed construction technique of yagavedi. Famous SS mathematicians are Baudhayana, Apastambhan, Kathyayana and Maithrayana of which Baudhayana's work contains more rigorous mathematical treatments. Baudhayana Sulbasutra contains three chapters and 525 formulae and constructional details of complicated yagavedis. It also describes the shapes of individual tiles to be used for such constructions.

Areas and shapes of yagavedi should be strictly adhered to the rules similar to the accuracy of mantra chanting.

What are the geometrical problems arising out of the design of yagana and pooja vedis? One may have to construct alters of different shapes but of equal or multiples of a basic value of area. For example it was believed that an emperor who conducted 101 ashwa medha yaga are unvincible even by gods. When yaga is repeated, each time the yagavedi and pooja alter should get enhanced by a fixed amount by modifying the dimension of the vedi. This is an important geometrical problem.

One of the shapes of a yaga vedi has a shape of a falcon with stretched wings and tail . The first layer of this vedi contains 136 bricks of four shapes as shown below:



Concept of Surds

Indeterminate numbers like $\sqrt{2}$ are called surds. For example the hypotenuse of an isosceles right angled triangle of sides unit magnitude is $\sqrt{2}$. Indians called such numbers as karani. An achievement of SS is the formula for evaluating the $\sqrt{2}$.

They gave the value as

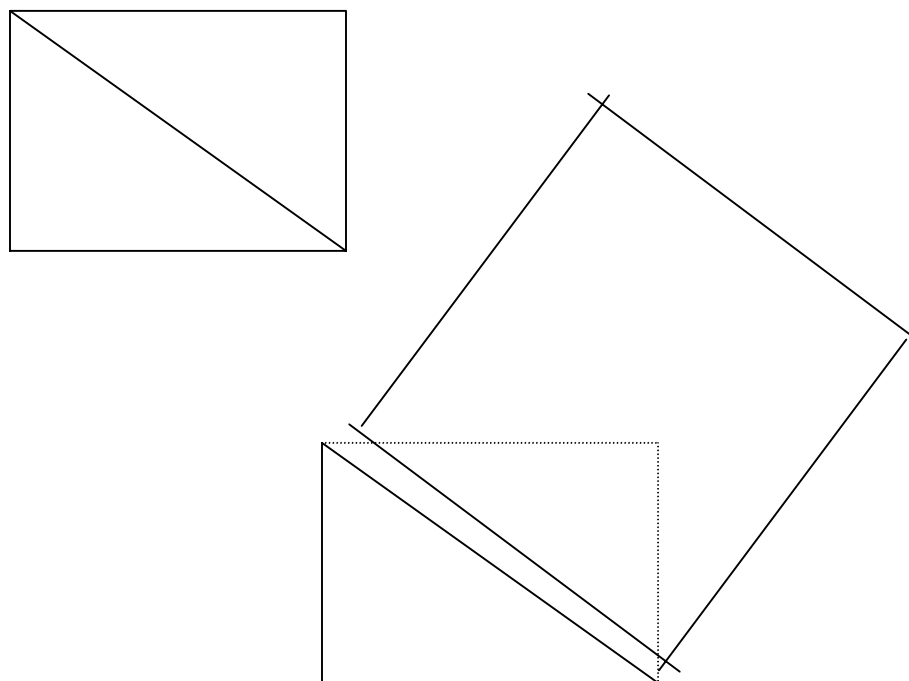
$$\sqrt{2} = 1 + \frac{1}{3} + \frac{1}{(3 \times 4)} - \frac{1}{(3 \times 4 \times 34)}$$

Paythagoras Theorem

Pythagoras theorem is well known relationship between three numbers as

$A^2 + B^2 = C^2$ and the three numbers are called Pythagorean triplets. Examples are 3, 4, 5; 5, 12, 13; 8, 15, 17 etc. In fact this fact was known well before Pythagoras (lifetime ~ 540BC) to Indian Mathematicians.

Baudhayana(600BC) states that the rope stretched across the diagonal of a sqaue produces an area double the size of the original size. This helps the construction of an alter double the area of a given value.



Katyayana says that the rope stretched along the length of the diagonal of a rectangle makes an area which the vertical and horizontal sides makes together. In fact the theorem was attributed to pythagoras about 500 years after his death.

Indians also knew that when dimensions of a three dimensional object is enhanced cube root 2 ($2^{1/3}$) times the volume can be doubled. For example volume of a cube of side L^3 . When side becomes $2^{1/3}L$ it is obvious that the volume becomes $2L^3$. This was a remarkable discovery since this will help to construct vessels of double the volume of the given size.

IV Zero

One of the greatest contributions of India to the field of Mathematics is the concept of zero. Indians might have stumbled on this concept through philosophical arguments as seen from the following quartet from Isavasyopanishad

Poornamada poornamidam

Poornad poornamudachyathe

Poornasya poornamadaya

Poornamevavasishyathe

That is infinite, this is infinite

From infinity emerges the infinity

When infinity is taken away from infinity

Infinity is left back

The paramatma and jeevatma are two infinities and the later emerges from the former. This philosophical insight resulted in to two forms of Brahma namely the nirguna r formless and saguna, the one with form. A mathematical translation to these concept has resulted in to two purnas or two zeros and later on took a concrete representation of zero and one. Later on one has been attributed to a single object from which the number concept (natural number) emerged. More numbers can be represented by defining

further symbols. By a stroke of genius they however limited to number of independent symbols to ten including 0 and nine other symbols. Since purna or zero does not have an independent existence it was used to add up values by placing it on the right side of the other symbols. Thus originated the wonderful decimal places . Thus one can write any large number by combining the number symbols with zeros. Whenever a digit shifts its position to left for giving room for a zero, the value of the number gets multiplied by ten. One does not know when the concept of zero emerged in the horizon of human knowledge.

In samhitas like yajurveda samhita, taittiriya samhita and maitrayani samhita, which date back atleast to 1500BC, word numerals based on decimal notation upto 12 places were mentioned. A large number like shashtim sahasra sapta satani navatim nava (60,799) available in these samhitas obviously implies that the idea of decimal place value was popular during those time. The representation of numbers with word numerals are described in earlier chapter where we saw how zero is represented by words like sunya, akasa, kha, poorna etc.

Symbolic representation of numerals were also known to exist as seen from ancient inscriptions. Some of such inscriptions use point symbol or sunya bindu as well as circular symbol for zero. The earliest evidence of zero symbol is found from Bakshali manuscript (400AD) details of which will be seen from a future chapter. Some examples are shown below

Symbolic expression	Number	reference
	330	Bhakshali Ms (400AD)
	846720	do
	60	Malay inscription (683AD)
	682	Inscription at Java (760 AD)

Yogadarsana Bhashya of Vyasa (dated before 700 AD) attests: yathaika rekha sathasthane satham dasasthane dasam ekamchaikasthane (a numerical sign denotes hundred in hundred's place, ten in ten's place and one in unit's place. Similar description is given by Sankaracarya in his Brhama Sutra Bhashya (800 AD). Thus , it can be made

sure that by these times, decimal system has been well established and known generally for daily use. This system was made to known to Arabs from tenth century AD from where it went to Europe and it has now been adopted by the modern world.

There is no doubt that the concept of decimal system was known to Arabs from India. Al-Baruni (1030AD) who stayed in India for a long time observed in his India

“ the numerical signs which we use are derived from the finest of the Hindu signs. “ The Indian name sunya was translated in Arabic as as-sifr or sifer. This was subsequently changed to zepherium (1202 AD , Fibonacci) tziphera(1340 AD, Planudes) and zeniro, zepiro (16th century AD, Italy). The zero in circular symbol has been used in European Manuscripts from 14th century onwards.

The eight fundamental operations of Indian arithmetics have been the natural consequence of decimal system. The eight operations are ; addition (samkalana), subtraction (vyvakalana), multiplication (gunana), division (bhagahara), square (varga) Square root(vargamoola), cube (Ghana) , cube root(Ghana mula).

IX Laws of Indices and Logarithms

Jains and Buddhists were fond of large numbers. In famous work Anuyogadvarasutra infinity with different dimensions are noted. To generate large numbers they used raising of a number with itself and was called varga samvargita.

For example

The first samvargita varga of a $= a^a = b$

The second samvargasamvargita of a $= b^b = c$

The third samvarga samvargita of a $= c^c$

For example the third samvargita of 2 becomes 256^{256} a number higher than the total number of electrons in the whole universe. Jaina authors during 300 BC devised rules of indices what is now called the laws of indices like

$$A^m \times a^n = a^{m+n}$$

We know that $2^3 = 8$. This was denoted by Napier (1550 – 1617) through logarithm as

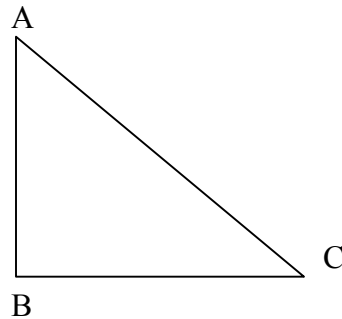
$\log_2 8 = 3$. During the period of the era of BC Jains conceived the idea of logarithms to the base 2, 3 and 4 called ardhaccheda, trikccheda and caturthaccheda.

$\log \log x$ is known as vargasalaka of x .

However, Indians did not develop logarithms further. This may be due to the fact that Indians had techniques to handle large numbers without the concept of logarithms. The main use of logarithm is to handle the calculations using large numbers.

V. Meaning of sin in $\sin A$

Trigonometric ratios are familiar in school mathematics.



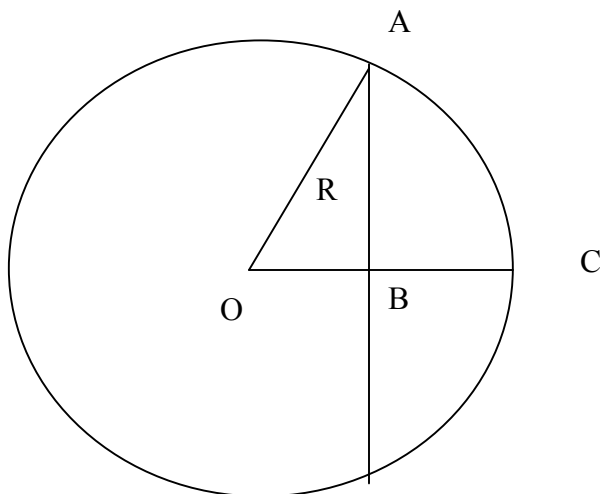
In the given right angled triangle ABC

$$\frac{BC}{AC} = \sin A$$

$$\frac{AB}{AC} = \cos A$$

$$\frac{BC}{AB} = \tan A$$

Nobody might have thought of the literal meaning of the terms sine, cosine. If there are few, they might have attributed them to some nonsensical words used by eccentric Mathematicians. In fact it was Aryabhata who introduced the specific names for such



$$\text{Jya } A = AB = R \sin A$$

$$\text{Kojya } A = OB = R \cos A$$

$$\text{Utkramajya } A = BC = R(1 - \cos A) \\ = R \text{Versin } A$$

Jya, Kojya and Utkramajya were used extensively by Indians to develop Geometry and Astronomy.

They also calculated the trigonometric ratios for any angle deriving standard relationship.

VI Division of a Circle

Circle and its properties were important topics for Indians in the context of Astronomy. They devised twelve zodiac signs along with the Sun travels with the earth as the center. To describe the movement of sun accurately along the zodiac sign, the circumference of the circle was divided in two ways.

Method I

Circumference	=	1 rasis
1 rasi	=	30 bhagas or amass
1bhaga	=	60 kalas or liptas
1 kala	=	60 vikalas

In modern terminologies, 1 bhaga is 1 degree, 1 kala is 1 minute and 1 vikala is 1 second This means that 1 bhaga of arc of a circle of unit radius will subtend 1 degree of angle at the center.

Method II

Circumference	=	21,600 (=360X60) ilis
1 ili	=	60 vilis
1 vili	=	60 talparas
1 talpara	=	60 pratalparas

Radius of a circle in terms of ilis is 3437 ilis, 44 vilis, 48 talparas and 22 pratalparas or In katapayadi system it is remembered as

Sresto devo visvasthali bhrgu

Which means 3437,44,48,22 . each comma separates ilis, vilis, talparas and pratalparas.

Note that ili and vili are same as kala and vikala.

The radius 3437,44,48,22 corresponds to 57 degrees, 17 min. and 44.8sec. which is 1 radian according to modern terminology.

Following is the figure used by astrologers for representing 12 rasis to distribute zodiac signs.

VII Aryabhata misunderstood

Aryabhata the famous Mathematician- Astronomer wrote Aryabhatiya in 499AD. In this book he developed necessary mathematics for explaining some of the astronomical phenomena.

Aryabhata was misunderstood by later interpreters due to errors in translation from the Sanskrit text. The finer aspects of Sanskrit grammar make this language a great one. If the text is not properly analyzed one will reach to erroneous conclusions. This was what happened with the interpretation of some of the formulae given by Aryabhata. Even some of the famous commentaries of Aryabhatiya say that Aryabhata was wrong when he gave formulae for volume of a pyramid and sphere. In the following section we show how these conclusions were reached.

The second part of Aryabhatiya contains a verse (verse 6)

Tribhjasya phalasarira samadalakotibhujardhasamvargah

Urdhvabhujatatsamvargardham sa ghanah sadasrir iti

Interpretation: Half (ardh) the product (samvargah) of the base (bhuj) and the height (koti) of an equilateral (samadala) triangle (tribhuj) forms the area (phala) of the solid (sariram) formed. Half (ardha) the product(samvarga) of this (area)and the perpendicular (urdhvabhuj) or the height is the volume (Ghana) of the solid with six edges (sadasri) or triangular pyramid.. This popular interpretation gives the formula for the volume as $\frac{1}{4} bh^3$ which is obviously incorrect.

Commentators like Kurf effering and Conrad Muller gave following interpretation:

Half the prodct of the base and the height of an equilateral triangle forms a solid by its area. Half the product of this area and the perpendicular of the solid forms a rectangular solid whose volume is equal to six (sad) pyramid (asri).

In the first interpretation, sadasri is taken as six-edged solid while in the second analysis it is split into sad (six) and asri (peak) or pyramid.

The triangular pyramid is made by dividing an equilateral triangle and folding up the three peripheral triangles over the central one. The toatal suraface area of the pyramid is equal to area of the original triangle. Six such pyramids took together will have a volume

equal to half the product of the original triangle and the height of the pyramid. Aryabhat describes in various contexts the volume of pyramid which give correct results. One wonders why even famous commentarians mistook the meaning of the verse.

Second example is about the volume of a sphere. This also is due to misinterpretation of the word nijamula in the verse. Nijamula is taken by the majority interpreters as nija mula which is square root and volume of the sphere is $\sqrt{\pi} \pi R^3$ instead of $\frac{4}{3} \pi R^3$. However Effering interprets nijamula as own base and in the present context is radius R. Then the verse deals with curved area of a hemisphere and is given by the correct formula $2\pi R^2$.

The two examples shown above proves the fact that in order to understand ancient Indian text of Mathematics or Philosophy one should be expert in both the subject as well as in the Sanskrit. Such combinations are rare.

VIII . Indian Mathematicians – in brief

India had a glorious past in every walks of knowledge . Their contributions in medicine and architecture are well known since such works were directly dealt with the public. Indian systems of medicine like Ayurveda are now accepted by the public and the policy makers. Their architectural skill is visible in the innumerable structures of temples and palaces. However, the Indian contributions to Mathematics and Astronomy are not so well known. This section gives the famous contributors to the fields of Mathematics and Astronomy from Vedic to late medieval period.

The sulbakars

The sulba period was a period of specialization during the vedic period (before 200BC) during which geometrical constructions occupied the central stage. Geometry was important in the construction of various types of Yaga vedis and fire alters. Along with the geometry Astronomy was also flourished since the proper times or muhurtas were fixed according to the postions of the heavenly bodies.

There were seven famous sulbakars namely,

Baudhayana, Apastamba, Katyayana, Manava, Maitrayana, Varaha and hiranyakesi. The oldest of the sulbakra was Baudhayana whose birthplace was in Andhra in south. His work Baudhyanasulbasutra, in three chapters describes various geometrical constructions. His works include general enunciation of what is commonly known as the Pythagoras theorem and obtaining the square root of 2 correct to the five decimals.

The Sulbakra Apastamba also belonged to Andhra. He describes detailed descriptions of geometrical constructions

The Jaina sect of religion was wide spread during 500- 300BC. The literature of Jaina is generally classified into four groups: 1) Dharmakathanuyoga (exposition of Principle of Religion) 2) Ganitanuyoga (exposition of Mathematical principles) 3) Samkyana (theory of numbers) and 4) Jyotisha (Astronomy). Umasvati (150 BC) of Kusumapura (ancient Pataliputra) near Patna was a famous Jain Mathematician . He belonged to a school originated by Jaina Saint Bhadrabahu(300BC). The culture of Mathematics and Astronomy were flourished in India during this period and for many centuries to follow. Aryabhata (5th century AD) might have taken his lessons from the Jaina School.

Many Hindu works also were originated during this period . Eighteen siddhantas were composed after their respective authors. They are Surya, Patyamaha, Vyasa, Vasishtha, Atri, Parasara, Kasyapa, Narada, Garga, Marichi, Manu, Angira, Lomasa, Paulisa, Cavana, Yavana, Bhrigu and Saunaka. However only five siddhantas are survived and remaining are lost. Of these Surya Siddhanta is famous. Paulisa Siddhanta, Romaka Siddhanta, Vasishtha Siddhanta and Paitamaha Siddhanta are other survived works.

Mathematicians of Early Medieval Period (AD 400 to 1200 AD)

Aryabhata I (birth 476 AD)

Aryabhata belongs to Kodungallor near Ernakulam, Kerala. He had his education at Kusumapura near Patna. His famous book Aryabhatiya was written in 499 AD at the age of 23. Details of this work will be given in another chapter.

Varahamihira (505-587AD)

Varahamihira was a native of Avanti and a student of his father Adityadasa. His original family came from Magadha. His work Panchasiddhantika is an exhaustive work in

Astronomy. It describes five siddhantas namely Paulisa, Romaka, Vasishta, Surya and Paitamaha .

Bhaskara I (600 AD)

One does not know the native place of Bhaskara I. He was the most competent exponent of Aryabhat I. Mahabhakariya, Aryabhatiyabhashya, and Laghbhaskariya are his famous works.

Brahmagupta (628AD)

Brahmagupta was the most prominent Hindu Mathematician belonging to Ujjain School. His father's name was Jishnu. In 628 AD he wrote his magnum opus Brahmasphutasiddhanta at the age of thirty. He wrote the book Khandakhadyaka in 655AD. Brahmagupta was a bitter opponent of Aryabhata I. However, during his later years he recognized the merits of Aryabhata. His works were translated into Arabic during the 8th century AD.

Lalla (768 AD)

Lalla belonged to Kusumapura School and the son of Bhatathrivikrama, His Sisyaddhivardhida is a work in Astronomy in 100 Slokas. This contains important informations about trigonometry. He also wrote two books Patiganita and Siddhantatilaka, both of which are lost. Patiganita was a book of Mathematics while Siddhantatilaka was similar to Brahmasphutasiddhanta.

Govindaswamin (800 – 850 AD)

Govindaswamin who wrote commentary on Mahabhaskariya of Bhaskara I belonged to Kerala in Mahodayapuram . His work Govindakriti was a sequel to Aryabhatiya and is lost. His works have been quoted extensively by Sankaranarayana (869AD) and Udayadivakara(1073 AD) and Nilakantha.

Skandasena (beginning of 9th century)

Skandasena systematized methods of multiplications described in Patiganita . He also gave geometrical interpretations of arithmetic series. However his works are lost.

Mahavira (850AD)

Mahavira, a famous Jain Mathematician wrote Ganitasarasangraha which is considered to be a brilliant work. He had associations with the school of Mysore and lived in the court of Rastrakuta monarch in Mysore. He showed ability in arithmetic and geometrical series as well as in permutations and combinations. He dealt with quadratic equations and indeterminate equations.

Sridhara (850 – 950)

We are not sure of the native place of Sridharacharya. Most probably he belonged to south India. He dealt with multiplication, division, square, cube, square-root, cube root etc. He for the first time gave a rule of extraction of roots of quadratic equations and is called Sridhara's formula.

Aryabhata II (950 AD)

Aryabhata II wrote Mahasiddhanta in 18 chapters which describes three branches of mathematics namely, pati, kuttaka and bija. He advised corrections in the treatment of solutions of simultaneous indeterminate equations. The subject kuttaka made popular by Aryabhata II

Sripati (1039 AD)

Sripati was a Jaina Mathematician and Astronomer. He wrote Ganitatilaka, Siddhantashekhara and Bijaganita. His book Bijaganita is lost. Ganitatilaka deals with arithmetics and Siddhantashekhara contains Astronomy and algebra vyaktaganitadhyaya and Avyaktaganitadhyaya.

Bhaskara II or Bhaskaracharya (1114 – 1200 AD)

Bhaskaracharya belonged to Bijalabida in Modern Karnataka. He had association with Ujjain School. His fame rests on three books Lilavati, Bijaganita and Siddhantasiromani. He also wrote a commentary on Siddhantasiromani called Vasanabhashya and a treatise on planetary motion called karanakuthuhala. He wrote Siddhantasiromani when he was 36 years old.

Narayana Pandita (1356 AD)

He was a pure Mathematician and developed a number of techniques to handle infinite series. His book Ganitakaumudi contains a number of innovative techniques in Arithmetics and algebra.

Madhava (1400AD)

Madhava was one of the well known Mathematician who wrote a treatise called Venvaroha. He was an authority in spherical astronomy and was known as golavid 9 expert on spherical mathematics). Madhava belongs to Samgama Village (Irinjlakkuda) in Kerala. He is famous for the correct determination of the value of pi as infinite series. It is now called Madhava-Gregary Series.

Parameswara (1430)

Parameswara belonged to asvathagrama (Alattur Village) in Kerala . His house vatasseri was on the bank of the river Nila (Bharatapuzha). He was the founder of drgganita system of Astronomy. He wrote commentaries on all the popular classical works on astronomy and mathematics. His commentaries are Bhatadipika (on Ayabhatiya), Parameswari (on Laghubhaskariya, Siddhantadipika or Karmadipika (on Mahabhaskariya), vivarana (on Suryasiddhanta) and Vyakhya (on Lilavati).

Nilakantha Somayaji (1443- 1543)

Nilakantha was from Trikkantiyur near Tirur of Kerala. His famous works are Aryabhatiyabhashya and Tnatrasamgraha. He was a student of Damodara, son of Parameswara. He also wrote Golasara and Chandracchayaganita.

Chitrabhanu (1475- 1550), Sankara Variyar (1500 – 1560), Jyeshtadeva (1500 – 1600), Achyuta Pisharoti (1550 – 1621), Munisvara (1603), Kamalakara (1616-1700) and Sankaravarman (1800 – 1838) were mathematicians and astronomers who contributed much to the progress of this branch of human knowledge.

Details of some of the famous works will be given in other chapters.