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Neither Newton nor Leibnitz: The Pre-History of Calculus in Medieval Kerala

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Sociology of Kerala

- The people of Kerala today belong to the three major religions: Christianity(20%) , Islam(20%) and Hinduism(60%).
- The proportions were different in the time we are speaking of: there was a small and ancient Christian church, founded by the Apostle St. Thomas himself if we are to believe in the legends.
- There was a tiny but vibrant jewish community. There were some converts into Islam along the coastal regions.
- But the vast majority of people followed the traditional religion of India known there simply as the 'Old Ways': the Sanaadhana Dharma. The Persians called the followers of this religion 'Hindus'- derived from their name for the Sindhu (Indus) river- which now is used even in India to describe them.



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The Hindu Religion-*Sanatana Dharma*

- Unlike modern religions (such as Buddhism, Christianity or Islam) Hinduism does not have a unique founder. Like Judaism it is a system of practices handed down from time immemorial.

- The basic spiritual texts are the four Veda, perhaps the oldest surviving texts of mankind. The word Veda simply means 'the knowledge'. These are supplemented in later times by the epics (puraana) (mainly the Ramaayana, MahaBhaaratha and the Bhaagavata) ; embedded in the epics are several important texts such as the Bhagavat Giita and the Yoga Vasishta. This classical literature is supplemented by the commentaries of saints the most important of whom is Sankara Achaarya.

- The Veda are a sort of encyclopedia of ancient knowledge. In addition to the hoary philosophy of the Upanishads, the Veda also contain the ancient rules of human behavior and of course, hymns and prayers.

- Although in its core Hinduism is not about Gods, but about a supreme existence of which we are all a part, much of the religious



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practice has to do with a multitude of Gods: each of which represent an aspect of this supreme reality.

- In the Veda, many of the Gods are identified with natural phenomena: the Sun, the Moon and the planets are minor Gods the major ones being Indra, Vishnu, Siva and so on.

- It is difficult to convey that there is an essence to Hinduism that lies beyond the Gods to those from another cultural and religious background: it often looks like a bewildering array of colorful, even scary images connected together by fantastic legends, much like the pre-Christian religions of Europe. However, abstract notions of the impersonal infinite are still quite familiar to Hindus and the abstractions of mathematics were often derived from this common religious background.





A Glimpse of Infinity

●As an example, here is a verse from the Isaavasya Upanishad of the Yajur Veda that many of us repeat daily even today:

*purnamadah purnamidam purnaat purnamudachyate
purnasya purnaamadaya purnameva vashishyate*

That is the Universe, This is the Universe,
The Universe arises from itself, it is said
If you subtract the Universe from the Universe
There remains the Universe, indeed.



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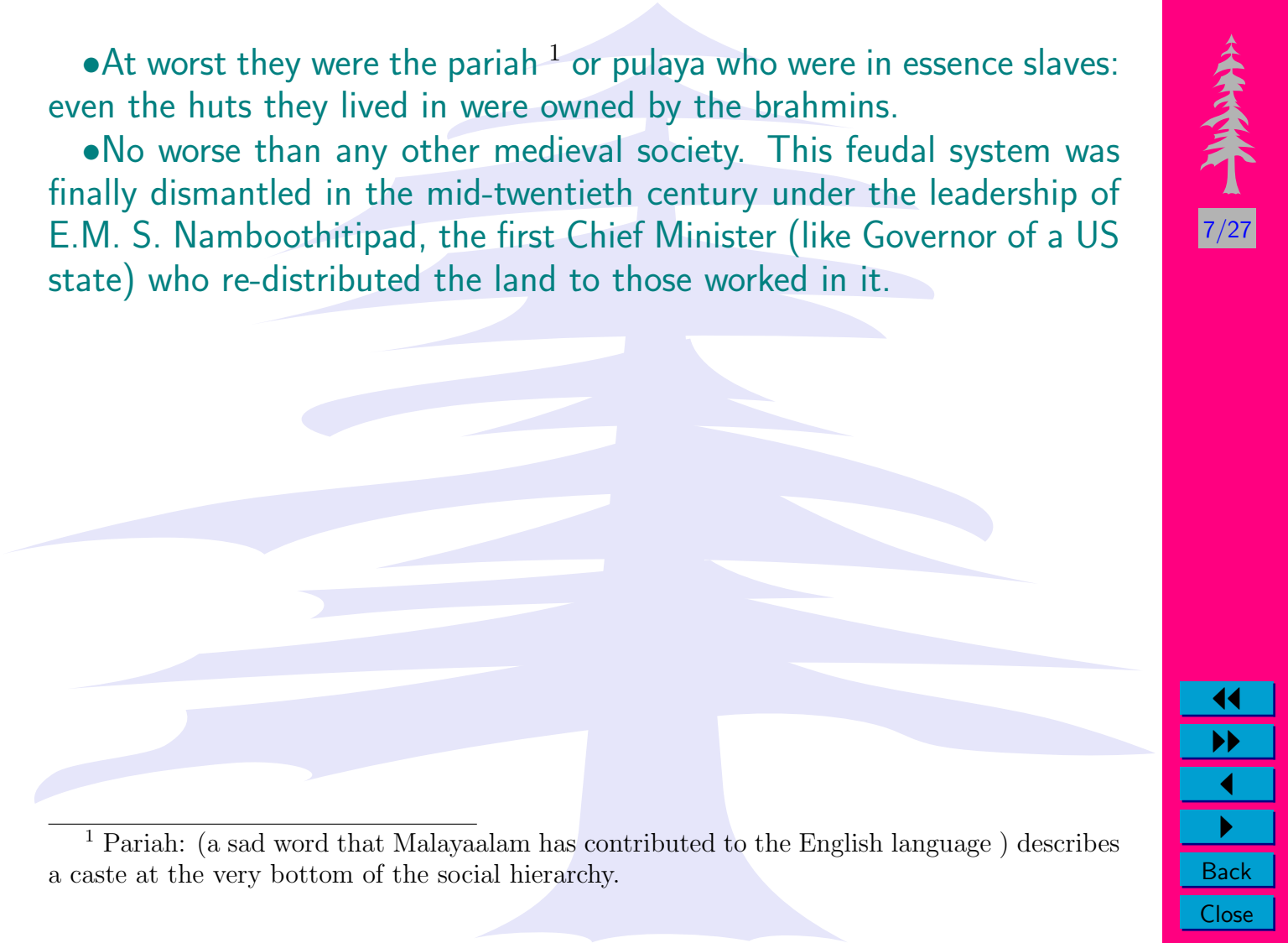
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Namboothiri: The High Priests

- Most of the astronomer-mathematicians of Kerala were *Namboothiris*, the highest ranking priests of the Hindu religion.
- They had the highest social status in the society, higher than the King.
- Although less than a half percent of the population, they controlled most of the wealth through land ownership.
- What they did not own out-right they controlled through the temple-trusts which were managed by them.
- The people who toiled in the fields (rice farming is very labor intensive) had no ownership of the land or its produce.
- Yet the enormous wealth that these rice plantations produced were entirely the product of their labor: without constant toil the land would have decayed out of over-cultivation in just a few years.
- At best, they were tenants who paid the landlords regularly for the privilege of cultivating the land.





- At worst they were the pariah¹ or pulaya who were in essence slaves: even the huts they lived in were owned by the brahmins.

- No worse than any other medieval society. This feudal system was finally dismantled in the mid-twentieth century under the leadership of E.M. S. Namboothiripad, the first Chief Minister (like Governor of a US state) who re-distributed the land to those worked in it.

¹ Pariah: (a sad word that Malayaalam has contributed to the English language) describes a caste at the very bottom of the social hierarchy.





How did the *namboothiris* Dominate ?

- The namboothiris are believed to have emigrated down the West coast of India starting with the fourth century CE. In any case by the ninth century every aspect of Kerala society came under their firm control.

- There are some sub-castes within the namboothiris who were later immigrants from *Thulu* region just to the North of Kerala. Madhava belonged to one of them: he was an *embranchiri*.

- The key to the dominance of the *namboothiris* was that they were the keepers of the sacred Hindu scriptures, the *Veda*.

- It was their sacred duty to perform the vedic sacrifices to maintain the harmony of the universe.

- The title Somayaji denoted someone who had performed one of the most difficult and ancient of these rituals, the *Soma-yaga*.

- Being the only allowed priests, they controlled the temples which were also the only centers of learning, art and culture.



- Each village had a small standing army of *Nairs* who protected the temple.

- The temples and could not be taxed; indeed the King was dependent on them even to raise an army.



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Simplicity, Dedication, Discipline

- The life of a *Namboothiri* was comfortable but by no means luxurious. There are no castles or opulent palaces in Kerala.
- They led a life of scholarship and spirituality.
- Food was strictly vegetarian. No alcohol or other intoxicants were allowed. Even strong tastes like onions were forbidden as it could inflame sexual appetite.
- Fasts on the eleventh day of each half of the lunar cycle .
- Servants were not allowed to cook food; it was the domain of the *namboothiri* women.
- Exercise was built into the spiritual practices; e.g., the prayer to the Sun God is an excellent aerobic workout. You can learn it in yoga classes in the US. They walked everywhere.
- They lived in large joint families (many unmarried adult brothers and sisters, the children of the oldest brother, the grandparents and sundry dependents) in a simple single story home.





- The women rarely travelled outside: the Malayalam word *antarjanam* for a Namboothiri woman means 'woman inside' (the house).

- The houses had one or two internal courtyards without a roof and was built either as a square or double square around them. (There is some resemblance to floor plan of the Roman Triclinium.)

- The roof was tiled, or in the older days a thatched with coconut leaves. This kind of roof had to be replaced annually. The floor was bare, just a mud: no form of cement or marble was used.

- There would be a shed some distance away for the cows and a sizeable stack of hay to feed them.

- Dress was also very simple: a piece of cotton cloth around the waist, a towel around the shoulders. A thread around the body indicating *brahmin* status. Even on the most formal occasions, men were bare chested. Marco Polo was aghast at that!

- Here is a picture of the High priest during the year 2003-2004 of the biggest temple in Kerala (Ayyappa kshetram): this was the typical dress of a *namboothiri* of that time.



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The Education of a Namboothiri

- The *namboothiris* held a total monopoly on education, both basic and advanced. The rest of the population was practically illiterate.
- Today the situation is entirely different. Kerala offers the broadest level of basic education in the world: the only state in India that claims a 100% literacy rate. The results of the reform started by EMS, the first Chief Minister.
- The education of a Namboothiri boy was intense, deep and broad.
- He started at the latest by the age of eight and continued at least to age sixteen.
- The teacher was often a family member, an uncle or father or grandfather.
- Every morning started before sunrise (always 6:00 am in these tropical parts) with prayers to the Sun God, Suurya. After a short break for lunch it would continue till sundown.





Learning the Veda

- The center piece of the education was the learning of the Veda. No other caste had the right to learn the Veda.
- The Veda could not be written down, the entire corpus had to be memorized. Each family inherited a piece of the Veda assigned to it according to tribal succession laws and passed it on to the next generation.
- The smartest boys learned the hardest and most abstract kind of knowledge: the Upanishads, about the nature of knowledge itself, that ultimate knowledge from which all else follows.
- Even the dumb ones at least had to memorize the Veda by rote without understanding its meaning. The chanting of the Veda is the ultimate duty of the Namboothiri.
- Each namboothiri were a living library of ancient knowledge.





Error Correction by Redundancy

- To make sure that no error would creep into the oral transmission of the Veda, there were intricate error correction techniques built into this rote learning.

- You would learn the Veda not only as if read from left to right, but also in the reverse order. Which would make equal sense to someone who doesn't understand the ancient Sanskrit to begin with. Not only that you would memorize each verse by taking a syllable from the middle then one to the left then one to the right and so on.

- This redundancy as well as the redundancy in the large number of people who learned the Veda compensated for the volatility of human memory. Indeed the Veda are extremely remarkably well preserved: you can compare the Veda as recited by a Namboothiri brahmin to a Kashmir pundit. There would be no difference not only in literal content but also in the pronunciation and rhythm of the singing.

- There are greater disputes over Shakespeare's writing than over the



text (*samhita*) of the Veda: in spite of the former being printed and much more recent. As the older generation who received this classical education die out, there is now the danger of entire branches of the Veda dying out with them. There is an ongoing project to record the chanting of the Veda before this happens.

- There were annual competitions in the recitation of the veda. Such a competition (*anyonyam*) still continues but at a much smaller scale.
- The various city states and temples competed to attract well known scholars to stay in residence. In return the scholars were expected to compose some salutary verses honoring the local ruler (Prasasti) which they completed with some grumbling.
- Secular subjects such as poetics, rhetoric, grammar, logic, astronomy (of which mathematics is a part), medicine occupied an important place in the education, but were considered distinctly inferior to the study of the Veda.





The *Guru*

- Each person has a guru or teacher responsible for his overall education; although occasionally there might be more than one teacher when someone has expertise in several areas.
- In this respect advanced education today at the level graduate school holds a remarkable similarity to this ancient system. But the guru was often a relative: an uncle or ones father.
- The guru was held in the highest regard, indeed as a form of divinity.
- The guru was responsible for spiritual and moral development as well as education. In return the student was to obey and protect the guru for life.
- The word guru means literally 'heavy' or ponderous. In astronomy, guru is also the name of the planet that we call Jupiter in English: because of its ponderous motion across the sky with a period of twelve years. In mythology this guru represents the teacher of the Gods, a play on the meaning of the word.

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●The schools or Madhams survived down to the early twentieth century. At this time the Namboothiris started to suffer from the lack of an English education. There was a popular reform movement which allowed the Namboothiris to adapt to the modern world.

●Now they have melted into the emerging vast Indian middle class as professionals: teachers, doctors, scientists and immigrants to the United States..





Some Salacious Details

- Wealth would not get diluted by division among the progeny.
- Only the oldest male member of the family was allowed to pass on the wealth to his successors.
- The others were not allowed to marry. More precisely, they were not allowed to marry a Namboothiri woman.
- They were allowed to enter into a sambandham (literally, 'relationship') with a lower caste woman (often a Nair and often married also to another man who would conveniently disappear when the Namboothiri arrived to visit.)
- But their children would not be brahmins, being basically illegitimate, and would have no right to the family property. Human beings are frail, so these rules had loopholes.
- The Nair were a caste of warriors with an elaborate code of honor. somewhat like the Samurai of Japan. Their status was above that of the laborers, but several rungs below the namboothiri. They received



education in martial arts at a *kalari*.

- Most oriental martial arts are of Indian origin: the shao-lin monks were Buddhists who carried the knowledge to China and eventually into Japan.

- Eventually many Nair families usurped some power and wealth through gifts; but never enough to truly threaten the established order.

- But down to modern times, Nair women hold the rights to all property and power in Nair society is definitely in the hands of the women-an anomaly anywhere, and especially so in India.

- This meant there were many unmarried Namboothiri women wasting away in each household.

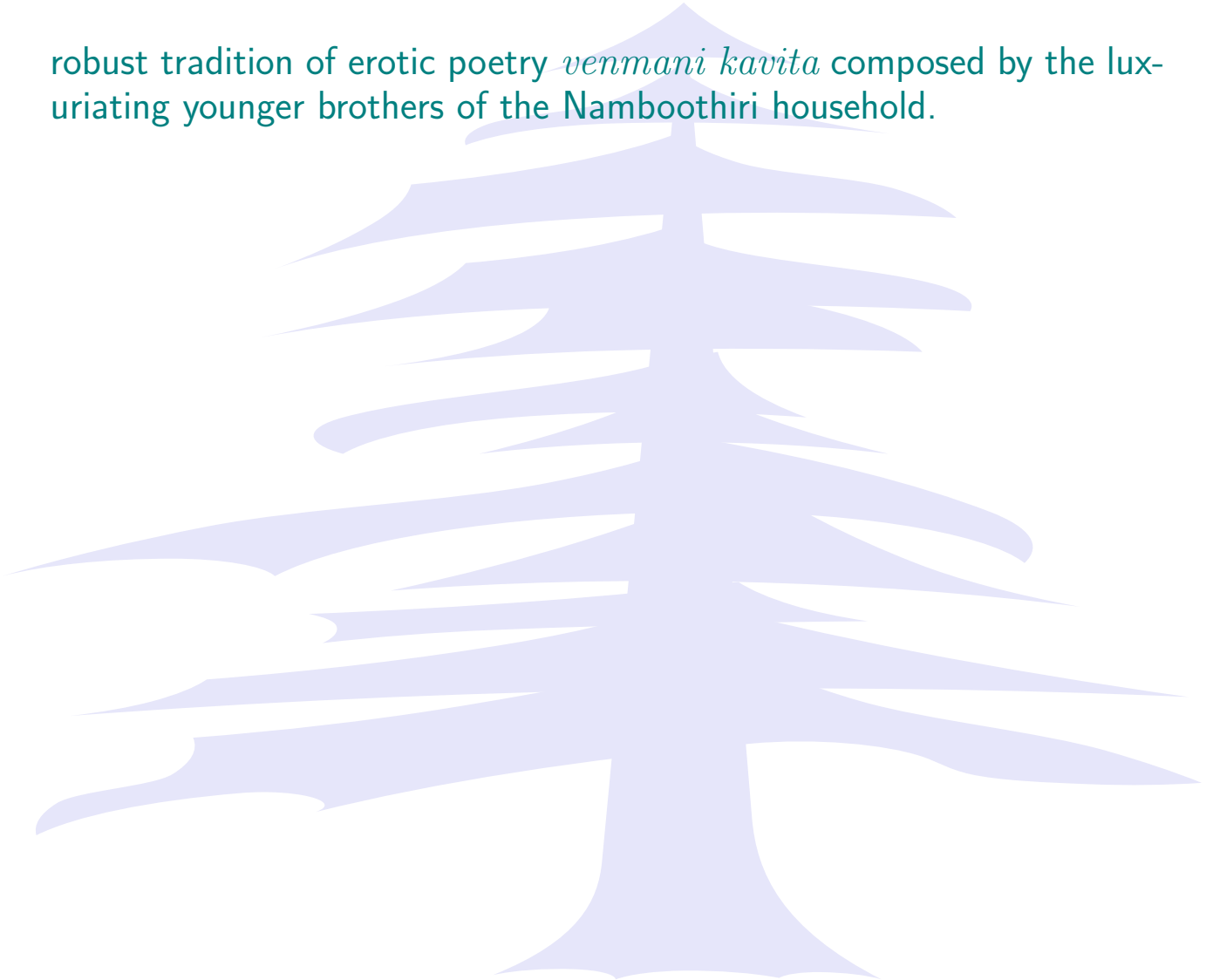
- Just as there were many younger Namboothiri brothers who had a life of leisure : not having to worry about either managing the family estate (the oldest brother's job) or caring for their progeny (the Nair stepfather was supposed to do that when he was not away fighting.)

- They were all highly educated and some of them turned to literature and the sciences- such as astronomy -as an outlet for their creative energies.

- Not all namboothiris were obsessed with spirituality. There is a



robust tradition of erotic poetry *venmani kavita* composed by the luxuriating younger brothers of the Namboothiri household.





Sutra, Bhashya, Sidhanta, Gitika

- Sanskrit technical literature is vast. The astronomy texts alone runs into the thousands, and they are but a tiny fraction of the overall library.
- In all technical subjects there are different levels of texts.
- The briefest are *sutra* (literally 'thread'). They contain short pithy statements in prose that is to be memorised. They contain precise definitions, statements of results. No explanations, motivations or proofs.
- The *Patanjali yoga-sutra* is the foundation of *astanga yoga*; the *vyakarana sutra* of *Panini* are the foundation of axiomatic linguistics the world over; the *Brahmasutra* of *Vyasa* are about the ultimate spiritual experiences of a saint.
- The *kamasutra* read almost like a parody of this technical literature. It will continue to disappoint curious teenagers for ages to come. The autobiography of Casanova makes far better reading.
- A typical astronomy text would be less pithy than a *sutra*. It would contain definitions, results, mathematical formulas, instructions on how to do



calculations, tables of functions such as sines, all expressed as Sanskrit poems.

- A mathematical work had to also be a good piece of poetry. Neelakanta especially was a total scholar knowledgeable in all six branches of Indian philosophy who could write exquisite mathematical poetry.

- The *aryabhateeyam* is composed in the noble *arya* meter.

- Did the author use a pseudo-nym because of the meter he chose? Or did he chose that meter because of his given name?

- A *bhashya* is a commentary on an established text such as a *sutra*. The commentary of Sankara on the Brahmasutra, and the ten Upanishads are the doudnation of the dominant philosophic tradition of India, the Advaita Vedanta.

- A *bhashya* is usually an explanation and elaboration containing motivations and proofs.

- But it can also contain much original work: the *bhashya* of Neelakanta on the *Aryabhateeyam* reports deep explorations into calculus.

- Sidhanta* is a theoretical work. The *Surya-siddhanta* is attributed to the Sun-God himself, and describes the motion of the sun.

- tantra* means technique; in the astronomical context, techniques of



calculations.

- *tantra* also has a separate spiritual connotation as a school of mysticism. For some reasons many western acolytes of Indian culture seem to think that tantra is all about sex.

- Could be useful. Maybe we can sell many copies of Neelakanta's Tantra-Sangraha: the "summary of (astronomical) technique".

- A *gitika* (song), *darpana* (mirror), *deepika* (light) are all elementary texts meant for beginners. Hence *siddhanta-deepika* would be "Introduction to Theoretical Astronomy".





Notation for numbers: katapayadi

- The decimal notation was well-established. It originates in India and was transmitted to the Europe via the Arabs (which is why they are called the 'Arabic numerals').

- Since mathematical works were poems, there had to be a way of converting numbers into words.

- The Sanskrit (same as Malayalam except for the fonts used) alphabet provides a natural way alpha-numerical system.

- There are twentyfive consonants arranged in a five by five table: ka

kha ga gha nga

cha chha ja jha nha

ta ttha Da Dha n.a

tha thha da dha na

pa pha ba bha ma There are also the miscellaneous sounds ya ra la va

s.a sha sa ha

These can be combined with any of sixteen vowels.





●ka stands for 1, kha for two and so on till nha which stands for zero. Then we start again with ta which stands for one and so on till na. Then again pa stands for one till ma which is five. ya is one again and so on upto ha which is eight. A pure vowel (which can only appear at the beginning or end of a word) stands for zero as well. Using these rules any number can be converted into a word.

●Each number is written out to base ten, then taken in reverse order and converted into a word by the above rules. With practice you can automatically turn any word into a number in your head: the way some of you can read *TeX* even without a previewer.

●Since a trailing vowel of a word in sanskrot is often lost when it is combined with other words, it would be convenient if it were irrelevant; the beginning zero of a number in the decimal system is irrelevant. So if we invert the number before converting it, these two rules would fit.

●There are many words for each number. It is up to the authors ingenuity to find a word that captures the meaning of the number; or fits rhythmically into a poem.

●A renowned Malayalam poet (*Vishnu Narayanan Namboothiri* visited Princeton and visited Einstein's house which was then a museum.



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He noted that the address of the house could be encoded as *thrimudi*:
the 'highest peak'.



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