Book of Abstracts

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Indian Society for History of Mathematics

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Ab-1
SOME NOT-WELL-KNOWN CALCULUS IDEAS IN THE KERALA SCHOOL OF ASTRONOMY AND MATHEMATICS

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The true longitude of the Sun or the Moon including the correction due to the 'equation of centre' involves the sine of the anomaly. So, the rate of change of the true longitude, or the 'true daily motion' would involve the rate of change of the sine function. The correct expression for this, employing the cosine as the 'rate of change' of the sine, was given by Munjāla (932 CE) in his *Laghumānasa* and also by Āryabhaṭa –II (950 CE) in his *Mahāsiddhānta*. In his *Siddhāntaśiromaṇi* (1150 CE), Bhāskara-II recognises the 'true daily motion' as the instantaneous velocity, and explains how the cosine function appears in the expression for it.

In the context of finding the sine function for an arbitrary angle, *Tantrasaṅgraha* of Nīlakaṇṭha Somayājī (1500 CE) explicitly gives the second order Taylor series for the sine and cosine functions, for the first time. *Yuktibhāṣā* (1530 CE) of Jyeṣṭhadeva (well known for the proofs of the infinite series expansions of π and sine and cosine functions) derives the results using a simple geometrical construction. In later Kerala texts like *Sphuṭanirṇayatantra* (1593 CE) of Acyuta Piṣāraṭi and *Dṛkkaraṇa* (1606 CE), (possibly a work) of Jyeṣṭhadeva also, the second order Taylor series for the sine and cosine function are explicitly used for finding their values for arbitrary values of the angle.

In *Sphuṭanirṇayatantra*, and also another work called *Karaṇottama* (around 1590 CE), considers an approximation to the '*śīghra*' correction to the longitude of an actual planet (Mercury, Venus, Mars, Jupiter and Saturn). It is of the form $\frac{r_s \sin M}{R + r_s \cos M}$, where r_s and R are constants and M is a variable called the '*śīghra-kendra*' (solar anomaly). The rate of change of this with respect to time t, is correctly given in the text (though not in the following modern notation) as

$$\frac{\Delta}{\Delta t}\left[\frac{r_s \sin M}{R + r_s \cos M}\right] = \left[\frac{r_s \cos M}{R + r_s \cos M} + \frac{{r_s}^2 \sin^2 M}{(R + r_s \cos M)^2}\right]\frac{\Delta M}{\Delta t} .$$

[Note : In Indian mathematics and astronomy, the sine is actually the 'length of the opposite side' in a right triangle with a given hypotenuse . Moreover, the argument of the sine is the relevant arc, not the 'angle'.]

Ab-02

SEMI-REGULAR CONTINUED FRACTION METHOD AS GIVEN IN *DṚKKARAṆA*

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A brilliant school of astronomers and mathematicians founded by Mādhava (c. 1340– 1420) flourished in Kerala between 14 th – 17th century CE. One among them was Putumana Somayāji, the author of *Karaṇapaddhati* (c. 1532 - 1560), which explains the mathematical basis of the *vākya* system of computing the planetary positions, in which the true positions of planets are found directly from mnemonics along with some simple arithmetical operations. Now, the calculation of the mean positions of the planets would be the first step in the computation of the true positions.These would be proportional to the rates of motion of the planets which would involve ratios of large numbers. Some other variables needed for obtaining the true positions also involve ratios of large 'mulitipliers' and 'divisors'. *Karaṇapaddhati* describes a mathematical technique known as *vallyupasaṃhāra* which is a variant of the kuṭṭaka method for solving linear indeterminate equations. In Karanapaddhati, this method is used for obtaining smaller multipliers and divisors for the aforesaid ratios. *Vallyupasaṃhāra* method of transforming the *vallī* (a row of numbers) is essentially the recursive process of calculating the successive convergents of the continued fraction associated with the ratio. In *Karaṇapaddhati*, it is the simple continued fraction expansions that is used. In a later text called *Dṛkkaraṇa* (1606 CE), probably authored by Jyeṣṭhadeva, we have a variant of this method in which semi-regular continued fraction expansions are prescribed, with modified recursion relations. In this talk, having discussed the method given in *Karaṇapaddhati*, we explain the semi-regular continued fraction method as given in the text *Dṛkkaraṇa*.

Ab-03

AN IN-DEPTH LOOK AT THE FIRST METHOD OF *UDAYALAGNA* COMPUTATION IN THE *LAGNAPRAKARAṆA*

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The determination of the ascendant (*udayalagna*) or the rising point of the ecliptic is an

important problem in Indian astronomy, both for its astronomical as well as socio-religious applications. Thus, astronomical works such as the *Sūryasiddhānta*, the *Brāhmasphuṭasiddhānta*, the *Śiṣyadhīvṛddhidatantra*, etc., describe a standard procedure for determining this quantity, which involves a certain approximation. However, Mādhava (c. 14th century) in his *Lagnaprakaraṇa* employs innovative analytic-geometric approaches to outline several procedures to precisely determine the ascendant. This paper discusses in detail the first method described by Mādhava in the *Lagnaprakaraṇa.*

Ab-04

DISSECTIONAL PROOF OF AN ALGEBRAIC IDENTITY FOUND IN *ĀRYABHAṬĪYABHĀṢYA*

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Starting from Āryabhaṭa, several Indian mathematicians have dealt with the problem of finding the cube and cube-root of an integer. In this connection, the commentators have also demonstrated their proofs in detail, which may be described as algebraic proofs. Besides this, they have also attempted to provide rationale for a given expression by resorting to a kind of dissectional proofs. Especially, Nīlakaṇṭha (1444---1544 CE) seems to have a proclivity to provide such proofs for demonstrating various mathematical principles. During the talk we shall take one such example related to the rationale behind the procedure for finding the cube of a number found in his *Āryabhaṭīyabhāṣya*.

Ab-05

A STUDY OF NĀRĀYAṆA PAṆḌITA'S 4 × 4 PANDIAGONAL MAGIC SQUARES WITH *TURAGAGATI*

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In India, magic squares have been known for more than two millennia and have been thoroughly studied and well presented in the last millenia alone based on the extant texts. Nārāyaṇa Paṇḍita has dedicated the entire fourteenth chapter of his *Gaṇitakaumudi* (c. 1356 CE) to *Bhadragaṇita* where he systematically introduces the principles governing the construction of magic squares and also details general methods for the construction of different forms of magic squares. The focus of this talk is to present a thorough study of the algorithm for constructing pandiagonal magic squares of order 4 using *Turagagti* or horse-moves as propounded by Nārāyaṇa Paṇḍita in *Gaṇitakaumudi*. Earlier studies by a few scholars starting with Dutta and Singh have presented this algorithm by showing how consecutive pairs get placed in horse-moves. Whereas, in our presentation, we shall demonstrate that the construction of the entire square can be made by employing only horse-moves. Besides presenting this algorithm in modern parlance, in this talk we shall also discuss various properties exhibited by these squares along with their proofs and further analysis.

Ab-06

ON THE IMPACT OF HISTORY ON MODERN RESEARCH AND TEACHING

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We have shown that the works of Brahmagupta, Baudhāyana and Tartaglia spell out not only theorems but their assumptions and the essential elements of proofs in the form of an apodictic discourse. To these results, we add three elements. First, the notion of apodictic discourse, absent from Aristotle's rhetoric, was not introduced sooner because of the weight given in some teaching traditions, especially British, to Hellenistic Mathematics, leading to an over-estimation of sources in Greek, observed even today. Second, "Modern" Science is partly Indian, for it is the result of an essential reorientation of Mathematics around 1900, influenced by the simultaneous realization that Hellenistic mathematics was not consistent, and that there were other forms of mathematics elsewhere: in India, the Middle East and China, but also in forgotten sources from the Mediterranean world. Third, if time permits, we shall show that tools from

History help obtain new results in "Modern" Science, focusing on our very recent results on Wave Mechanics. Other earlier results of ours may be viewed as illustrations of the same approach.

Ab-07

DAVID GREGORY'S MANUSCRIPT "ISAACI NEWTONI METHODUS FLUXIONUM" (1694): ITS SIGNIFICANCE FOR THE SCRIBAL CIRCULATION OF NEWTON'S MATHEMATICAL METHODS

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In the 1690s Newton circulated knowledge about his method of fluxions among the circle of his correspondents and acolytes. Most notably, he shared his method of fluxions with Wallis and Fatio de Duillier. As its is will known, Newton sent a presentation of the basic concepts and notation for fluents and fluxions, together with some theorems on quadratures, to John Wallis, who published it in the second volume of his Opera (1693). Wallis's colleague at Oxford, David Gregory (1659-1708), after visiting Newton in Cambridge in May 1694, was shown several mathematical manuscripts, including works related to fluxions. He took excerpts and, back in Oxford, composed a short treatise on the method of fluxions which circulated amongst some British mathematicians. In this talk I will discuss the significance of Gregory's manuscript treatise on fluxions for the understanding of Newton's strategy of publication and of Gregory's self-fashioning as an active player on the British mathematical scene.

Ab-08

D. E. SMITH AND THE WRITING OF A « HISTORY OF HINDU MATHEMATICS »

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Through a collective project on the work and legacy of the American educationist, book collector and historian of mathematics D. E. Smith (1860-1944), his correspondance with people in India, and/or working on the history of mathematics and astronomy in India was uncovered spanning from 1907 to 1934 and counting a total of 62 letters. In this paper I would like to explore how this correspondance highlights his influence on several projects concerned with the history of mathematics in South Asia at the beginning of the 20th century and notably the impulse he seems to have given to what has become one of the reference manuals, Datta and Singh's History of Hindu Mathematics. Indeed, these still unpublished exchanges show that from an early stage, D.E. Smith had a vision and encouraged those he met concerned by the topic, to write a 'History of Hindu Mathematics'. Along with this vision, came a number of questions that will become

familiar, much discussed, topics: in the letters what is mostly at stake is the use, existence and date of the decimal place value notation. This took the form of several sub-threads dealing with the dates of the earliest evidence of the decimal place value notation in India, the existence of an abacus and the use or existence of alphabetical notations, the shape of ancient numerals, early evidences of zero. But he was also interested in other questions, such as the latitude and longitude of Laṅkā, the Sanskrit word for square and cube roots or the origins of algebra and indeterminate analysis. As Indian mathematicians will discover his publications on these topics, as they will react to them, the questions he raised will become standard discussions, tropes, that will structure the way the history of mathematics (and astral science) in South Asia will be written. In a previous publication, (Keller, 2011), I had shown how G.R. Kaye's publications had triggered reactions from a group of related mathematicians S. K. Das, B. Datta and S. Gāṅguli, to correct him. The correspondence of Smith with Kaye, Datta, Gāṅguli and Sengupta sheds a new light on this story. It shows that Smith did more than just relay emerging voices from India. He interacted with them, helped them publish and publicise their ideas abroad, encouraged them to write a history of 'Hindu mathematics', raising questions that they engaged with, sometimes with exasperation and anger.

Ab-09

TWO ALGEBRAIC UNKNOWNS IN LATIN AND ITALIAN MATHEMATICS, 1200-1500: KNOWN BUT NOT CONSIDERED ANYTHING SPECIAL

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The use of several algebraic unknowns was well-known in India at least since Brahmagupta, and in Arabic algebra we know it (in a different form) from AbūKāmil. In Europe, they are important from Viète and Descartes onward. What can be said about European algebra before 1500?

It is known that Leonardo Fibonacci solves one first-degree problem in the *Flos* by means of the algebraic unknowns *res* and *causa*, both meaning *thing.* Less noticed is that three similar cases can be found in the *Liber abbaci*(with unknowns *thing* and *purse*, *amount* and *thing*, and *thing* and *part*), while a second-degree problem in the presentation of algebra section makers use of *thing* and *denarius*. Close reading of these problems shown that the last example (borrowing the Arabic use of a coin name as second unknown) was badly copied and not understood, while the former are considered examples of *regula recta*, borrowed from the Arabic West and not considered anything special. The next occurrence is in Antonio de' Mazzinghi's*Fioretti*, where the technique is independently developed, and used in second-degree problems. Without claiming so, Antonio must have been aware of creating something new – but those who copied him with admiration in the following century did not understand that aspect of his work. Instead, an anonymous manuscript from the early 15th century takes up a vaguely remembered and not fully understood technique from the *regula recta*. Only Benedetto da Firenze, around 1460,

develops the *regula-recta* technique with two unknowns, and even uses is with letter abbreviations – but even he without inspiring others.

Why would an idea that later turned out to be fundamental in the transformation of mathematics not unfold for three centuries? The talk suggests an answer.

Ab-10

ROLE OF HISTORY OF MATHEMATICS ON EDUCATION OF MATHEMATICS

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In this article we are going to discuss how new and old mathematics are related on works of Islamic mathematician and how history of mathematics can help education of mathematics to improve and motivate it.

Ab-11

DAIBAGYA BALBHADRA & BALBODHINI WITH ACHARYA SATANANDA & BHASHWATI

(An Academic Relation between Nepal and India)

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Daibagya Balbhadra (1494) was a residence of Jumla district. He had wrote commentary of the Bhashwati in the name of the 'Balbodhini' (1542). Balbhadra's 'Balbodhini' is a manual book of mathematics which gives explanatory note and many examples to practice the mathematics from Bhashwati. It is the third commentary of Bhashwati; the first commentary of Bhashwati was Aniruddhas' 'Shishuboddini' (1496) and the second commentary was Madhvas' in 1526. It was the 226 years ago than Prithvinarayan Shah (1722-1774) as the King (1768-1775) of Nepal. It is 181 years ago than the time of the appointment of Royal astrologer in the Royal observatory at Greenwich.

Satananda (1068) was born in Jagannathpuri of Orissa. He wrote the Bhashwati Karana (1099). Satananda's Bhashwati was as a text book of Mathematics that helps to count calendars (Panchanga) and teaching addition, subtraction, multiplication and division for Mathematics

practices. It is based in Surya Siddhanta. It was the time of 576 years ago than the appointment of the Royal astrologer in the Royal observatory at Greenwich. Probably Satananda is the first gleaming trail-blazer astrologer cum astronomer in Bharatavarsa.

Ab-12

ARITHMETIC MEAN IN ANCIENT INDIA AND EUROPE

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The importance of the Arithmetic Mean was articulated in 1809 by C.F. Gauss, one of the pioneers of mathematical statistics, as follows: “it has been customary certainly to regard as an axiom the hypothesis that if any quantity has been determined by several direct observations, made under the same circumstances and with equal care, the arithmetic mean of the observed values affords the most probable value, if not rigorously, yet very nearly at least, so that it is always safe to adhere to it.”

Like the decimal system, the Arithmetic Mean now appears as a natural concept to us who have grown up with it. But the history of the concept shows that its introduction must have involved conceptual subtleties. S.M. Stigler, a distinguished statistician of our time, considers the Arithmetic Mean as the first of the “five ideas that changed statistics and continue to change the way we think about the world”.

The Arithmetic Mean has been variously perceived: as an exact mathematical concept, as an applied tool for combining measurements in experimental sciences, as a measure of the central tendency in statistical data, etc. Any measure of the central tendency seeks to identify that [central] value of the distribution which can be taken to be its best representative. In this talk, we shall discuss the emergence of some of the avatars of the Arithmetic Mean at different time points, in different contexts, in different mathematics cultures.

The word “mean” is derived from Old French meien meaning “middle” or “centre”. And indeed the Arithmetic Mean captures the concept of the “centre”. In fact, the first recorded definition of Arithmetic Mean is as a geometry concept in ancient Greece (c. 500 BCE): a number equidistant from two given numbers, i.e., as the “middle” point of two numbers. But it does not appear to have been envisaged as a statistics concept (average or best representative). The general Arithmetic Mean $\bar{x} = x_1 + x_2 + \cdots + x_n$ and its statistical applications have not been found in European treatises prior to the sixteenth century CE. The formulation $\bar{x} = x_1 + x_2 + \cdots + x_n$ (whether expressed through symbols or words) is something intrinsically algebraic and, for effective application, requires good algorithms for performing all the elementary arithmetic operations. The appearance of the arithmetic mean in Europe coincides with her adoption of the decimal system and arithmetic methods based on the decimal system (which are, in essence, of Indian origin) and with the emergence of algebra. A basic idea at the heart of the Arithmetic Mean as a statistical estimate is to combine observations — to replace several numbers by a single number. Thinkers on statistics like Stigler feel that this idea is counterintuitive: for it seeks, paradoxically, to gain information about the data by discarding information, namely, the individuality of the observations. This could also explain the delay among European scientists in developing a precise method (like Arithmetic Mean) for obtaining a best estimate on the basis of several observations. They relied on their judgments to select a particular observation thought to be the best rather than combine (and thereby spoil) it with other observations.

The technique of repeating and combining measurements on the same quantity can be seen in the work of Tycho Brahe and a few other astronomers towards the end of the sixteenth century, but the method for combining the repeated observations into a single number is not stated explicitly. Historians of statistics have usually identified the earliest unambiguous statistical use of the Arithmetic Mean in a work of the English astronomer Henry Gellibrand (1635). In his Presidential address at the American Statistical Association in 1971, Churchill Eisenhart stated, "I fully expected that I would find some good examples of mean-taking in ancient astronomy; and, perhaps, also in ancient physics. I have not found any. And I now believe that no such examples will be found in ancient science."

But, as in the case of numerous other scientific concepts, the above account of history completely overlooks the clear, precise and abundant use of the Arithmetic Mean in the

treatises of ancient Indian mathematicians like Brahmagupta (628 CE), Śrīdharācārya (c. 750 CE), Mahāvīrācārya (850 CE), Pr.thūdakasvāmī (864 CE), Bhāskarācārya (1150 CE) and others. In fact, the Indian mathematicians define and apply the more general and sophisticated concept of the weighted Arithmetic Mean. An intuitive awareness of the law of large numbers for Arithmetic Mean also comes out in a commentary by the mathematician Gan.es.a (1545 CE).

The chapters in Indian arithmetic called khāta-vyavahāra (mathematical processes pertaining to excavations) describe how to compute the [average] depth, width or length of an irregular-shaped pool of water and thereby estimate its volume. It is in these chapters that the Arithmetic Mean is defined and used in the statistical sense — as the best representative value for a set of observations. Brahmagupta is one of the earliest Indian mathematicians in whose text the concept of [weighted] Arithmetic Mean occurs explicitly in this sense. He uses it to represent the depth of a ditch, when the depth is different in different portions of the ditch. The ancient Indian terms for Arithmetic Mean, like sama rajju (mean measure of a line segment) or samamiti (mean measure) which use the word sama (equal, equable, same, common, mean) confirm that the Arithmetic Mean was perceived by ancient Indian scholars as the "common" or "equalizing" value which would be the appropriate representative measure for various observed measurements. The treatment of the excavation problems through the Arithmetic Mean was possibly one of the factors which shaped the gradual development of calculus in India.

The weighted arithmetic mean also appears in ancient Indian arithmetic treatises as an exact mathematical formula in chapters on miśraka-vyavahāra (computations pertaining to mixtures) which address the problem of computing the proportion of pure gold in an alloy formed by blending of several pieces of gold of different weights and purities.

Ancient India had a strong tradition in computational mathematics and algebra which provided a conducive mathematical environment for the emergence of the statistical arith- metic mean. The conceptualization of the Arithmetic Mean involves the idea of combining several numbers into a single number. Ancient Indian mathematics is replete with various ideas of "combination". One is reminded of the profound bhāvanā of Brahmagupta — a law of composition which combines two solutions of a certain quadratic equation in three variables to produce another solution of the equation, a principle with momentous consequences in mathematics.

Ab-13

KṢETRAVYAVAHĀRA IN THE *BUDDHIVILĀSINĪ*

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The *Buddhivilāsinī* , an erudite commentary on the Līlāvatī of Bhāskara II, was written by Gaṇeśa Daivajña in 1545 CE. It is one of the few Indian works which concentrate on giving upapattis for the results stated in the texts. Gaṇeśa ascertains this aim when he says,' '*atropapattikathane akhilasārabhūte pashyantu sujñagaṇakā mama buddhicitram*' which means 'Let the well-informed mathematicians look at my variety of analytical thinking in the entirely essential statement of *upapattis* here'. There are more than a hundred *upapattis* in *Buddhivilāsinī* and in *Kṣetravyavahāra* alone there are forty four *upapattis*. This unit starts with the classification of plane figures in *Buddhivilāsinī* .There are three sections here namely the triangles, quadrilaterals and circles. Some of the selected *upapattis* on the properties of right triangles, area and diagonals of quadrilaterals, chord, arrow and diameter of circle etc. from the three sections will be presented here.

Ab-14
MENSURATION OF THE BOW FIGURE IN ANCIENT TIMES

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The ancient Jaina scholars had formulae concerning the geometry of the bow figure, namely a chord in a circle together with the smaller arc of the circle cut off by it. In this talk we shall discuss the formulae, their significance from a mathematical point of view, analogues in other ancient cultures, and other related issues.

Ab-15
NON LINEAR EQUATIONS IN *BIJAGAṆITA*

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Bhaskaracarya of the 12th century was one of the earliest mathematicians to write separate treatises on Algebra and Arithmetic. His Algebra text is *Bijaganita* where he initially expounds the six operations namely addition, subtraction, multiplication and division, squaring and extraction of square root of negative and positive numbers, zero, unknown variables and surds. Calling these the tools of algebra, Bhaskara then teaches their application in equations.

Equations are denoted by the word *samikarana* meaning 'making equal'. The two sides, known and unknown are made equal and the value of unknown is found out.

Bhaskara and later his commentator Krishna Davajna who wrote *Bijapallava,* divide equations into two classes (1) Equations of one unknown and (2) Equations in two or more unknowns. The class (1) again comprises two sub classes (a) simple equations and (b) quadratic and higher equations. The class (2) has three sub classes (a) simultaneous linear equations (b) equations involving the second and higher powers of unknowns and (c) equations involving products of unknowns.

The *vargaprakrti* equation $Nx^2 + 1 = y^2$ or indeterminate equation of second degree is not being analyzed here, considering the vastness of the topic. This paper however shall be concentrating on classes (1 b) and (2 b).

Ab-16

Indic Computational Thinking and Relevant Ideas in Programming Language Design

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In this talk, we discuss Computational Thinking in India as it relates to some ideas in Programming Language Design. We present examples from combinatorics, logic and linguistics.

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Ab-17

BHASKARA-I: AN ANCIENT MATHEMATICIAN AND ASTRONOMER (600-680AD).

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Very little is known about the life of Bhaskara-I, but the credit for the representation of numbers in a positional and systematic way goes to him and he was the first mathematician to use first nine Brahmi numbers from 1 to 9 using a small circle for zero in a scientific manner in Sanskrit. He wrote two treatises *The Mahabhaskariya* and *Laghu Bhaskariya,* and also wrote commentaries on the work of Aryabhatta which is known as *Aryabhatiyabhashya*. Bhaskara-I elaborates Aryabhatta's method for solving linear equations and emphasized in providing mathematical rules.

Keywords: *Mahabhaskariya, Laghu Bhaskariya, Aryabhatiyabhashya.*

Ab-18

PRIME NUMBERS IN *TILOYASÅRA*

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A prime number is a natural number greater than one which has exactly two positive divisors, one and itself only. The study of prime numbers was important in ancient times and now it has become more significant in modern times due to its application in solving the real world problems. The Greek mathematician Euclid (325-265 BCE), in his famous book *The Elements*, has discussed prime numbers for the first time in History of Mathematics. Another Greek Eratosthenes (276-194 BCE) developed an algorithm for finding all possible primes. Nicomachus (c.100 CE) has given prime and composite numbers in his *Introduction of Arithmetic*. Fifteen centuries later Pierre de Fermat (1601-1665 CE) has discussed prime numbers extensively and has given Fermat numbers like $F_n = 2^{2n} + 1$ and Fermat's Little Theorem. Marin Mersenne (1588-1648) has given particular numbers of the form $Mp=2^p - 1$. Mersenne claimed Mp is prime for p=2, 3, 5, 7, 13, 17, 19, 31, 67, 127, and 257 and composite for all other numbers p<257. It was established that Mersenne's list was not accurate because he excluded p=61, 89 and 107 and included incorrectly 67 and 257. Many other scholars like Euler, Gauss, Riemann etc have contributed in the development of prime number theory.

In this paper, we will discuss in detail that great Jain Mathematician Nemicandra Siddhåntacakravartî (975 CE) has given prime numbers in *Tiloyasåra*. He was the first Indian who contributed to development of prime numbers.

Ab-19

NAMES OF DECIMAL PLACES IN SANSKRIT LANGUAGE

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We take a review of names of decimal places in the Indian System from Vedic times to recent times used by various authors in Sanskrit Language.

Ab-20

लीलावती : एक लोकप्रिय नाम

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12 हवीं शताब्दी ईसवी के महान भारतीय गणितज्ञ भास्कराचार्य (1114 ई. जन्म) की सर्वाधिक चर्चित कृति सिद्धांत शिरोमणि ह ै। इस कृति के 4 भागा ें में से प्रथम भाग लीलावती ह ै। लीलावती के व्यक्तित्व के बारे में अनेक कि ंवदन्तियाँ प्रचलित ह ैं किन्तु इस बात स े सभी सहमत ह ैं कि लीलावती का सृजन भास्कराचार्य द्वारा लीलावती की स्मृति का े अक्षुण्ण रखन े ह ेतु किया गया। देश के विविध अंचलों में लीलावती की शताधिक पाण्डुलिपियाँ संरक्षित ह ैं जा े इसकी लोकप्रियता का सबल प्रमाण हैं। इस महत्त्वपूर्ण कृति की दर्जना ें टीकायें भी 15 वीं से 19 वीं श.ई. क े मध्य रची गई। इस कृति की लोकप्रियता के कारण 12 वीं श. से 19 वीं. श. के मध्य अनेक लेखका ें ने अपनी कृतियों का नामकरण लीलावती किया।

1. लीलावती (कन्नड़) – राजादित्य (1190 ई.)

2. भाषा लीलावती – मथुरानाथ

3. भाषा लीलावती – अज्ञात

4. भाषा लीलावती – लालचंद

5. भाषा लीलावती – मा ेहन मिश्र (1657 ई.)

6. लीलावती की बैखरी अनुवाद – लाभचंद्र उर्फ लाभवर्द्धन (1679 ई.)

7. लीलावती चन्द्रिका (ब्रज भाषा में)– लाला अनूप राय 8. लीलावती भाषा चउपई – अज्ञात

9. भाषा लीलावती – अज्ञात

10. भाषा लीलावती – आनन्द मुनि (1674 ई.)

11. भाषा लीलावती – तेजसिंह

12. लीलावती भागवत – लालेन्द्र जैन कवि

13. लीलावती (कन्नड़) – बाल वैद्यद चेलुव (1715 ई.)

इन सब प्रकाशित/अप्रकाशित कृतियों का स ंक्षिप्त परिचय प्रस्तुत लेख में प्रस्तुत ह ै।

Ab-21

IN HOW MANY DAYS WILL HE MEET HIS WIFE?*

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In how many days will he meet his wife? This is a question asked at the end of each of two problems embedded in the verses of the last chapter of the *Vyavahāra-gaṇita* ('Mathematics of Transaction') of Rājāditya of 12th century. Those two problems are based on the subject of speed. He infuses elegance in them by choosing the charming idea of a husband"s meeting with his wife after their quarrel. This paper not only understands the algorithms offered by him to solve them on their own terms as well as on modern terms and discusses historicity of those two problems but also provides an insight into why he posed those two problems using those three terms, namely, wife, husband, and quarrel between them. The idea of setting each of his two problems using those three terms is either a composition of "make learning fun by posing a value based question" and "real life incident witnessed by him" or that of "make learning fun by posing a value based question" and the motif of "broken string and scattered pearls". The latter composition seems to be more plausible. His variation to the motif is just indicative.

Ab-22

NUMBERS, MANTRAS, YANTRAS (MYSTIC DIAGRAMS) IN INDIAN TRADITIONS AND THEIR IMPACT

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Mathematical numbers have their own importance since ancient time. The common men have always fascination about the numbers. There are many myths associated with the numbers due to some superstitions. Religion has been the dominant feature in all the culture. People associated Magic Squares, Mantras, Yantras with their religious faith and are using them to achieve prosperity and peace. It was believed that Magic Squares, Mantras, and Yantras have some relation with Planets and Deities. Different Magic squares, Mantras, and Yantras were prepared for different Planets, Deities, God, and Goddess. Magic Square was well known to Indians and it was also called 1 as A1⁄2ka Yantra. In Vedic and Jaina culture - Mantras, and Yantras were prepared according to their (Stotras) Rituals. Yantras are treated as mystic diagrams which are used in worship, meditation and ritual practices in Vedic and Jaina traditions.

The present paper deals with the various aspects of Mantras and Yantras including traditional views, classification, and technical terminology along with appropriate historical remarks mentioned in Vedic and Jaina manuscripts. The Śrîyantra, Ga¿esh, Durgā, Rudra Yantra and

Jaina's Yantras- Siddhacakra, Âśima¿ðala, and Gha¿tåkar¿a etc. have been given special attention. I think that the general study of Yantras and Mantras will motivate and draw the attention of researchers to this neglected field of ancient and medieval culture in India. The present paper is a humble attempt to find various aspects about Numbers, Magic squares, Mantras, and Yantras (Mystic Diagrams) and their impact in Indian traditions.

Ab-23

GENERALIZED BRAHMAGUPTA-JAYADEVA-BHĀSKARA PROBLEM

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One of the famous problems in the history Indian Mathematics is the one stated by Brahmagupta in the seventh century and completely solved by Bhāskara in twelfth century. The problem is to solve the equation $Dx^2 + 1 = y^2$ where D is a given nonsquare positive integer and the desired solutions x, y are integers. In seventeenth century, the same equation was contemplated by Fermat without the knowledge of Indian history and he posed it as a challenge to the mathematicians. Its solution led to many techniques in Quadratic forms in number theory and the high point was the work of Gauss in eighteenth century.

We discuss a generalized version of the original problem which asks for all possible integers c such that $Dx^2 + c = y^2$ for some integers x, y.

The generalized question naturally arises from the method of the Indian solution which consists of solving the generalized problem for some convenient c and then cleverly modify it to lead to the desired solution.

We present a solution to the generalized problem by the same method as Bhāskara by using the Theory of Bhāskara forms in Ayyangar's paper "New light on Bhāskara's chakravala · · · " in JIMS(1929-1930) vol. 18.

We also compare and contrast the solution with the techniques of using the Gauss' theory of Quadratic forms in Number Theory.

Ab-24

RAMANUJAN – THE LOST MASTER OF MATHEMATICS

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Shrinivasa Ramanujan was one of India's greatest mathematical geniuses. He made substantial contributions to the world of Mathematics. He demonstrated unusual mathematical skills at school , winning accolades and awards In our survey we observed that very less number of students are aware of Shrinivasa Ramanujan's contribution in mathematics. The contribution of great Indian Mathematicians was acknowledged by the world but unfortunately we Indians are unaware with these. In this paper I give some of the important contributions and brief introduction of the great Mathematician. The aim of this paper is that the students get motivation themselves for the study of unique work of the great Indian hero Shrinivasa Ramanujan and enlighten the maximum number of students by his contribution. I have illustrated some of his mathematical problems and its solutions to highlight his intelligence in the field of mathematics.

Ab-25

EVIDENCE AND IMPLICATIONS OF BRAHMAGUPTA'S DEFINITION OF *ŚŪNYA* FAILING TO BE TRANSMITTED TO RENAISSANCE EUROPE VIA THE ARABIC WORLD

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Historians of Indian mathematics are familiar with Brahmagupta's 7th C. 'Laws of Sign' involving positives, negatives and zero. From chapter 18 of his 628 CE *Brāhmasphuṭasiddhānta,* 18 simple sutras can be distilled that are in agreement with modern Laws of Physics. However, 21st C. Foundational maths pedagogies remain disconnected from both Bharat's Maths and the physics of our time. This presentation addresses the reason why. A cross-cultural review will reveal an incomplete understanding of Bharat's zero in the Medieval Arabic world. This meant zero as a placeholder was transmitted to Renaissance Europe, yet the more profound role of zero as a number, defined as the sum of equal yet opposing positive and negative quantities, was not. Along the way, neither negatives nor zero were involved in the development of Arabic algebra. The aftermath, perpetuated by Fibonacci, was a failure of the British to correctly understand the true nature of zero mediating a symmetric set of integers that empirically melded symbolic simplicity with laws of matter and energy. Thus, a confused asymmetric pedagogy arose via

Britain's fixation on Euclidean notions in which zero, one and negatives were excluded from the realm of number. Equipped with such insights, we can now explore ways to better integrate laws of mathematics, physics and common sense for the benefit of maths teachers today.

Ab-26

DEVELOPMENT OF CORRECTIONS FOR SOLAR LONGITUDE

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Obtaining the correct positions of luminaries with great accuracy has always been the priority of astronomers and mathematicians in all civilizations. Since the sun's position is pivotal in the preparation of almanacs (*pañcāngas*), my present talk focusses on it. After obtaining the mean Solar longitude, the equation of center (*mandasaṃskāra*) is applied to obtain the true Solar longitude. In Indian astronomy, by default, the mean and true Solar longitudes are calculated first to Ujjain's longitude (same as *Laṅkā*), as it is considered the prime meridian. After this step, certain corrections are prescribed for other locations, i.e., the *deśāntara, udayāntara, bhujāntara* and cara. My talk includes the development of these corrections from ancient to modern times, along with their significance and mathematical ratio-nale, with some illustrations.

Keywords: Solar longitude, corrections, Indian astronomy.

Ab-27

ON NILAKANTHA'S EXPLANATION OF PLANETARY MOTION IN 15TH CENTURY

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This paper is devoted to throw light on *Tantrasangraha* of Nilakantha Somayaji. Nilakantha Somayaji was an adorable Mathematician and Astronomer of 15th century belonged to Kerala. His work wasmostly in Sanskrit and also in Malayalam. There were several attempts made to translate and explain indetail all his worksin particular *Tantrasangraha*.*Tantrasangraha* is a book on Astronomy consists of 432 Sanskrit verses and 8 chapters. The first two chapters deals with motion and longitudes of planets. The first chapter deals with longitude motion of celestial objects. This paper is to study his theory on planetary motion in detail. This paper is divided into two sections. The first part of the paper is study the biography of Nilakantha Somayaji. And Second part is to throw light on the first chapter of *Tantrasangraha*. The second part of this

paper describes how Nilakantha Somayaji had described the year into 365 days, into months, into days, *tithis*, *adhimāsas*, the reason for in auspicious months, Solar eclipse and lunar eclipse etc.

Ab-28

A MODEL-BASED ANALYSIS OF COVID-19 BIG DATA: AN ADVANCED LINEAR ALGEBRAIC APPROACH

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This paper deals with Coronavirus disease (COVID-19) who has raised urgent questions about to mitigate and develop suitable analytical strategies to analyse big data which were collected from standardised protocols. It becomes important to immediately assess available data to learn what standard of care approaches are the most effective and evaluate it as fast as possible. Merging and cleaning of data from large multi-centre hospitals is crucial and requires sophisticated data management. Machine learning algorithms cannot work with raw data directly; data must be converted into numbers, specifically vectors of numbers. For that machine learning model is required. Then to feed the data in a machine learning model which is described by using the notation and operations of linear algebra. This paper presents a classic mathematical model which can timely identifies and successfully classifies COVID-19 infected and healthy persons. The proposed focus is global.

When dealing with high dimensional data, it is often useful to reduce the dimensionality by projecting the data to a lower dimensional subspace which captures the "essence" of the data. Dimensionality reduction involves reducing the number of input variables or columns in modelling data. The most convenient mathematical language to express data models is "Linear Algebra‟. The main concept used is Singular Value Decomposition (SVD) which automatically performs dimensionality reduction. The (SVD) of a matrix is a central matrix decomposition method in linear algebra. It has been referred to as the "fundamental theorem of linear algebra" (Strang, 1993) because it can be applied to all matrices, not only to square matrices, and it always exists.

Keywords: COVID-19, Singular Value Decomposition (SVD), Eigenvalue Decomposition, Eigen vectors Computation

Ab-29

FOLDING METHOD OF NĀRĀYAṆA FOR THE CONSTRUCTION OF *SARVATOBHADRA* OR MOST-PERFECT MAGIC SQUARES

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Pandiagonal magic squares (squares where, apart from the two principal diagonals, the six broken diagonals also add to the magic sum) of order 4 have been considered in India from the time of Nāgārjuna and Varāhamihira (c.550 CE). The properties of such *sarvatobhadra* squares were discussed by Bhaṭṭotapala (c.950) in his commentary on Varāhamihira's *Bṛhatsaṃhitā*. In his seminal work *Gaṇitakaumudī* (c.1350), Nārāyaṇa Paṇḍita gave a general method for the construction of pandiagonal magic squares of order 4, by a sequence of *turagagati* or horse movements. He also explicitly showed how all the 384 pandiagonal squares of order 4 can be constructed in this manner.

Nārāyaṇa Paṇḍita was also a pioneer in the introduction of the *saṃpūṭavidhi*, or the method of folding, by which a large number of magic squares can be generated by the composition of two auxiliary squares. Similar methods were later considered in Europe in the 18th century by de la Hire and Euler and this approach continues to be preferred way of constructing various types of magic squares in most of the contemporary investigations.

In this talk, we shall highlight the fact that the templates used by Nārāyaṇa Paṇḍita for the construction of *samagarbha* magic squares, or squares of order 4*n*, lead to not just to pandiagonal squares–they indeed generate what have come to be characterised as the "most-perfect magic squares" in recent decades. Similarly in the case *viṣama* or odd-order squares, by a simple alteration of the templates considered by Nārāyaṇa, the folding method can be seen to be the simplest method for the construction of magic squares which are both pandiagonal as well as associative.

Ab-30

HISTORY OF GENERALISATIONS OF METRIC SPACE AND FIXED POINT THEORY

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In this talk, we present about the historical development of various generalisations of metric space like G-metric, S-metric, b-metric, rectangular metric, partial metric. Topological properties of these spaces are also discussed and existence of fixed points in these spaces is also examined.

MSC 2010: 47H10, 54H25 **Keywords:** Metric space, fixed point

Ab-31

THE EXACT Π SOLVES THE MOON ILLUSION MYSTERY

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The moon illusion is an age old mystery. What is moon illusion? The moon seems larger in angular size when it is near the horizon than when it is high in the sky.

When the moon is closest to the Earth its angular size is about eleven percent larger than when it is most distant. This is explained in this presentation.

Ab-32

ON THE DEVELOPMENT OF POINTWISE DYNAMICS

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In 1970, Reddy has introduced pointwise expansive homeomorphisms to answer the problem brought to his attention by W. H. Gottschalk. This problem asks whether there exists any non-expansive homeomorphism which is expansive at each point or not. This notion has led to the introduction of a subfield of topological dynamics known as pointwise dynamics. In this talk, we

discuss the development of pointwise dynamics throughout this period to emphasize the importance of this field over the study of topological dynamics from a global viewpoint.

Ab-33

FIXED POINTS OF NON-EXPANSIVE TYPE MAPS AND APPLICATIONS

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Fixed Point Theory is a very important area of Topology, Noninear Functional Analysis and Applied Sciences, especially for the purpose of its applications. Moreover, its crucial role in quantitative sciences make it attractive to researchers. Due to its attraction, fixed point theory has been rapidly improved in the last few decades and several nice results have been established. The aim of this paper is to present some fixed point theorems for non-expansive type maps. Futhermore, we have given their applications to dynamic programmings.

Keywords: fixed and coincidence points, single-valued maps, multivalued maps and non-expansive maps.

Ab-34

BANACH CONTRACTION PRINCIPLE AND ITS JOURNEY OF LAST CENTURY: A SURVEY

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Historically, the classical result in fixed point theory was given by L.E.J. Brouwer in 1912. After, Banach Contraction Principle(1922) this field came into limelight and attracts many researchers towards this area. In this paper, we give some historical results which are generalizations and extensions of Banach contraction principle.

Keywords: Contraction, fixed point, complete metic space.

Ab-35

A CONCEPT OF METRIC AND ITS GENERALIZATIONS: A BRIEF HISTORY

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Frechet in 1906 gave the concept of distance function and define metric space. This concept was generalized in many different settings by sevral mathematicians during the last century. In this paper, we present the historical generalizations and topological properties of metric space and its generalizations in different settings from 1906 to till date.

Keywords: Fixed point, metic space.

Ab-36

FIXED POINT THEOREMS FOR MULTIVALUED SUZUKI TYPE $Z_{\mathfrak{R}}$-CONTRACTION IN RELATIONAL METRIC SPACES

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In this paper, we introduce the notion of a multivalued Suzuki type $Z_{\mathfrak{R}}$-contraction on a metric space endowed with a binary relation and establish some fixed point results for such mappings. Our results extend and unify the several well known results in the literature of fixed point theory. We have some illustrative examples to highlight the utility of our main results. Moreover, we also provide an application to an integral inclusion of Fredholm type equation.

Keywords: Binary relations; $Z_{\mathfrak{R}}$-contraction; simulation functions; $\mathcal{R}$-continuity.

AMS Subject Classification: 47H10, 54H25.

Ab-37

COUPLED COINCIDENCE POINT RESULTS INVOLVING SIMULATION FUNCTIONS

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In this paper, we prove some coupled coincidence point theorems using simulation functions. Our results extend and generalize the result of Khojasteh et al. (Filomat, 29 (6) (2015), 1189-1194) and Bhaskar and Lakshmikantham (Nonlinear Anal. TMA, 65 (2006), 1379-1393). We provide some examples in support of our results and also give an application in nonlinear integral equations.

2010 Mathematics subject classifications: 47H10, 54H25.

Keywords: Coupled coincidence point, simulation function, partially ordered set.

Ab-38

ON THE DEVELOPMENT OF MULTIPLICATIVE METRIC SPACES

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In this survey paper, we discuss some of the development of multiplicative metric spaces.

2010 MSC: 47H10, 54H25.

Keywords: fixed point, metric space, multiplicative metric space, b-multiplicative metric space, extended b-multiplicative metric space, contraction mapping.

Ab-39

ON UNIVALENT FUNCTION THEORY

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Let S be the class of analytic and univalent functions in the unit disk $|z| < 1$, that have a series of the form $f(z) = z + \sum_{n=2}^{\infty} a_n z^n$. In this talk, we will discuss about univalent function theory and its properties as coefficients bound, growth and distortion theorem, and necessary sufficient conditions of univalent function. Also we will discuss its geometric subclasses like starlike, convex, and close-to-convex function and their properties.

Keywords: Univalent function, starlike and convex functions, subordination, coefficients

Subject Classification: 30C45.

Ab-40

A HISTORICAL DEVELOPMENT OF C−CLASS FUNCTIONS IN FIXED POINT THEORY

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Abstract. The aim of this talk is to discuss the historical development of C−class functions that envelope enormous classes of celebrated and contemporary contractive conditions. We demonstrate that C-class functions, cone C−class functions, multiplicative C-class functions, inverse C-class functions, CF-simulation functions, C∗-class functions are powerful and fascinating weapons for the generalization, improvement, and extension of considerable conclusions establishing the existence of a unique fixed point and perform a magnificent role in the expansion of metric fixed point theory.

Key words. C-class, fixed point, metric space.

Ab-41

COMMON FIXED POINT IN QUASI-PARTIAL METRIC SPACE

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In this paper, we establish coincidence and common fixed point in a quasi-partial metric space for quadruple mappings via conditional compatibility and conditional reciprocal continuity. An application is furnished to demonstrate the applicability of results obtained and some interesting examples are also given to validate our results.

Keywords: Common fixed point, quasi-partial metric space, Banach contraction.

AMS Subject Classification: 47H10, 54H25.

Ab-42

ALTERNATED CHAOTIC PARTICLE SWARM OPTIMIZATION USING SUPERIOR LOGISTIC MAP

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Particle swarm optimization is a population based algorithm inspired by the birds flocking and fish schooling in nature. Chaotic particle swarm optimization gives optimum solution in a given search space more rapidly than particle swarm optimization in the presence of high inertia values. Logistic map is used in chaotic particle swarm optimization to generate the chaotic sequence. Parrondo's paradox has been applied to the logistic map to get the alternate discrete system. In this paper, an improved alternate superior logistic map is proposed in PSO algorithm. This approach gives more promising results in terms of rate of convergence than chaotic particle swarm optimization in the presence of lower to higher values of inertia.

Keywords: Particle swarm optimization (PSO), Chaotic particle swarm optimization (CPSO), Alternate chaotic particle swarm optimization (ACPSO)

Ab-43

GENERALIZED BINARY CARDS

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Binary number is the *base two numeral system*. We are familiar with the base ten numeral system since that's how we normally represent numbers. In binary magic cards the trick is to take the pile of cards that contains their number and simply add the upper-left number from each card. The sum of these values will be the number that was chosen. For example, if the person choose the number 21, they would hand you the 3 cards that contain this number. These 3 cards have a "1", "4" and "16" as their upper-left numbers. If you add these numbers together, you get 21. But what does this have to do with binary?In this talk we discuss a generalized formula to construct the binary magic cards.
