The Mathematics Consortium

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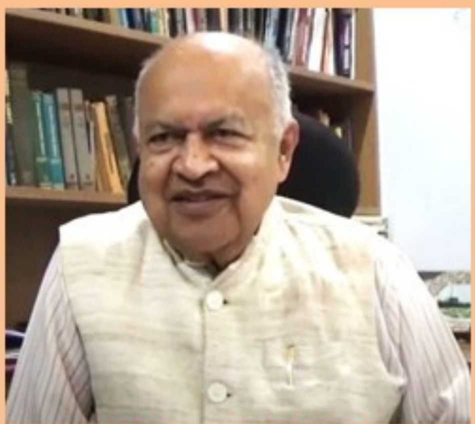
With Our Tributes To



Prof. Jayant V. Narlikar
(19-7-1938 – 20-5-2025)

Prof. R. P. Bambah
(17-9-1925 – 26-5-2025)

Prof. S. Balachandra Rao
(24-12-1944 – 14-5-2025)

Chief Editor: Shrikrishna G. Dani

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The Mathematics Consortium

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Contents

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From the Editors' Desk

Recent developments in mathematics reveal that young researchers, often quite early in their careers (sometimes just after their PhDs or as postdocs), make groundbreaking contributions bringing fundamental shift in the prevailing paradigm, and paving the way for new areas. In the process, these researchers venture to challenge long established theories, identifying a subtle flaw, a limiting assumption, or a novel perspective on an existing problem that, when explored, blossoms into something entirely new.

Prof. Jayant Narlikar, who left us recently, in the 1960s (in collaboration with his mentor Fred Hoyle) proposed the cosmological model (later named as Hoyle-Narlikar model) alternative to the popular Standard Big Bang Model of the universe, which adopts the view that the process of continuous creation of matter is going on, with formation of new galaxies which also keep on moving away from others.

Évariste Galois, revolutionized the approach to solving polynomial equations by focusing on the *symmetries* of their roots. He introduced the concept of what we now call a "group" (specifically, the Galois group of a polynomial). This was a radical shift from algebraic manipulation to abstract structural analysis, bearing in mind that solving polynomial equations using radicals involves solvability of the associated Galois groups. And now, a new way for approaching solutions of polynomials has come to the fore with the work of Norman Wildberger, involving power series using hyper-Catalan numbers.

Divya Tyagi, a young aerospace engineering student at Penn State university, USA, has taken on the challenge of refining optimum rotor disk solution provided by renowned aerodynamicist Hermann Glauert, a seminal work in the field of aerodynamics. Her innovative approach is expected to influence the design of the next generation of wind turbines, making them more efficient, and thereby economically more promising.

In Article 3, Dr. D. V. Shah gives an account of such significant developments in the Mathematical world during the recent past, including the work of Wildberger, Divya Tyagi, resolution of Hilbert's sixth problem, as well as the solution of Multidimensional Shape-Slicing Problem. He also presents some highlights of the work of the winners of Abel Prize, Breakthrough Prize in Mathematics, New Horizons in Mathematics Prize.

In the month of May 2025, we lost a celebrated Number theorist Prof. R. P. Bambah, renowned Cosmologist and promoter of science and scientific thinking, Prof. Jayant V. Narlikar, and an erudite educator of classical Indian astronomy and mathematics, Prof. S. Balachandra Rao. Obituary notes on Prof. Bambah, Prof. Narlikar as well as mathematician Peter D. Lax, are included in Article 3. We also plan to bring to our readers more on the important role played by the works of Prof. Bambah and Prof. Narlikar, in our forthcoming issues. Article 4 presents a glimpse of the life and works of Prof. Rao, as our tribute to him.

In the opening Article 1 (the first part of the multi-part article), Prof. S. G. Dani discusses the mathematics from the works starting from the early period until about the end of the first millennium CE. Article 2 is our regular column on "A Peep into History of Mathematics" wherein Prof. S. G. Dani reviews two recent articles in History of Mathematics, one by Argante Ciocci, and other by J. Marshall Unger.

Article 5 presents a report of the various compact courses organised jointly by RBET and TMC during 2024-25. Dr. Ramesh Kasilingam gives a calendar of academic events, planned for October, 2025 to February, 2026, in Article 6.

We are happy to bring out this first issue of Volume 7 in July, 2025. We thank all the authors, all the editors, our designers Mrs. Prajkta Holkar and Dr. R. D. Holkar, and all those who have directly or indirectly helped us in bringing out this issue on time.

Chief Editor, TMC Bulletin

1. Ancient Indian Mathematics : An Overview

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1.1 Introduction

In this multi-part article we aim to present an overview of ancient and medieval Indian mathematics. The engagement with mathematical ideas in the Indian context indeed goes back to the Indus valley civilization, or perhaps even earlier. However, for the early period adequate inputs are lacking, and as our focus here will be on a discussion on development of mathematical ideas that are manifest in the available sources in a definitive fashion, we shall not dwell on them.

In this first part we shall discuss the mathematics from the works starting from the early period until about the end of the first millennium CE. In terms of themes this includes Śulbasūtras, the Jaina tradition, development of the number system and the numerals, early works in the Siddhānta tradition by Āryabhaṭa and Brahmagupta, the Pātīgaṇita works of Śrīdhara and Mahāvīra, and the Bakhshālī manuscript.

We shall discuss these topics individually with the themes as above.

1.2 Śulbasūtras

A major part of mathematical knowledge from the Vedic period that has come down to us is from the Śulbasūtras. The Śulbasūtras are compositions aimed at providing instruction on the principles involved and procedures applied in the construction of the vedis (altars) and agnis (fireplaces) for the performance of the yajnas, which were a key feature of the Vedic culture. The Śulbasūtras formed a part of the *Kalpasūtras* of the *Vedāṅga* literature associated with the numerous individual Vedic branches. Only a handful of these are extant however, and four of them have now been translated into European languages and studied, to varying degrees of detail, over the last one and half centuries; these are Baudhāyana Śulbasūtra, Āpastamba Śulbasūtra, Mānava Śulbasūtra and Kātyāyana Śulbasūtra.[2] While the period of the Śulbasūtras is difficult to ascertain, even within an accuracy of some centuries, and has been much debated, there is now a general consensus that the compositions would be from between 800 BCE and 200 BCE, with Baudhāyana Śulbasūtra as the oldest and Kātyāyana Śulbasūtra the latest (see [48], [36], [9] and [11] for more details on this).

The fireplaces for the yajnas were constructed in a variety of shapes such as falcons, tortoise, chariot wheels, circular trough with a handle, pyre, etc. (depending on the context and purpose of the particular yajna) with sizes of the order of 20 to 25 feet in length and width, and there is a component of the Śulvasūtras describing the setting up of such platforms with tiles of moderate sizes, of simple shapes like squares, triangles, and occasionally special ones like pentagons. Many of the vedis involved, especially for the *yajna*s for special occasions, had dimensions of the order of 50 to 100 feet, and implementing the overall plan involved being able to draw perpendiculars in that setting. They were aware of the method for this that is now taught in schools, involving perpendicularity of the line joining the centres of two intersecting circles with the line joining the two points of intersection. However, their favorite method for producing perpendiculars is seen to be via the use of the converse of Pythagoras theorem; they were familiar with the Pythagoras theorem, and explicit and unambiguous statement of the theorem is found in all the four major Śulbasūtras mentioned above, together with various theoretical and practical applications. The

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[1]This is a revised and expanded version of the electronic publication [3], which in turn was based on a talk given in "*Future of the past*", a workshop organized under the aegis of the International Centre for Theoretical Studies, Bangalore, during November 22-26, 2011 at Mangalore. The author would like to thank Prof. Mayank Vahia, the organizer of the conference and editor of the publication, for the inspiration for writing [3], and for granting now the permission to publish an updated version of the article.

[2]Recently one more, the Maitrāyaṇīya Śulbasūtra has been translated and edited; see [35].

Śulbasūtras also contain descriptions of various geometric principles and constructions. These include procedures for converting a square into a circle with equal area, and vice versa. These were evidently motivated by a limited purpose, and are relatively crude. One finds however a good approximation, in the Baudhāyana Śulbasūtra, to the square root of 2, as $1+\frac{1}{3}+\frac{1}{3\times 4}-\frac{1}{3\times 4\times 34}$; in decimal expansion this corresponds to $1.4142156\ldots$, in place of $1.4142135\ldots$ [3] (see, for instance, [48], [36], [2], [9] for more details).

The Śulbasūtras, like other Vedic knowledge, were transmitted only orally over a long period. There have also been commentaries on the Śulvasūtras, in Sanskrit, but their period remains uncertain; based on the references involved in them, most of them are inferred to be from the second millennium CE, with a few possibly from the later part of the first millennium. When the first written versions of the Śulbasūtras came up is unclear. The text versions with modern commentaries were brought out by European scholars (Thibaut, Bürk, van Gelder and others) starting from the second half of the nineteenth century (see [53], [40], [41], [48], [36], [14]).

While the currently available translations are reasonably complete, some parts have eluded the translators, especially in the case of the Mānava Śulbasūtra which turns out to be more terse than the others. New results, not recognised by the original translators, have been brought to light by R. C. Gupta, Takao Hayashi, Jean-Michel Delire, S. Kichenassamy and the present author (see [2] and [9] for details and references), and perhaps others. Lack of adequate mathematical background on the part of the earlier translators/editors could be one of the factors in this respect. There is a case for a relook on a substantial scale to put the mathematical knowledge in the Śulbasūtras on a comprehensive footing. There is also scope for work in the nature of interrelating in a cohesive manner the results described in the various Śulbasūtras. The ritual context of the Śulbasūtras lends itself also to the issue of possible interrelation between the ritual and mathematical developments in the society, and there is a case for analyzing the relationship. The claims, such as in Seidenberg [47], of "ritual origin of geometry" are however exaggerated and questionable (see [9] for a discussion on this).

1.3 The early Jaina tradition

There has been a long tradition among the Jainas of engaging with mathematics. Their motivation came not from any rituals, which they abhorred, but from contemplation of the cosmos, of which they had evolved an elaborate conception. In the Jaina cosmography the earth, viz. *Jambudvīpa* (island of Jambu), is considered to be a flat disc, with diameter 100000 *yojanas*, surrounded by concentric annular regions alternately consisting of water and land, extending indefinitely, which seems to have inspired studies in geometry of the circle and the notion of infinite.[4] The Jainas also had the notion of the earth being divided by seven mountain ranges running along parallel chords of the disc shaped earth, bringing in the aspect of study of geometry of chords of the circle. On the whole, mathematics is seen to have played an important role in the overall discourse, even when the scholars engaged in it were primarily philosophers, rather than practitioners of mathematics. Many properties of the circle, relating the arcs, chords, and diameters, have been described in *Sūryaprajñapti* which is believed to be from the fourth or fifth century BCE and in the work of Umāsvati, who is supposed to have lived around 150 BCE according to the Śvetāmbara tradition and in the second or third century CE according to the Digambara tradition of Jainas; see [46], p. 7.

One of the notable features of the Jaina tradition is the departure from old belief of 3 as the ratio of the circumference to the diameter of a circle; *Sūryaprajñapti* recalls the then traditional value 3 for it, and discards it in favour of $\sqrt{10}$; see [46], § 3.2. Circumferences were calculated in various contexts to a great degree of accuracy; e.g. the circumference of the Jambudvīpa was

[3]It may also be recalled in this context that the ancient Babylonians also had a similarly accurate value for $\sqrt{2}$, expressed in the sexagesimal system, which corresponds $1.4142129\ldots$; see [19] for details.

[4]It may be mentioned that the cosmography involved is also shared by the *Purāṇas*, but no mathematical developments as in this instance have been found in that tradition.

calculated to the accuracy of a finger-width, using the above value for the ratio; see [13], p. 132 for details. Interestingly this value for π, often referred to as the Jaina value, was adopted also by Brahmagupta and many later astronomers in the Siddhānta tradition until almost the 17th century; though *Āryabhaṭīya* provided the more accurate value 3.1416 for the ratio, it was not convenient for computations; see also Footnote 10, infra, in this respect. The area of the circle is described in the Jaina literature, starting already with *Sūryaprajñapti*, to be $\frac{1}{4}$th of the product of the circumference and the diameter; see for example [46], § 3.3; thus they were aware in particular that the ratio of the area of the circle to the square of its radius is the same as the ratio of the circumference to the diameter.

Another noteworthy fact from Jaina geometry is an approximate formula for the lengths of circular arcs cut off by chords of a circle. The length of the smaller arc cut off by a chord is given to be $\sqrt{c^2+6h^2}$, where c is the length of the chord, and h is the length of the corresponding arrow (the segment joining the midpoints of the chord and the arc). Similar formulae for the arc-length, in terms of c and h as above, were introduced by Heron of Alexandria, a second century engineer in the Greek tradition, and it turns out that the Jaina formulae fare better for chords corresponding to a wide range of angles; see [6] and [5] for details.

Permutations and combinations, number of partitions of a given natural number, sums of (finite) sequences, categorization of infinities are some of the other mathematical topics on which elaborate discussion is found in Jaina literature; see [49], and other papers in that volume, for various details. These themes, though their appearance in the early works is seen to be at a rudimentary level, seem to have been influential in further development of the topics at the hands of later Jaina scholars especially 8th century onward, discussed later in this article.

The ancient Jaina works also indicate presence of an evolved pedagogical scheme for dissemination of mathematics, with classification of various mathematical topics etc.; see [13]. The details of its implementation seem to be lost however.

1.4 Development of the number system and numerals

Study of development of the number system in India cuts across the Vedic, Jaina and Buddhist traditions. From the early times one sees a fascination for large numbers in India. For a composition with a broad scope, including spiritual and secular, the Ṛgveda shows considerable preoccupation with numbers, with many numbers going close to 100,000 occurring in it, and the usage of decimal representation of numbers is seen to be rooted there; see [1] - see also [7] and [8].[5] In the Yajurveda one finds names introduced for powers of 10 upto 10^{12} and various simple properties of numbers are seen to be involved in various contexts; see [39], § 2.1 - see also [11]. (It should be borne in mind however that the numbers were not written down, and the reference here is mainly to number names.) In the ancient Jaina works, in the decimal system they used the terms *kodī* and *kodākodī*, for 10^7 and 10^{14} respectively, but they also had scales going upto enormously large powers (see [24] and [49]). Large numbers are also found in the Buddhist tradition, and Buddha himself was renowned for his prowess with numbers; *Tallakṣaṇa*, a term from the Buddhist tradition, represented 10^{53}.

Though powers of 10 were accorded names up to high powers, one finds that these names, the decuple terms, varied substantially over traditions and also over periods; e.g. the names adopted by Śrīdhara and Mahāvīra differ substantially, for higher powers, than the Vedic tradition. Within the Hindu tradition *Parārdha* (which means 'half way to heaven'), meant 10^{12} in the Yajurveda nomenclature, but stood for 10^{17} in later works such as of Śrīdhara and Bhāskara II; on the other hand Ārayabhaṭa does not mention it at all, being content to end the list of decuple terms with

[5]The choice of 10 as a 'base' for counting, in terms of grouping as involved here, and reference to powers of 10 up to 10^6, through special symbols conceptualizing them, is also found used in the ancient Egyptian civilization; see [20] of [43] for instance. Also, while the Babylonians adopted the sexagesimal system, involving base 60, 10 did play a significant role in their reckoning; see for instance [28] or [44].

10^9, even though his special scheme for representing numbers accommodates much higher powers.[6] The variations suggest that the naming of higher powers was more in the spirit of simply pursuing an idea, and did not concern practical application or use. The engagement however is likely to have played a beneficial role in the emergence of decimal representation in written form at a later stage, apparently in the early centuries of the common era. This connection is however not very straightforward; there was a long period in between, of several hundred years, when written form of numbers did not follow the place-value notation; besides, even after the decimal place-value system with zero came into vogue the other systems seem to have continued to be used for quite a while; see [7], [8] and [15] for details. One may wonder about the reasons for this in the context of the frequent references to the powers of 10 in the oral tradition, and the apparent convenience and elegance of the decimal place-value system.[7] Introduction of zero, initially as a place holder, paved the way for the writing the numbers as we do now, as far as the whole numbers are concerned; the full decimal representation system as we now use, extending also to the fractional part, with a separating decimal point, came in vogue in the 15th century Europe, though it is noted to have been first used by Arabs, beginning with Al Kashi in the 10th century; see [31].

Conceptualisation of zero as a number, integrated into the number system, happened in the early centuries of the common era in India, and in *Brāhmasphuṭasiddhānta*, composed by Brahmagupta in 628 CE, we find a systematic exposition, which includes also arithmetic with negative numbers. It may be recalled here that negative numbers eluded the European mathematics until the middle of the second millennium; see [37].

The development of the numerals is a parallel topic. Written numerals in various forms have been studied. The earliest of these could go back to the Indus seals, with strokes representing numbers. Kharoṣṭhi numerals which were used between 3rd century BCE to 3rd century CE, found in the inscriptions from Kalderra, Takṣaśilā and Lorian, and Brāhmī numerals from Naṇeghāt (first century BCE) are some of the ancient numerals; incidentally they did not use the place-value system. The earliest extant inscriptions involving the decimal numeral system is said to be from Gujarat, dated 595 CE; it has however been argued by R. Saloman in [45] that this is a spurious inscription. The oldest known zero in an inscription in India is from 876 CE and is found in a temple in Gwalior (an image of this may be viewed online, thanks to Bill Casselman; see also the cover-page of TMCB Vol. 1, Issue 1); see [7] and [12] for more details. Much research was done by Bhagwanlal Indraji in the late nineteenth century, an account of which may be found, apart from the details incorporated in [15], in the book of George Ifrah [29]; (a good deal of what Ifrah says has been contradicted by various reviewers - see [16] for details - one may nevertheless suppose that what he reports from the work of Bhagwanlal Indraji would be reliable; Ifrah also is seen to go widely off tangent in his discussion on the significance of the decimal representation of numbers practised in ancient India - see [11], Appendix, for detailed comments on this aspect).

Apart from the inscriptions in stone, copper plates that were legal documents from around the 7th to 10th centuries, recording grants of gifts by kings or rich persons, have been examined for numerals presented in decimal system. Numerals appearing in ancient manuscripts are another source in this respect. I will not go into further details on this here, and will content myself

[6] Āryabhaṭa, though he deployed powers of 10 in his representation of numbers, did not use the decimal place-value system; also, contrary to a common misconception, he did not invent the zero; see [8], Footnnote 11, for some details; as noted there, the verse concerning an algorithm for computing square-roots (*Gaṇitapāda*, 4), which is often interpreted in terms of the decimal representation of numbers, has in fact no clear connection with the decimal place-value system, and is open to an alternative interpretation, akin to the approximation procedure, arguably of geometric origin, involving the formula $\sqrt{a^2+b} \approx a + \frac{b}{2a}$. I may add here that the analogous algorithm described in the following verse (*Gaṇitapāda*, 5), for finding cube-roots, being independent and unconnected with the decimal place-value system is even more evident than in the case of the square-roots. The procedure is apparently a generalization introduced by Āryabhaṭa of the general approximation procedure associated with the formula recalled above.

[7] On the other hand the Chinese seem to have used decimal place-value system for representation of numbers, without a symbol for zero in place of which they left a blank space, from very early times and at least from the 3rd century BCE.

referring the reader to [7] and 8 for a discussion, and to [15] for detailed information.

Before concluding this section I would like recall here for the reader that various Indian languages have their own symbols for the individual digits, and the genesis of these systems would also be a related issue. The author is not aware of any comprehensive study on the topic. A systematic archiving of the material in this respect from various sources is very much called for, followed by an analysis of the path of development of ideas as may be discerned from the sources.

1.5 The Siddhānta astronomy tradition - the early years

The Siddhānta or mathematical astronomy tradition has been the dominant source of mathematical development in medieval India. It flourished continuously for close to a thousand years, beginning from about the third or fourth centuries. Āryabhaṭa (476 - 550) is the first major figure from the tradition, and is regarded as the pioneer of scientific astronomy in India. He was followed, among others, by Brahmagupta in the seventh century. Bhāskara II (1114 - 1185) is one of the later stalwarts of the Siddhānta tradition, and in the Western historiography of the last century he was regarded as the last major exponent in the pursuit. The tradition however extended well beyond him, and notable work was done by Nārayaṇa Paṇḍita in the 14th century, developing further the mathematical ideas involved. The tradition was also instrumental in the emergence of what is called Kerala School of mathematics which we shall come to later.

The origins of the Siddhānta astronomy can be traced to Greco-Babylonian inputs received around 100 BCE; see, for instance, [34]. In respect of mathematics, this was accompanied also by an import of basic principles of trigonometry. Greek trigonometry was based on chords, rather than the half-chords involved in the sine function of the present-day trigonometry. However, in the course of working with it, in the practice of astronomy, it was realized, in India, that it is more convenient to work with half-chords, which led to the genesis of the sine function; see [39]. The originally Greek chord measures as well as the Indian half-chord measures were not with reference to the unit circle as we have today, but with reference to a circle with a large radius, evidently so that the half-chord values involved could be taken, approximately, to be integers. Thus the function involved was $R\sin$, R being the chosen radius. The choice of the value of R varied with the practitioners. $R = 3438$ was a relatively common choice, and was in particular adopted by Āryabhaṭa; a significance of the choice is that the circumference is then very close to 21600, the number of minutes around the circle, which leads to $R\sin\theta$ being approximately θ, measured in minutes. Analogues of our sine tables were used for the $R\sin$ function, but to step-size 225 minutes, viz. 24th part of the right angle.

The *Āryabhaṭīya*, composed by Āryabhaṭa in 499, is the earliest completely surviving and reliably datable[8] composition from among the Siddhānta works, and is foundational to the subsequent developments in the tradition, and also to the later works of the Kerala school of Mādhava. It consists of (only) 121 verses, divided into four chapters *Gītikāpāda, Gaṇitapāda, Kālakriyāpāda* and *Golapāda*. The first one is devoted to introducing various astronomical constants used later in the work, and also contains what may be considered an analogue of our trigonometric tables. In a single verse it lists the 24 successive differences between values of $R\sin n\theta_0$, namely $(R\sin n\theta_0 - R\sin(n-1)\theta_0)$ for $n = 1, \dots, 24$, where θ_0 is the 24th part of the right angle.

The second chapter, as the name readily suggests, is devoted to mathematics. It may be noted that in the opening verse Āryabhaṭa announces that he is "presenting the knowledge honoured in Kusumapura"; thus it is meant to be an exposition, though it is likely, one may say certain, that some of what is presented is his own contribution. The chapter has 33 verses. The first few verses are on arithmetical procedures, including for finding square roots and cube roots, and formulae for areas and volumes of various geometric figures.[9] Verse 10 provides an approximate expression

[8]The earliest versions of the *Sūrasiddhānta* are possibly older than *Āryabhaṭīya*, but since the extant versions are in much evolved form, no reliable early date can be assigned to its contents.

[9]The formulae given for volumes of the pyramid (over a triangular base) and the sphere turn out to be wrong – these

for π, equivalent to assigning the value 3.1416 to the ratio, which is one of the landmarks, in the Indian context, with regard to understanding the ratio.[10],[11] This is followed by two procedures for determination of $R\sin$ values; while the first one presumably pre-dates Āryabhaṭa, the second one is arguably original to him; an interesting feature of it is that it involves a second order finite-difference equation for the sine function. Verse 17 states what is now called the Pythagoras theorem, together with an application to chords of a circle. Later verses include formulae for sums of consecutive integers, sums of squares, sums of cubes, and computation of interest, the rule of three (*trirāśika*); see [52]. The last two verses concern a method for solving problems which in our present framework correspond to equations (no symbolic notation is involved in the original) of the form $ax + b = cy$, where a, b, c are given positive integers, for x, y in positive integers, known as *Kuṭṭaka*. While the verses themselves are rather too cryptic (even by the general standards of that time), they seem to have been influential for subsequent expositions on the topic, by Bhāskara-I and other later authors.

The other two chapters are concerned with astronomy, dealing with distances and relative motions of planets, eclipses etc.; (we shall not discuss them here).

Bhāskara-I (600-680) and Brahmagupta (598-668) are the next two major figures from the Siddhānta tradition, especially with regard to contribution to mathematical foundations; Varāhamihira (505–587)[12], the author of *Pañcasiddhāntikā*, who is also a major personality from the Siddhānta tradition however was focused on astronomy, and astrology.

Bhāskara-I seems rather like a disciple of Āryabhaṭa, and at one time was thought to be one, until there was clarity about the periods of the two, and the time gap between the two was realized. Brahmagupta on the other hand manifests a rather adversarial relationship with Āryabhaṭa; the major controversies involved however concern issues in astronomy which we need not go into.

Bhāskara-I is known for his commentary *Āryabhaṭīyabhāṣya*, elucidating the work in *Āryabhaṭīya*, which seems to have been greatly responsible in making various cryptic parts of the latter accessible. Apart from his mastery over the *Āryabhaṭīya* he seems to have had good acquaintance with Jaina mathematics, and a broader arithmetic tradition that seems to have existed in the earlier times, sources for which are no longer extant. This is reflected in his presentation of the commentary. Bhāskara-I is also known for his works *Mahābhāskarīya* and *Laghubhākarīya* on astronomy. As was common in the Siddhānta tradition, in these works exposition on trigonometry was also included with astronomy. In particular, there is an interesting approximate formula described in *Mahābhāskarīya* for $\sin\theta$ as $\frac{4\theta(180-\theta)}{40500-\theta(180-\theta)}$, for the angle θ expressed in degrees; except for small values of the angle the formula is accurate within 1%; see [5] and [21] for details. Several practitioners of astronomy seem to have found it convenient to use the formula for computation rather than using the table for sines, which was made only for step sizes of $3°45'$.

The bulk of the work presented in Brahmagupta's *Brāhmasphuṭasiddhānta* is on astronomy; see [50] and [39] for details. There are however two chapters, 12th and 18th, devoted to mathematical theory. Also, the 21st chapter has verses dealing with trigonometry. An unusual feature of the work is Chapter 11, which is a rather severe critique of various earlier works including, mainly, the

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were presumably prevalent, based on some (unjustified) extrapolation and our author may have included them "for the sake of completeness".

[10]It is contended in [27] that various values used in India in the later centuries until the Kerala works, such as $\frac{22}{7}$, and even the more accurate value $\frac{355}{113}$, were in fact derived from this value, as substitutes with smaller denominators, for convenience in practical use, for which 3.1416 (viz. 31416/10000, in their context) was not suitable; thus, arriving at those values did not involve recourse to any method to approximate the true value of π, but rather 3.1416 instead, and the fact that $\frac{355}{113}$ is a better approximation to π than 3.1416 was fortuitous, and also may not have been known to be such.

[11]The Chinese mathematicians Liu Hui (225-295) and Zu Chongzi (429-500) did notable work on the ratio; the latter showed π to be between 3.1415926 and 3.1415927 and introduced the approximation $\frac{355}{113}$.

[12]It may be borne in mind that many of the dates quoted here are approximate, as there is no reliable historical information available on them and the dating is based on various indirect inferences.

Āryabhaṭīya; like in other scientific communities, the Siddhānta tradition had also many internal controversies, and sometimes involved use of strong language against the adversaries.

Chapter 12 is known for its systematic formulation of arithmetic operations, with a classification of the topics into what are referred to as *parikarma*s. The presentation of arithmetic here is the earliest extant exposition from India. It may be mentioned in particular that it includes systematic methods of dealing with fractions. The chapter also deals with geometry, and includes in particular his famous formula for the area of a quadrilateral as $\sqrt{(s-a)(s-b)(s-c)(s-d)}$, where a, b, c, d are the lengths of the sides and s is the semiperimeter of the quadrilateral; it may be noted that the formula generalizes the well-known formula for the area of a triangle, attributed to Heron of Alexandria (2nd c.). The above formula is valid only for cyclic quadrilaterals, and while apparently Brahmagupta meant it accordingly (see [33] and [17] for details on this) the conditionality was lost on the followers in the subsequent centuries - while some of them treated it as valid in general, Āryabhaṭa-II and Bhāskara-II are seen to have been highly critical of the formula (see [4]), having missed the point that it in fact holds for cyclic quadrilaterals. The chapter also includes formulae for the diagonals of a (cyclic) quadrilateral, and construction of quadrilaterals with rational sides which have also served as major highlights from the chapter. The chapter also includes formulae for computation of volumes of excavations, including, for the first time in the Indian tradition, a correct formula for the volume of a pyramid.

The 18th chapter, called the *Kuṭṭakādhyāya*, is devoted to topics that we may now categorize as Algebra, and Brahmagupta's is the first such known segregation. The chapter begins with two verses giving a synopsis of the contents of the chapter, followed by a detailed treatment of the *Kuṭṭaka* method; while the method described is the same as Āryabhaṭa's, Brahmagupta dwells on it elaborately, with numerous examples, devoting 27 verses to the topic. The next group of five verses concerns "algebra" of numbers, and the verses are frequently quoted, especially in respect of the operations with zero mentioned in them. It is notable that negative numbers, which eluded European mathematics until the middle of the second millennium, appear in this discourse in a full-fledged way. With reference to them Plofker [39], § 5.1.3, p. 151, comments that "almost all of which are identical to their counterparts in modern algebra.", and it has also been eulogised in similar terms by others, including some professional algebraists. While undoubtedly the verses are of considerable significance pedagogically, and from an historical perspective, such an assessment as the one quoted above, involving comparison with modern framework, calls for some circumspection. Actually a careful look suggests that Brahmagupta's concern in the verses is to emphasize segregation of positives and negatives as categories of numbers, with zero as the residual category, and it is quite likely that it was in response to mix-ups between them witnessed in the handling of arithmetic by beginners. Apart from the general phraseology involved in the verses this is especially noticeable in statements such as "sum of a positive and zero is positive", and not quite that adding zero to a number leaves it unaltered, as would be said in a modern book dealing with the topic. While of course the stronger assertion would be known, its not being part of the statement is a pointer to a difference in perspective.

The subsequent verses deal with a variety of topics in algebra, presenting methods of solving a variety of equations. There are no symbols used for the unknown or the operations of addition, but the problems and solutions are presented in words in appropriate generality. In particular the solution of a general quadratic equation $ax^2 + bx = c$, $a \neq 0$, is given as $(\sqrt{4ac+b^2} - b)/2a$.[13] Preparatory to dealing with these equations Brahmagupta also introduces techniques of handling the surds, providing a variety of formulae, which also seems to have influenced the future course of development substantially. The notion of a polynomial in several variables is seen to be emerging in the work.

[13] In later works the formula is often found referred to as "Śridharācārya's rule". This could be either due to an attribution by Bhāslarācāraya, or because of Śridhara's work having been exposed to a wider community, extending outside those involved with astronomy. The formula however does indeed go back to Brahmagupta, in terms of explication, and is also implicit in some sūtras in *Āryabhaṭīya*, which was earlier.

The part from the chapter that may be said to have influenced the most, concerns indeterminate equations of the form $Nx^2 + k = y^2$, where N and k are natural numbers, to be solved for x and y in integers. The special focus is on the case $k = 1$, which in modern parlance corresponds to Pell's equation; it was posed by Fermat as a challenge problem to some British contemporaries, for various specific values of N; see [54] and [18] for detailed accounts on the topic. The equation with a general k as above was adopted by Brahmagupta who introduced, for each fixed N, a 'composition law', termed as *bhāvanā*. It associates with two solutions (x, y) and (x', y') corresponding to values k and k' respectively, a solution corresponding to the value kk'; the latter consists of the pair $(xy' + x'y, Nxx' + yy')$. That the composite as defined is a solution corresponding to kk' constitutes an identity, which is now called the Brahmagupta identity. Using the composition (coupled with cancellation of factors common to all the terms, which becomes possible) he solved the equation for $k = 1$ (Pell's equation) for various values, including $N = 92$ and 83. The general case was posed as a challenge, and it engaged the minds of several mathematicians for the next five centuries, some of which we will come to later. The composition law played a crucial rule in the eventual resolution of the problem.

After Bhāskara-I and Brahmagupta there seems to have been a lull in the tradition with regard to mathematics-related activity, though the tradition is seen to have continued in terms of astronomy/astrology related works. Thus in the following period one finds in particular the work of Lalla in astronomy; his precise period is uncertain. From a mathematical, or more specifically trigonometric point of view, from the period being discussed here, one may note the work of Govindasvāmī (ca. 800-860), on refinement of Āryabhaṭa's table of 24 sine-differences giving the relevant expressions in up to the second sexagesimal fractional digital terms, in place of integers in the original. He also discusses some interesting numerical methods for approximating the sine-differences, focusing on the range between 60 and 90 degrees, where sine-differences increase rapidly, and linear interpolation is inefficient (see [39], § 4.3.3, pp. 82-83). The Siddhānta tradition then seems to have rejuvenated around the turn of the millennium, culminating in the work of Bhāskarācārya in the 12th century, and then Nārāyaṇa Paṇḍita in the 14th century. We shall discuss this in the second part of this article. We now come to works of the *Pāṭīgaṇita* genre which are seen to have played a prominent role during the interim.

1.6 *Pāṭīgaṇita* and the later Jaina works

In the Siddhānta works the exposition of mathematics was coupled with astronomy, and thus may have catered only to a limited section of the society. Subsequent to the works of Brahmagupta and Bhaskara-I, however, one witnesses diffusion of the accumulated mathematical knowledge taking place. Especially, *Pāṭīgaṇita*, which covers arithmetic and mensuration, seems to have spread to other sections of the society, including those involved in mercantile activity, artisans and a broader community of mathematics enthusiasts, through expository works aimed at them, without reference to astronomy. It may be said that these works collectively served as precursors of the arithmetical practices followed in the second millennium CE, and continuing into our times, and now around the world. Systematic methods for carrying out multiplications, divisions, square, cubes, square-roots, etc. came to be devised and propagated through these texts, together with a whole variety of applications to practical contexts, and recreational problems that would in turn advance overall understanding of the concepts. Apart from the mathematics emerging from the Siddhānta tradition this process may have also benefited from the old Jaina tradition and also certain folk aspects of mathematics.[14] We shall however not go into the details of these, as it would be too expansive, and content ourselves by highlighting some of the more advanced features of the knowledge accumulated by then, coupled with an historical overview of the period concerned.

Śridharācārya may be viewed as the pioneer of this *Pāṭīgaṇita* genre, at least as far as the

[14] There are some older names Maskari, Pūraṇa, Mudagala, and Patana mentioned by Bhaskara-I in this respect (see [51] p. v, [46], § 3.7) but nothing more is known about them or their works.

extant literature goes; for a more detailed exposition on Śridharācārya I refer the reader to [10] - here I shall only include brief comments, and an amendment (see below). There was earlier some debate about his period but it now seems to be settled that he flourished in the 8th century, quite likely around the middle of it; see [22]. Though at some point he seems to have been lost track of, at one time he was considered an unparalleled genius, and was widely cited in various works; see [51] or [10]. He is often counted among Jaina scholars, with the claim to that effect going back to a 1947-article by N. C. Jain, in Hindi (see [22] for citation details), and such a premise is manifest in several papers, including [30] and various articles in the volume on Jaina mathematics containing [6]; in particular he was treated as such in [6] and [10]. However, as pointed out to the author recently by Takao Hayashi, K. S. Shukla's argument in [51] (pages xxxv-xxxvi) that in fact Śridharācārya was a *śhaiva* has never been convincingly countered, and even the mid-way position that he may have converted to Jainism at some point in his life, as suggested in [30] and [22], lacks evidence.

He authored the book *Pāṭīgaṇita*, of which however only a small portion, about $\frac{1}{3}$rd of the original, is extant. He also wrote a simpler condensed version of it for wider dissemination (the first author to do so!) titled *Triśatikā*, which has come down to us. Apparently he also wrote a book on algebra, as may be inferred from a reference to it in Bhāskarācārya's work, but it has not come down to us.

Finding a formula for the volume of a sphere was a bugbear in the ancient times - the first satisfactory formula in the Indian tradition was given by Bhāskara-II in the 12th century; see[46], § 8.10. Śridhara's formula for this comes close, and unlike the formulae in other works which appear rather ad hoc, it seems to have been based on a mathematical reasoning, but no actual details of how he may have arrived are known; see [10].

During the remaining centuries of the millennium, in sustaining the *pāṭīgaṇita* genre various Jaina scholars seem to have played a major role.[15] While the Jaina tradition had been dormant for a period after the early centuries of the millennium, a resurgence is witnessed around the 8th century, and it may have continued until the middle of the 14th century. The activity was carried forward the spirit of the ancient Jaina pursuit of mathematics on one hand, and on the other hand, it incorporated many later mathematical developments arising from the Siddhānta tradition.

Mahāvīrācārya has been by far the best known Jaina scholar from the medieval times, with a large pedagogical impact. His book *Gaṇita sāra saṅgraha* seems to have served almost as a textbook, with a large number of people having learnt from it, over much of south India over several centuries, perhaps until Bhāskarācrya's *Līlāvatī* came on the scene in the 12th century. From the introductory verses in the work eulogizing the Rāṣṭrakūṭa king Amoghvarṣa, it is inferred that Mahāvīra flourished in mid-ninth century Karnataka. An edition of the book with an English translation was brought out by M. Rangacharya in 1912; it has been recently reprinted [42], and has been much cited in works on history of mathematics. There is also an edition with English and Kannada translations together with the original text, brought out by Padmavathamma [38]. The work consists of an extensive and leisurely exposition, with well over 1100 verses divided into 9 chapters, dealing with various topics including arithmetic, combinatorics, geometry, and indeterminate analysis (the *kuṭṭaka* method). The exposition is rich with numerous examples in the form of exercises, which are deeply rooted in everyday life of his time, and entertaining.

One of the highlights of his treatment of geometry, in the chapter *Kṣetragaṇita-vyavahāraḥ*, which is the second longest chapter in the book with well over 200 verses, is the discussion of numerous shapes including unconventional curved figures such as the conch-shapes or oblongs. Mensuration of the former is by treating it as (approximately) a union of two semicircular regions joined along their diagonals. The oblongs treated by Mahāvīra have been conflated in much of

[15]There are also works of some Hindu scholars, including Skandasena, Lalla and Govinda, from around the 8th and 9th centuries that we know of from other works, to have dealt with arithmetic and mensuration. However, their contributions have not come down to us, and there is little that can be said about their contents definitively; see [51], pp. vii-ix.

contemporary literature on the topic as ellipses. As I have argued in [6], that is not justifiable. Rather, they are meant to be general roundish oblong figures, with some symmetries, as may be seen from the structure of the (approximate) mensuration formulae proposed for them. Interestingly the fine (*sūkṣma*) formula for the circumference of an oblong is seen to be derived using the ancient Jaina formula for the (smaller) arc of a circle cut out by a chord, in terms of the lengths of the chord and the corresponding arrow, discussed earlier; see [6].

Vīrasena (8th century) is another Jaina mathematician of renown. His name is generally associated with an approximation for π, the ratio of the circumference to the diameter of a circle, as $3 + \frac{16}{113} = \frac{355}{113}$. It is a very good approximation, accurate to seven significant places.[16]. The historical veracity of the attribution is rather obscure, however. It is based on a verse in his commentary on the *Ṣaṭkhaṇḍāgama* of Puṣpadanta and Bhūtabali, which translates as "sixteen times the diameter, together with 16, divided by 113 and thrice the diameter becomes a very fine value (*sūkṣmādapi sūkṣamaṃ*) (of the circumference)". A discerning reader would notice that there is something incongruous and surprising about the part "together with 16"; it is only if one omits the part that the rule would correspond to the approximation as above. There have been various explanations/responses to the incongruity that we shall not go into here.[17] One thing that seems to emerge however is that while $\frac{355}{113}$ is indeed a better approximation to π than Āryabhaṭa's value, and had been adopted in India even before Vīrasena, it may not actually have been recognized to be a better approximation, in absence of any specific knowledge of the true value.

Vīrasena, on the other hand, deserves to be better known for his formula, in his Dhavalā Ṭīkā, for the volume of a conical frustrum; see [46], § 8.5. Unlike in much of the ancient and medieval mathematical literature in India, we find in this work a description of the method of determining the volume. Moreover, the method involves summation of an infinite series and the idea of infinitesimals, akin to Calculus; see [46], § 8.5, for details.

Vīrasena, and later Nemicandra (around 980), were also involved in developing further the theory of *archaccheda*, which corresponds to logarithm to base 2, which was mentioned earlier in this article among the notions involved in the early Jaina works. While they do not seem to have managed to get a satisfactory extension of the notion to numbers that are not of the form 2^r with r a rational number, and it is not clear whether the notion was involved in any practical applications, various basic properties of the function were noted by them; see [49]. It seems to have served largely as another index for gauging and comparing largeness of numbers, in parallel with decimal representations.

For an overview of various aspects of Jaina mathematics the reader may consult [23], and the more recent exposition in [26]; see also [13], an older account on the topic; the recently edited volume containing the papers [24], [49] and [6] also has various other papers with interesting information on Jaina mathematics. On the whole, however, there has not been adequate systematic study of the Jaina works from a mathematical point of view (even compared to other branches of ancient Indian mathematics), especially with regard to the older works from BCE and the early centuries of CE.

1.7 The Bakhshālī manuscript

Apart from the works discussed above there is also another rather unique manuscript which broadly falls in the *Patīgaṇita* framework, viz. dealing with arithmetic and mensuration, independently of

[16]As noted in Footnote 11 the formula was given earlier by Chong-Zhi in China in the 5th century.

[17]In this respect it is pointed out in [27] that Vīrasena was quoting the verse from an unknown source, and the authors contend that whoever composed the rule described in the verse, was aware of the approximation $\frac{355}{113}$ beforehand, and the rule was an attempt, a rather misconceived one as it turns out, to improve upon it further; apparently it aimed to get the value closer to Āryabhaṭa's approximation $\frac{62832}{20000}$ for π, rather than π itself. In this perspective, the description as "a very fine value (*sūkṣmādapi sūkṣamaṃ*)" seems to refer to improvement from $\frac{355}{113}$ towards Āryabhaṭa's value, rather than from Āryabhaṭa's value to the true value of π, as may appear from a simple-minded reading of the verse.

the pursuit of astronomy: the Bakhshālī manuscript. It has been a crucial but enigmatic source in the study of ancient Indian mathematics, with total lack of clarity with regard to its relation with other sources of ancient and medieval mathematics, leading to many open issues and controversies around it.

The manuscript was found in 1881, buried underground in the village Bakhshālī, near Peshawar, from which it derives its name. It was initially passed on to the Indologist A.F.R. Hoernle who studied and published a short account on it, and later in 1902 presented the manuscript to the Bodleian library at Oxford, where it has been since then; see [8] for a more detailed account in this regard. The manuscript consists of 70 folios of *bhūrjapatra* (birch bark); of these, 51 folios contain original text in a fair proportion - of the rest, one folio is blank while others are either much damaged or mostly blank. Birch bark (unlike palm leaf which is another material that was extensively used for manuscripts) is generally known to be a more fragile material that tends to deteriorate relatively fast, and is vulnerable to crumbling on being handled, when it is more than two or three hundred years old; see [55] for a discussion on ancient manuscripts. Fortunately the manuscript was in a condition suitable enough for the early studies, but unluckily certain steps taken for preservation of the leaves are said to have apparently made the folios inaccessible for direct studies. Facsimile copies of all the folios were brought out by Kaye in 1927 [32], which have since then been the source for the subsequent studies. The date of the manuscript has been a subject of much controversy since the early years of its discovery, and though the Bodleian library carried out a carbon-dating exercise on it, in 2017, the outcome has hardly helped in resolving the dating issue; see [8] for an exposition of the varied claims, and the issues involved. T. Hayashi who produced what is perhaps the most comprehensive account [25] on the work so far has, after examining various issues in detail, concluded that the manuscript may be assigned some time between the 8th and the 12th century, while the work may most probably be from the 7th century.

An approximate formula for extraction of square-roots of non-square numbers, used systematically in many problems in the manuscript, dealing with quadratic equations, has attracted much attention. Some calculations in the manuscript involve computations with fractions with large numerator and denominator (each expressed in decimal representation). One of the verifications of a solution of a quadratic equation involves a fraction whose numerator has 23 digits and the denominator has 19 digits! See [8], where it is referred to as a celebration of the decimal system (!), for more details.

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References

1. Bhagyashri Bavare and P. P. Divakaran, Genesis and early evolution of decimal enumeration: evidence from number names in Ṛgveda, Indian J. Hist. Sci. 48 (2013), no. 4, 535-581.

2. S. G. Dani, Geometry in Sulvasutras, in: Studies in the history of Indian mathematics, pp. 9-37, Cult. Hist. Math. 5, Hindustan Book Agency, New Delhi, 2010.

3. S. G. Dani, Ancient Indian mathematics: an overview, in: an online publication of papers from "Future of the past", A workshop organized under the aegis of ICTS, November 22-26, 2011 at Mangalore.

4. S. G. Dani, Mensuration of quadrilaterals in the *Līlāvatī*, in: *Bhaskara-prabha*, Culture and History of Mathematics 11, Ed: K. Ramasubramanian, Takao Hayashi and Clemency Montelle, pp. 129-139, Hindustan Book Agency 2019.

5. S. G. Dani, Some Approximate Formulae from the Ancient Times, The Mathematics Consortium Bulletin, Vol. 3, Issue 3, January 2022, pp 23–32.

6. S. G. Dani, Geometry in Ancient Jaina Works - a Review, in: Mathematics in Ancient Jaina Literature, edited by S.G. Dani and S.K. Jain (Ohio University, USA), with the cooperation of Pankaj K. Shah (Jain Centre of Greater Boston, MA, USA), pp. 57–86, World Scientific publishers 2023.
7. S. G. Dani, The decimal place-value system, Part I : The vedic roots, The Mathematics Consortium Bulletin, Vol. 4, Issue 3, January 2023, pp. 14–18.
8. S. G. Dani, The decimal place-value system, Part II : Advancing to maturity, The Mathematics Consortium Bulletin, Vol. 4, Issue 4, April 2023, pp. 1–12.
9. S. G. Dani, Ancient Indian Mathematics: Śulbasūtras – A Mathematical Review, in: Sriraman, B. (ed.), Handbook of the History and Philosophy of Mathematical Practice, Springer, Cham, 2023.
10. S. G. Dani, Śrīdharācārya - a mathematician of mathematicians from medieval India, The Mathematics Consortium Bulletin, Vol. 5, Issue 3, January 2024, pp. 1–14.
11. S. G. Dani, Mathematics in India before 300 BCE, in: *A Comprehensive History of India*, Krishna Mohan Shrimali and Vishwamohan Jha (eds.), Vol. I, part 2, Manohar Publishers, New Delhi, (to be published).
12. S. G. Dani, Engraved zeroes from ancient times, IWSA Newsletter, The official publication of Indian Women Scientists Association, Vol. 51, no. 2, 2024 (issued in March 2025).
13. B. B. Datta, The Jaina School of Mathematics, Bull. Cal. Math. Soc., Vol 21 (1929), No. 2, 115-145.
14. B. B. Datta, The Science of the Sulba, a Study in Early Hindu Geometry, University of Calcutta, 1932.
15. B. B. Datta and A. N. Singh, History of Hindu Mathematics, A Source Book (2 volumes), Motilal Banarasidas, Lahore, 1935 (Part I) and 1938 (Part II), Asia Publishing House, Bombay, 1962 (reprint), Bharatiya Kala Prakashan, Delhi, 2001 (reprint).
16. Joseph Dauben, Book Review of The Universal History of Numbers and the Universal History of Computing by Georges Ifrah, Notices of the Amer. Math. Soc. 49 (2002), 32-38.
17. P. P. Divakaran, The Mathematics of India - Concepts, Methods, Connections, Culture and History of Mathematics 10, Hindustan Book Agency, New Delhi, 2018.
18. A. K. Dutta, *Kuṭṭaka, Bhāvanā* and *Cakravāla*, in Studies in the history of Indian mathematics, pp. 145-199, Cult. Hist. Math. 5, Hindustan Book Agency, New Delhi, 2010.
19. D. Fowler and E. Robson, Square Root Approximations in Old Babylonian Mathematics: YBC 7289 in Context, Historia Math. 25 (1998) 366 - 378.
20. R. J. Gillings, Mathematics in the Time of Pharaohs, Dover Publications, New York, 1972.
21. R. C. Gupta, Bhāskara I's Approximation to Sine, Indian Journal of History of Science, Vol. 2, No. 2 (1967), pp.121-136; reprinted in *Gaṇitānanda* - selected works of Radha Charan Gupta on history of mathematics, K. Ramasubramanian (ed.), Springer, Singapore, [2019] (Second edition).
22. R. C. Gupta, On the date of Śridhara, Gaṇita Bhāratī 9 (1987), 54-56; reprinted in the volume *Gaṇitānanda* cited above.
23. R. C. Gupta, Ancient Jain Mathematics, Jain Humanities Press, Tempe, Arizona, USA, 2004.

24. R. C. Gupta, Decimal numerals and zero in ancient Jaina literature, in: Mathematics in Ancient Jaina Literature, edited by S.G. Dani and S.K. Jain (Ohio University, USA), with the cooperation of Pankaj K. Shah (Jain Centre of Greater Boston, MA, USA), pp. 1-26.

25. Takao Hayashi, The Bakhshali Manuscript, An ancient Indian mathematical treatise, Groningen Oriental Studies, XI, Egbert Forsten, Groningen, 1995.

26. Takao Hayashi, Jain Mathematics, Brill's Encyclopedia of Jainism, ed. by K. A. Jacobsen, et al., Leiden: Brill, 2020, pp. 869-882.

27. Takao Hayashi, Takanori Kusuba and Michio Yano, Indian values for π derived from Āryabhaṭa's Value, Historia Scientiarum 37, 1989, 1-16.

28. Jens Hoyrup, Lengths, widths, surfaces - A portrait of old Babylonian algebra and its kin, Sources and Studies in the History of Mathematics and Physical Sciences. Springer-Verlag, New York, 2002. xiv+459.

29. George Ifrah, Universal History of Numbers, Translated from the 1994 French original by David Bellos, E. F. Harding, Sophie Wood and Ian Monk. John Wiley & Sons, Inc., New York, 2000.

30. Jain, Anupam, *Jain Darshan evam Gaṇit* (in Hindi), Shrut Samvardhan Samsthan, Meerut 250002, India, 2019.

31. Victor J. Katz, A History of Mathematics - an Introduction, Addison-Wesley, 2009.

32. G. R. Kaye, The Bakhshali Manuscript: A Study In Medieval Mathematics, 3 Parts, Calcutta 1927; reprinted Aditya Prakashan, 2004.

33. S. Kichenassamy, Brahmagupta's derivation of the area of a cyclic quadrilateral, Historia Mathematica, vol. 37 (1) (2010) p. 28-61.

34. Rajesh Kochhar, Ancient Indian astro-mathematical tradition - Evolution and linkages, in: Mathematics and Astronomy: A Joint Long Journey: Proceedings of the International Conference, Manuel de León, D. M. de Diego and R. M. Rosa (Eds.), Madrid, 2009.

35. R. P. Kularia, *Maitrāyaṇīya Śulbasūtram* (with Sanskrit Commentary of Sankara, Hindi Commentary Sulbamitra, English Translation, Explanations and Geometrical Figures), Abhishek Publications, 2016.

36. Raghunath P. Kulkarni, Char Shulbasutra (in Hindi), Maharshi Sandipani Rashtriya Vedavidya Pratishthana, Ujjain, 2000.

37. David Mumford, What's so baffling about negative numbers - A cross-cultural comparison, in: Studies in the history of Indian mathematics, pp. 113-143, Cult. Hist. Math. 5, Hindustan Book Agency, New Delhi, 2010.

38. Padmavathamma, *Gaṇita-sāra-saṅgraha* of Mahāvīra, Original text with Kannada and English translation, Siddhanthakirthi Granthamala of Sri Hombuja Jain Math, Shimoga District, Karnataka, India, 2000.

39. Kim Plofker, Mathematics in India; Princeton University Press, Princeton, NJ, 2008.

40. Satya Prakash and Ram Swarup Sharma, *Baudhāyana Śulbasūtram*, with Sanskrit Commentary by Dvarakanatha Yajvan and English Translation and Critical Notes by G. Thibaut, The Research Institute of Ancient Scientific Studies, New Delhi, 1968.

41. Satya Prakash and Ram Swarup Sharma, *Āpastamba Śulvasūtra*, with commentaries from Kapardiswamin, Karvinda and Sundararaja and English translation by Satya Prakash, The Research Institute of Ancient Scientic Studies, New Delhi, 1968.

42. M. Rangacharya, The *Gaṇita-Sāra-Saṅgraha* of Mahāvīracārya, Sanskriti text and English translation, Government Press, Madras, 1912. xxvii+325 pp.; reprinted by Cosmo Publications, 2011.

43. David Reimer, Count like an Egyptian - A hands-on introduction to ancient mathematics, Princeton University Press, Princeton, NJ, 2014.

44. Eleanor Robson, Mesopotamian Mathematics, in: Katz, Victor J. (ed.), The Mathematics of Egypt, Mesopotamia, China, India, and Islam: A Sourcebook, Princeton University Press, p. 143.

45. R. Salomon, Indian Epigraphy, A Guide to the Study of Inscriptions in Sanskrit, Prakrit, and the Other Indo-Aryan Languages, Oxford University Press, 1999.

46. Saraswati Amma, Geometry in Ancient and Medieval India, Motilal Banarasidas, Delhi, 1979.

47. A. Seidenberg, The ritual origin of geometry, Archive for History of Exact Sciences (Springer, Berlin) Vol. 1, No. 5, January 1975.

48. S. N. Sen and A. K. Bag, The *Śulbasūtra*s, Indian National Science Academy, New Delhi 1983.

49. Ratnakumar S. Shah, Evolution and Development of Mathematical Ideas through Jaina Scriptures, in Mathematics in Ancient Jaina Literature, edited by S. G. Dani and S.K. Jain, pp. 27-55, World Scientific publishers 2023.

50. Ram Swarup Sharma (Ed.), *Brāhmasphuṭasiddhantaḥ,* Indian Institute of Astronomical and Sanskrit Research, New Delhi, 1966.

51. Kripa Shankar Shukla (ed.), *Pāṭīgaṇitā* of Śridharācārya (with translation) Lucknow, 1959.

52. Kripa Shankar Shukla and K. V. Sarma (eds.), *Āryabhaṭīya* of Āryabhaṭa, Critically Edited with Translation, Indian National Science Academy, New Delhi, 1976.

53. G. Thibaut, The *Śulvasūtra*s, The Journal, Asiatic Society of Bengal, Part I, 1875, Printed by C. B. Lewis, Baptist Mission Press, Calcutta, 1875; Edited with an introduction by Debiprasad Chattopadhyaya and published by K P Bagchi and Company, Calcutta, 1984; the original also published as a book, Cosmo Publications, 2012.

54. Andre Weil, Number Theory, An approach through history from Hammurapi to Legendre, Birkhauser (1984).

55. Dominik Wujastyk, Indian manuscripts, in Manuscript Cultures: Mapping the Field, Jörg Quenzer and Jan-Ulrich Sobisch (eds.), De Gruyter, Berlin, 2014.

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2. A Peep into History of Mathematics

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Here are my picks for a peep into history for this issue.

Argante Ciocci, Frederico Commandino and the Latin edition of Apollonius's *Conics* (1566), Archive for History of Exact Sciences 77 (2023), 393 - 421.

Latin editions of various ancient Greek mathematical works brought out by Frederico Commandino (1505-1575) have had a great impact on scientific research in the subsequent centuries. His edition of Apollonius's *Conicorum libri quattuor* (Four books on cones) published in 1566 is noted, in particular, to have served as a reference work for several scholars including Kepler (1571-1630), Galileo (1564-1642), Cavalieri (1598–1647), Desargues (1591-1661), and Descartes (1596-1650), in their studies in Optics, Geometry, Astronomy and Kinematics. There was indeed an earlier edition of the work, from 1537, by Giovan Battisa Memmo, but Commandino provided a new Latin translation that amended various faults, clarified several points that had remained obscure, and also illustrated the text with new axonometric drawings in place of the ungainly diagrams in the earlier edition. Apart from this, Commandino's edition included exposition of various subsequent works on the topic, by other ancient Greek scholars including Pappus, Serenus and Eutocius, and also some of his own results. These improvements on multiple fronts resulted in his edition proving, as commented in the paper, to be a fundamental text for the start of the scientific revolution in the 17th century.

In view of the unique role played by the book, there has been much curiosity among historians concerning the genesis of the work, in terms of the overall context and inputs involved. In particular, identifying the Greek sources used in the translation is noted as having been an issue that had "hitherto been unanswerable". In the paper the author identifies one of the Greek codices involved, analyzes the additions made, and offers a thorough discussion, with numerous references, on Commandino's endeavor.

J. Marshall Unger, Cyclic quadrilaterals: Solutions of two Japanese problems and their proofs, Historia Math. 65 (2023), 1 - 13.

Consider a cyclic quadrilateral $ABCD$, with the vertices A, B, C and D labeled cyclically, and let O be the point of intersection of the two diagonals AC and BD. Let $\mathcal{C}$ denote the circumcircle of $ABCD$ and R the radius of $\mathcal{C}$. Partition of $\mathcal{C}$ by the diagonals AC and BD produces four non-overlapping triangles OAB, OBC, OCD and ODA. Let r_1, r_2, r_3, r_4 be the radii of the incircles of the four triangles. In the 18th and 19th centuries Japanese mathematicians (*wasanka*, in Japanese) discovered a formula for R in terms of r_1, r_2, r_3, r_4; we shall not go into the (rather cumbersome) precise expression, and content ourselves mentioning that it is a ratio of two quadratic polynomials in r_1, r_2, r_3, r_4 and $s = \sqrt{(r_1 + r_2 + r_3 + r_4)^2 - 4(r_1r_3 + r_2r_4)}$, with integer coefficients. The only available proof of this is a modern one, relying heavily on trigonometric substitutions, which are unlikely to have been accessible to the *wasanka*.

The *wasanka* also described a formula for R in terms of the radii of the incircles of the four (skewed) sectors of $\mathcal{C}$ produced by the partition by the diagonals AC and BD. In this case, however, two proofs given by Aida Yasuaki (1747-1817), an outstanding *wasanka,* have come down to us from the original context.

The paper under review consists of a comprehensive discussion, with proofs of the results alluded to above, together with the relevant history. It concludes with some significant comments on the techniques involved in the work of Aida Yasuaki. In particular the author notes that "use of a resultant in solving the skewed sector problem is noteworthy because resultants did not appear in the Western literature until the 19th century".

□□□

3. What Is Happening In the Mathematical World?

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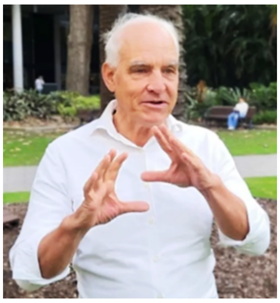
3.1 A General Method Found for Solving Polynomial Equations of Degree five or Higher



The University of New South Wales Honorary Professor *Norman Wildberger* has solved a 200-year-old mathematics problem after figuring out a way to crack higher-degree polynomial equations, without using radicals or irrational numbers. The method developed by Wildberger solves one of algebra's oldest challenges by finding a general solution to polynomial equations of degree five or higher. Polynomials are a foundational part of mathematics and essential to many scientific and engineering applications. But, while the second-, third-, and fourth-degree equations have been solved for centuries, the method of radicals involved does not extend beyond degree 4.

Since the work of Henrik Abel and Évariste Galois in the nineteenth century it is known that no general solution is possible for quintic equations using radicals. In the aftermath mathematicians have turned to approximate methods instead. Though widely used, these approaches fall outside the realm of pure algebra and depend heavily on numerical computation. Now, Wildberger's method introduces a new way for approaching solutions of higher-degree polynomials involving power series. By carefully truncating these series, he and *Dean Rubine*, a computer scientist, generated accurate, rational approximations of solutions to complex equations, and this is achieved without leaving the bounds of logical, constructible mathematics.

The method is built around a unique mathematical structure the researchers call the *Geode*, which extends the well-known *Catalan numbers*, a sequence that describes how shapes like polygons can be divided into triangles, into multiple dimensions. Wildberger highlighted that these complex number patterns, which come from combinatorics, provide a logical foundation for constructing solutions to high-degree polynomials, just as Catalan numbers are tied to simpler quadratic equations.

The Catalan numbers were introduced by Euler in 1751 to count subdivisions into n triangles of a fixed planar convex $(n+2)$-gon, for a natural number n, with the convention that $C_0 = 1$. In 1838, Catalan obtained the formula:

$$C_n = \frac{1}{n+1}\binom{2n}{n} = \frac{(2n)!}{n!(n+1)!}.$$

To see how the Catalan numbers relate to quadratic equations, consider the equation $1-\alpha+t\alpha^2 = 0$ which according to the usual quadratic formula has the solution in radicals: $\alpha = (1 \pm \sqrt{1-4t})/2t$. Applying Newton's binomial expansion to the minus sign solution reveals the generating series of the Catalan numbers as the formal power series solution:

$$\alpha = \sum_{n>0} \frac{(2n)!}{n!(n+1)!} t^n = \sum_{n>0} C_n t^n.$$

A general quadratic equation $c_0 - c_1 x + c_2 x^2 = 0$ can be reduced to above form by setting $x = c_0\,\alpha/c_1$ and thereby a formal power series solution can be found for a general quadratic equation. In order to extend the above argument to higher degrees, N. J. Wildberger and Dean Rubine introduced the **hyper-Catalan number** corresponding to a *subdigon* which is defined to be a planer convex roofed polygon S which is subdivided by non-crossing diagonals into polygonal faces of multiple types. If S is subdivided into m_2 triangles, m_3 quadrilaterals, m_4 pentagons and so on, then S is said to be of **type m** $= [m_2, m_3, m_4, \ldots]$. Necessarily, there are only a finite number of nonzero m_k. The **hyper-Catalan number** $C_{\mathbf{m}} \equiv C[m_2, m_3, m_4, \ldots]$ is defined to be the number of subdigons of type **m**. The usual Catalan numbers are given by $C[m_2]$. Figure 1, illustrates $C[2,0,1]=28$.

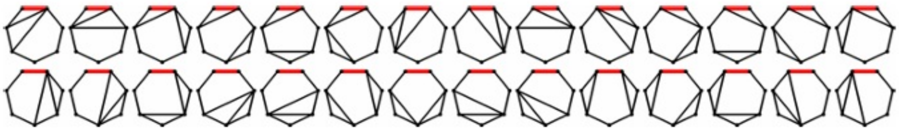


Figure 1. $C[2, 0, 1] = 28$ subdigons with two triangles and a pentagon.

Wildberger and Rubine proved that the polynomial or power series equation $0 = 1 - \alpha + t_2\alpha^2 + t_3\alpha^3 + t_4\alpha^4 + \dots$ has a formal power series solution:

$$\alpha = S = S[t_2, t_3, t_4, \dots] = \sum_{m_2,m_3,m_4,\dots\geq 0} C[m_2, m_3, m_4, \dots] t_2^{m_2} t_3^{m_3} t_4^{m_4,\dots} = \sum_{m\geq 0} C_m t^m.$$

The implications of this discovery go beyond theory. The method could enable new types of computer algorithms that solve complex equations using power series instead of traditional approximations based on irrational numbers.

Sources:

1. *https://interestingengineering.com/science/math-200-year-old-algebra-rule-falls*
2. *N. J. Wildberger & Dean Rubine (2025) A Hyper-Catalan Series Solution to Polynomial Equations, and the Geode, The American Mathematical Monthly, 132:5, 383-402, DOI: 10.1080/00029890.2025.2460966.*

3.2 To 122-Year-Old Triangle-to-Square Puzzle is Resolved

On April 6 1902, Henry Ernest Dudeney a self-taught English mathematician and puzzle columnist, posed a puzzle: “cut any equilateral triangle ... into as few pieces as possible that will fit together and form a perfect square” (without overlap, via translation and rotation). The puzzle became known as “Dudeney’s dissection” or the “Haberdasher’s problem”; it was featured in Scientific American’s June 1958 issue. Within two weeks of posing of the puzzle, Mr. C. W. McElroy of Manchester had found a four-piece solution. Since this discovery over 120 years ago, it had remained open whether this dissection is optimal, or whether the record will someday be improved upon.

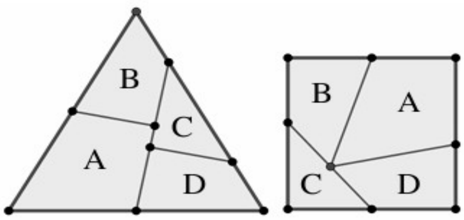


Figure1: The four-piece dissection between an equilateral triangle and a square.

Now, more than 122 years after it was first proposed, *Tonan Kamata* (Center) from JAIST, Japan, together with MIT mathematician *Erik Demaine* (Left) and JAIST mathematician *Ryuhei Uehara* (Right), have finally proved that a solution with fewer pieces is impossible. Kamata and the two mathematicians had been developing a new approach to tackle origami-folding problems using graph theory.

Dissection is the process of transforming one shape A into another shape B by cutting A into pieces and rearranging those pieces to form B (without overlap).

Given two specific polygons, can we find the dissection between them with the fewest possible pieces? In general, this minimization problem is NP-hard, even to approximate within a factor of $1 + 1/1080 - \varepsilon$. Also, the existence of a k-piece dissection is not known to be decidable, even for $k = 2$ pieces.

A k-piece dissection of a pair of polygons (target shapes) (P, P') consists of k polygons (pieces) $P_1, P_2, \ldots, P_k$. A dissection of (P, P') divides each target shape $X \epsilon P, P'$ into pieces by cut lines. A finite geometric graph is called the cut graph GX , which represents the cut lines and the boundary of X. Specifically, G_X has faces that correspond one-to-one with the pieces, vertices $V(G_X)$ which consist of the corners of X and the points along the cut lines having at least one surrounding angle not equal to π, and edges $E(G_X)$ which consist of the cut and boundary lines connecting these vertices. The vertices and edges are classified into different types.

A subdivision H_X of the cut graph G_X is a graph obtained by replacing internal edges of G_X with paths consisting of paired vertices (an internal vertex where exactly two piece corners meet). An equivalence relation '$\sim$' is defined on all possible cut graphs as: $G_{X0} \sim G_{X1}$ if there exist subdivisions H_{X0} and H_{X1} of the graphs G_{X0} and G_{X1} respectively, and a bijection $\phi : V(H_{X0}) \to V(H_{X1})$ such that ϕ is a graph isomorphism that disregards geometry while preserving vertex types. For the specific case of Dudeney's puzzle, P is a square S and P' is an equilateral triangle T. The vertices and edges of S and T are highlighted in the figure 1. The side lengths of S and T are denoted by σ and τ, respectively, and setting $\sigma = \sqrt{\sqrt{3}}$ and $\tau = 2$ it is ensured that both areas are $\sqrt{3}$. First it has been proved that a two-piece dissection is impossible by showing that in any dissection of T and S, no piece contains two corners of T. This is because a piece that contains two corners of T, has a Euclidean distance $\tau = 2$, whereas the longest distance between any two points in S is $\sqrt{2\sqrt{3}} < 2$. So the number of pieces must be at least 3. Thus, Demaine and team focused on proving the impossibility of a three-piece dissection. To do so, they classify the finitely many possible topologies for cutting each polygon that could potentially result in a three- piece dissection, using the equivalence classes under relation $\sim$ defined above. Although this is essentially a brute-force exhaustive search, fundamental properties of dissections are used to narrow down the feasible combinations of these cutting topologies for the two shapes. Finally, they have shown that all remaining combinations are infeasible using the new concepts of "matching diagrams", which handle the potentially unbounded number of cut segments.

Sources:

1. *https://www.scientificamerican.com/article/mathematicians-find-proof-to-122-year-old-tria-ngle- to-square-puzzle/*
2. *Erik D. Demaine, Tonan Kamata and Ryuhei Uehara, Dudeney's Dissection is Optimal, arXiv:2412.03865v2 [cs.CG] 4 Apr 2025.*

3.3 125-Year-Old Hilbert's Sixth Problem has been Resolved

Mathematicians have recently solved a problem that has eluded scientists for over 125 years, bridging three key theories that describe the motion of fluids. This milestone addresses a long-standing challenge in unifying different levels of fluid dynamics. The significance of this discovery lies in its connection to the famous list of unsolved mathematical problems proposed by legendary mathematician *David Hilbert* in 1900. The task of developing adequate mathematical models for describing motion of fluids is not easy, and the path to achieving this goal has been paved with incremental steps and advancements.


Now, mathematicians *Yu Deng* (left) from the University of Chicago and *Zaher Hani* (right) and *Xiao Ma* from the University of Michigan published their work suggesting that they had cracked a crucial part of this problem. They claim to have found a way to unify three fundamental theories that describe fluid motion at different scales. These theories are:

1. Kinetic theory of Gases (Microscopic scale) which describes fluid motion at the molecular level. It treats a gas as a vast collection of individual molecules in constant, random motion, colliding with each other and with the container walls. Becomes computationally intractable for dense fluids.

2. Boltzmann Equation (Mesoscopic Scale) acts as a bridge between the microscopic kinetic theory and macroscopic fluid dynamics. It describes the evolution of the probability distribution function of particles in phase space (position and momentum). Too complex to solve analytically and often requires numerical methods for practical applications.

3. Navier-Stokes Equations (Macroscopic/Continuum Scale) are a set of partial differential equations that describe the motion of viscous fluid substances incorporating the effects of pressure, viscosity, and external forces. They are derived from the conservation of mass, momentum, and energy for a continuous fluid. They are also not valid for highly rarefied gases where the continuum assumption breaks down.

Hilbert's sixth problem was about developing mathematically the limiting processes which lead from the atomistic view to the laws of motion of continua. Hilbert suggests a program which aims at giving a rigorous derivation of the laws of fluid motion, starting from Newton's laws on the atomistic level, using Boltzmann's kinetic theory as an intermediate step. More precisely, this refers to giving a rigorous justification of the diagram as shown in Figure 1.

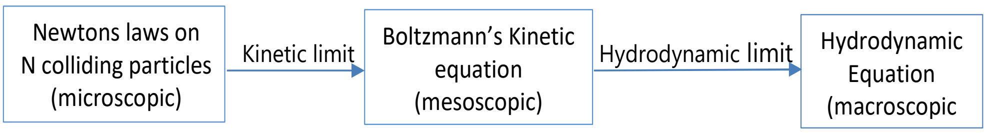


Figure 1: From Newton to Boltzmann to fluid equations

Yu Deng and the team in their paper referred in source 2, complete Hilbert's program and justify the limiting process in Figure 1. Specifically they have proved the following results:

1. Derivation of the Boltzmann equation on $T^d(d = 2, 3)$. Starting from a Newtonian hard-sphere particle system on the torus $T^d(d = 2, 3)$ formed of N particles of diameter undergoing elastic collisions, and in the Boltzmann-Grad limit $N\varepsilon^{d-1} = \alpha$, the Boltzmann equation $(\delta t + v.\ x)n(t, x, v) = \alpha Q(n, n)$, has been derived as the effective equation for the one-particle density function $n(t, x, v)$ of the particle system, where $Q(n, n)$ is the hard-sphere collision kernel.

2. Derivation *of the incompressible Navier-Stokes-Fourier system from Newton's laws.* Starting from the same Newtonian hard-sphere particle system on the torus $T^d(d = 2, 3)$ close to global equilibrium, and in an iterated limit where first $N \to \infty, \varepsilon \to 0$ with $\alpha = N\varepsilon^{d-1}$ fixed and then $\alpha \to \infty$ separately, the incompressible Navier-Stokes-Fourier system has been derived as the effective equation for the macroscopic density and velocity of the particle system.

3. Derivation of the compressible Euler equation from Newton's laws. Starting from the same Newtonian hard-sphere particle system on the torus $T^d(d = 2, 3)$, and in an iterated limit where first $N \to \infty, \varepsilon \to 0$ with $\alpha = N\varepsilon^{d-1}$ fixed and then $\alpha \to \infty$ separately, we derive the compressible Euler equation as the effective equation for the macroscopic density, velocity, and temperature of the particle system.

Physicists have long struggled to unify theories explaining fluid dynamics at different scales. Deng, Hani, and Ma's breakthrough addresses this challenge by linking the statistical behavior of individual particles to the collective behavior of fluids.

Sources:

1. *https://dailygalaxy.com/2025/04/physics-puzzle-finally-cracked/aticians-find-proof-to-122-year-old-triangle- to-square-puzzle/*

2. *Yudeng, Zaherhani, Andxiaoma, Hilbert's Sixth Problem: Derivation of Fluide Euations via Boltzmann's Kinetic Theory, arXiv:2503.01800v1 [math.AP] 3 Mar 2025.*

3.4 Affirmative Resolution of Multidimensional Shape-Slicing Problem

In 1986 Belgian mathematician *Jean Bourgain* posed a seemingly simple question that continued to puzzle researchers for decades. Bourgain's slicing problem asks whether every convex shape in n-dimension of unit size has a "slice" such that the cross section is bigger than some fixed value independent of the shape and the dimension n.
Now, *Boaz Klartag* (left) of the Weizmann Institute of Science in Rehovot, Israel, and *Joseph Lehec* (right) of the University of Poitiers, France has finally provided a definitive answer: yes.

Bourgain's slicing problem, also known as the hyperplane conjecture, admits several equivalent formulations; One such formulation focuses on the relationship between two different measures of the "size" of a convex body: the volume of the convex body and the determinant of its covariance matrix. For a probability measure μ on $\mathbb{R}^n$ with finite second moments covariance matrix of μ is written as $\mathrm{Cov}(\mu) = (\mathrm{Cov}_{ij}(\mu)), i, j = 1, \ldots, n, \in \mathbb{R}^{n\times n}$, given by

$$\mathrm{Cov}_{ij}(\mu) = \int_{\mathbb{R}^n} x_i x_j d\mu(x) - \int_{\mathbb{R}^n} x_i d\mu(x) \int_{\mathbb{R}^n} x_j d\mu(x).$$

For a convex body $K \subseteq \mathbb{R}^n$ (i.e., a compact, convex set with a non-empty interior) we write λ_K for the uniform probability measure on K. Abbreviate $\mathrm{Cov}(K) = \mathrm{Cov}(\lambda_K)$. The isotropic constant of the convex body $K \subseteq R^n$ is defined to be

$$L_K := \left(\frac{\det \mathrm{Cov}(K)}{Vol_n(K)^2}\right)^{\frac{1}{2n}} \text{ and } L_n = \sup_{K\subseteq\mathbb{R}^n} L_K$$

where the supremum runs over all convex bodies $K \subseteq \mathbb{R}^n$.
In one of its formulations as given by Klartag, B., Milman, V. in 2023, Bourgain's slicing problem asks whether $L_n < C$ for a universal constant $C > 0$. In December, 2024, Qing Yang Guan proved that $L_n \leq C \log\log n$.
Klartag and Lehenin in their recent paper (See source 2) have proved that $\sup_{n\geq 1} L_n < \infty$.
Using this result, they proved the following main result, which settles Bourgain's slicing problem in affirmative.
Main result: For any convex body $K \subseteq \mathbb{R}^n$ of volume one, there exists a hyperplane $H \subseteq \mathbb{R}^n$ such that $\mathrm{Vol}_{n-1}(K \cap H) > c$. Here $c > 0$ is a universal constant.
Sources:

1. *https://www.yahoo.com/news/mathematicians-solve-multidimensional-shape-slicing-120000-304.html*

2. *Boaz Klartag and Joseph Lehec, Affirmative Resolution of Bourgain's Slicing Problem using Guan's Bound, arXiv:2412.15044v1 [math.MG] 19 Dec 2024.*

3.5 The Existence of Certain Geometric Mappings in Higher Dimensions Proved

In 1981, *Misha Gromov*, winner of the Abel Prize, posed a question about the existence of certain geometric mappings in higher dimensions. Specifically, he asked whether there exists closed simply connected manifolds, which are not quasiregularly elliptic. This problem belongs to the field of differential topology, which studies the shapes and spatial structures that can be deformed without breaking or losing key properties.

Susanna Heikkilä (right), a Finnish mathematician, in collaboration with another professor, *Pekka Pankka* (left), have now classified quasiregularly elliptic varieties in four dimensions, thus answering a question posed by *Misha Gromov*. They have shown that if a closed, connected, and oriented Riemannian n-manifold N admits a non-constant quasiregular mapping from the Euclidean n-space $\mathbb{R}^n$, then the de Rham cohomology algebra $H^*dR(N)$ of N embeds into the exterior algebra $\bigwedge^* \mathbb{R}^n$. As a consequence, they obtained a homeomorphic classification of closed simply connected quasiregularly elliptic 4-manifolds. Quasiregularly elliptic varieties are mathematical structures that can be deformed under certain rules without losing their geometric essence. They are fundamental in geometry because they help understand how spaces behave in higher dimensions. Heikkila's work is based on De Rham cohomology, a theory that allows analyzing the shape of spaces using mathematical analysis tools.

She was inspired by crochet, a process of creating textiles by using a crochet hook to interlock loops of yarn, thread, or strands of other materials. Passing thread over and over, a knot here, another there, and what was once a simple thread ends up becoming a beautiful sweater, or a lovely scarf.

Now, *Heikkilä* has shown that this skill could be used not only to make scarves or clothing but to solve mathematical problems. To support her theory, Heikkilä crocheted a sphere and used a chessboard fabric in her thesis defense, so that abstract geometric concepts could be visualized. Crochet allowed them to create structures that represented the curvature of mathematical spaces, and the chessboard fabric showed how these mappings behaved.

Sources:

1. *https://unionrayo.com/en/mathematician-crochet-solved-problem/*
2. *Susanna Heikkilä and Pekka Pankka, De Rham Algebras of Closed Quasiregularly Elliptic Manifolds are Euclidean, arXiv:2302.11440v2 [math.CV] 7 Dec 2023.*

3.6 Optimization of the Power Coefficient of A Rotor Disk Achieved by means of Calculus of Variations

Divya Tyagi, a young aerospace engineering student at Penn State, has taken on the challenge of refining optimum rotor disk solution provided by renowned aerodynamicist *Hermann Glauert*, a seminal work in the field of aerodynamics. Glauert's solution originally aimed to determine the maximum power coefficient of wind turbines, a measure of how efficiently these machines convert wind into electricity. However, it did not account for the total force and moment coefficients on the rotor, crucial factors that affect turbine performance.

Tyagi's addendum to this classic problem provides a more comprehensive model that includes these missing variables. By solving for the real flow conditions that wind turbines encounter, she has developed a method that maximizes power output while considering the mechanical stresses on the blades. This holistic approach ensures that turbines can withstand the downwind thrust force and root bending moment, ultimately improving their efficiency and longevity.

The classical rotor disk formulation according to Glauert considers an axi-symmetric streamtube model that encompasses a wind turbine. Glauert approached the mathematical optimization problem of maximizing C_P, the rotor power coefficient, as a function of tip speed ratio, λ. C_P is computed in terms of local tip speed ratio $\lambda_r = r\lambda/R$, where R is the rotor disk radius and r is local radius, axial induction factor a, and the angular induction factor a', using following formula:

$$C_P = \frac{8}{\lambda^2}\int_0^{\lambda} a'(1-a)\lambda_r^3 d\lambda_r.$$

To maximize C_P, Glauert considered formal optimization model given by:
Maximize $f(a, a') = a'(1-a)$
Subject to constraint $16a^3 - 24a2 + (9-3\lambda_r^2)a + (\lambda_r^2 - 1) = 0$.
Glauert solved this equation iteratively using Newton-Raphson algorithm. Glauert also found a practical relation between a and a' as, $g(a, a') = \lambda_r^2 a'(1+a') - a(1-a) = 0$ and a simple expression for $a'(a)$ as $a' = (1-3a)/(4a-1)$. Next, Glauert substituted the optimum solutions for $a(\lambda_r)$ and $a'(a)$ back into the formula for C_P and solved for the exact integral for computing the maximum power coefficient, C_{Pmax}, as a function of tip speed ratio, λ.
Tyagi and Schmitz solve the optimization problem:
Maximize $f(a, a') = a'(1-a)$ subject to constraint $g(a, a') = 0$.
They defined Lagrangian function $L(a, a', \mu) = f(a, a') + \mu g(a, a')$. The stationary points of $L(a, a', \mu)$ determined by setting all partial derivatives of L with respect to a, a', and μ, equal to 0. They solved this system of equations for polynomials $a(\lambda_r)$ and $a'(a)$ which is achieved by calculus of variation. However, both approaches produce identical results for the optimum flow conditions. Further, limiting cases of $a'(a)$, and C_{Pmax}, for low and high tip speed ratio have been discussed in the paper. Also exact integrals of the thrust coefficient C_T and of the bending moment coefficient C_{be} are given by

$$C_T = \frac{8}{\lambda^2}\int_0^{\lambda} a(1-a)\lambda_r d\lambda_r, \qquad C_{be} = \frac{8}{\lambda^3}\int_0^{\lambda} a(1-a)\lambda_r^2 d\lambda_r$$

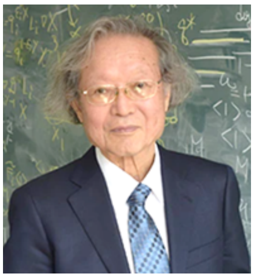
which are evaluated based on optimum solution obtained by them. Also, the limiting values of C_T and C_{be} are computed for low and high tip speed ratio.
The implications of Tyagi's solution are profound. Even a modest improvement in the power coefficient can have substantial effects on energy production. This highlights the importance of Tyagi's work in the context of global energy needs.
Her innovative approach is expected to influence the design of the next generation of wind turbines, making them more efficient and thereby more economically viable.
Sources:

1. *https://www.sustainability-times.com/research/century-old-puzzle-finally-solved-mathematicians- crack-code-that-can-supercharge-the-worlds-most-powerful-turbines/#google_vignette*
2. *Divya Tyagi and Sven Schmitz, Glauert's optimum rotor disk revisited– a calculus of variations solution and exact integrals for thrust and bending moment coefficients, Wind Energ. Sci., 10, 451–460, 2025. https://doi.org/10.5194/wes-10-451-2025*

3.7 Awards

3.7.1 Masaki Kashiwara of Kyoto University Awarded Abel Prize for His Groundbreaking Work

Prof. Masaki Kashiwara, an exceptionally prolific Japanese mathematician, a professor at Kyoto University's Research Institute for Mathematical Sciences, has been awarded the prestigious Abel Prize for 2025. The prize is given for his "fundamental contributions to algebraic analysis and representation theory, especially for the theory of D-modules and crystal bases". He is much-admired for building bridges between different fields of mathematics for the past 50 years, and inspiring generations of researchers.



The Abel Prize, often referred to as the "Nobel Prize of Mathematics," is awarded annually to mathematicians who have made outstanding contributions to the field. The prize, which includes a cash award of NOK 7.5 million, is funded through the academy and the Norwegian government. Kashiwara is the first Japanese mathematician to receive the Abel Prize.

His research career was shaped by renowned mathematician *Mikio Sato* (1928-2023). In 1970, at the age of 23, Kashiwara completed his master's thesis under Sato's supervision. This thesis established the foundations of D-Module Theory, a new basis for studying systems of linear differential equations with algebraic analysis. Kashiwara's work has opened the door to a new mathematical field.

In 1973, Kashiwara collaborated with Sato and *Takahiro Kawai* to publish a groundbreaking scientific paper that has become a bible of algebraic analysis. It is often referred to as the "SKK Paper," after their initials. He continued to publish groundbreaking discoveries and new solutions, such as proving the Riemann-Hilbert Correspondence and developing the theory of crystal bases for quantum groups. He is also known for the Kashiwara Watermelon Cut Theorem, which brought together hyperfunctions, vector fields and analytic wave fronts.

Kashiwara has had more than 70 collaborators so far. Even after his official retirement in 2010, he stayed with the university, traveling overseas and writing papers. "His work continues to be at the forefront of contemporary mathematics and to inspire generations of researchers.

Previous awards that Kashiwara received include the Asahi Prize, the Japan Academy Prize, the Kyoto Prize and the Chern Medal.

Source: *https://www.ams.org/news?news_id=7402*

3.7.2 Dennis Gaitsgory Receives the 2025 Breakthrough Prize in Mathematics

Dennis Gaitsgory of the Max Planck Institute for Mathematics has won the Breakthrough Prize in Mathematics, endowed with 3 million US dollars, for numerous breakthrough contributions to the geometric Langlands program.

Citation: Gaitsgory wins the prize for foundational works and numerous breakthrough contributions to the geometric Langlands program and its quantum version; in particular, the development of the derived algebraic geometry approach and the proof of the geometric Langlands conjecture in characteristic 0.

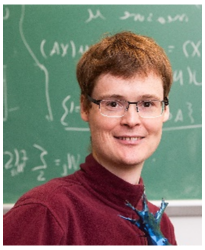
Gaitsgory has dedicated much of the last 30 years to the geometric Langlands conjecture. In 2013 he wrote an outline of the steps required for a proof, and after more than a decade of intensive research in 2024 he and his colleagues published the full proof, comprising over 800 pages spread over 5 papers. This is a monumental advance, expected to have deep implications in other areas of mathematics too, including number theory, algebraic geometry and mathematical physics.

The Langlands program is a broad research program spanning several fields of mathematics. It grew out of a series of conjectures proposing precise connections between seemingly disparate mathematical concepts. Such connections are powerful tools; for example, the proof of Fermat's Last Theorem reduces to a particular instance of the Langlands conjecture.

Gaitsgory completed his studies at Tel Aviv University before earning his doctorate in 1997 at the Hebrew University of Jerusalem under *Joseph Bernstein*. He then held a visiting position in Princeton, USA, followed by roles as a Clay Research Fellow and a professor at the University of Chicago. In 2005, he joined Harvard University as a professor. In 2021, the Max Planck Society appointed him as a Scientific Member and Director at the Max Planck Institute for Mathematics in Bonn.

The Breakthrough Prize was established in 2012 by *Sergey Brin* (Google), *Mark Zuckerberg* (Facebook), and others to recognize outstanding researchers for their groundbreaking discoveries.
Source: *https://breakthroughprize.org/News/91*

3.7.3 Ewain Gwynne, John Pardon and Sam Raskin Awarded the New Horizons in Mathematics Prize



Modern physics and higher mathematics share intimate connections, and it is notable that the research areas of all three of this year's New Horizons in Mathematics Prize winners have links to quantum physics.
Ewain Gwynne from University of Chicago is recognized for his work in conformal probability, which studies probabilistic objects such as random curves and surfaces. Topics he worked on include Schramm-Loewner evolution, Liouville quantum gravity, random planar maps, random permutations, random walk in random environment, and various random growth processes.

American mathematician *John Vincent Pardon* of Stony Brook University has produced a number of important results in geometry and topology, particularly in the field of symplectic geometry and pseudo-holomorphic curves. He is primarily known for having solved Gromov's problem on distortion of knots, for which he was awarded the 2012 Morgan Prize. He is a permanent member of the Simons Center for Geometry and Physics in Stony Brook, New York and a full professor of mathematics at Princeton University.

Sam Raskin, a professor at Yale University has contributed significantly to the major recent progress on the geometric Langlands program including the theory of the Whittaker model and the final proof of the geometric Langlands conjecture in characteristic 0.
New Horizons in Mathematics Prize is given to early-career researchers who have already produced important work in their fields. The prize amounts to \$1,00,000.
Source: *https://breakthroughprize.org/News/91*

3.7.4 Si Ying Lee, Rajula Srivastava, Ewin Tang Awarded Maryam Mirzakhani New Frontiers Prize

The Maryam Mirzakhani New Frontiers Prize is awarded to outstanding women mathematicians who have recently completed their Ph.D.
Si Ying Lee (left) of Stanford University (Ph.D. Harvard University 2022) has found a new approach to an important problem in the Langlands program, succeeding in reducing it to a local problem (Shimura varieties).
Rajula Srivastava (right) from University of Bonn and Max Planck Institute for Mathematics (Ph.D. University of Wisconsin 2022) has made progress in a challenging area at the intersection of harmonic analysis and number theory. Her work focuses on bounding the number of lattice points one can find near a given smooth surface, with important applications to Diophantine approximation in higher dimensions.

Ewin Tang (left) of University of California, Berkeley (Ph.D. University of Washington 2023) has invented quantum computing algorithms for machine learning. She also proved that certain calculations, for which quantum algorithms were widely considered to be exponentially faster at solving, can actually be solved in comparable time by a normal (non-quantum) computer.
Source: *https://breakthroughprize.org/News/91*

3.8 Obituary

3.8.1 Peter D. Lax, Mathematician who Found Order in the Natural World Passes away at 99

The US–Hungarian mathematician Peter Lax who revealed connections in fundamental equations that govern many physical processes and was a pioneer in the development of computer-based methods for solving them, passed away on 16 May 2025 at the age of 99. Computer models that grew from his equations have been used in medicine, aviation and weather forecasting.

Peter Lax was one of the greatest pure and applied mathematicians. He was known for his work in partial differential equations, numerical analysis, and mathematical computing. His name is connected with many major mathematical results and numerical methods, such as the Lax-Milgram Lemma, the Lax Equivalence Theorem, the Lax-Friedrichs Scheme, the Lax-Wendroff Scheme, the Lax Entropy Condition and the Lax-Levermore Theory. The Lax equivalence theorem gives a good demonstration of the style of Lax's work. Because many phenomena can be analyzed through partial differential equations, Lax's work influenced many fields, including fluid dynamics, aerodynamics, weather forecasting and imaging. He also had a key role in applying high-performance computing to a wide range of problems.

He advised 55 doctoral students during his long career at the Courant Institute, New york. He brought together pure and applied mathematics, and was awarded the Abel Prize in 2005 for his groundbreaking contributions to the theory and application of partial differential equations and to the computation of their solutions. The prize citation described him as "the most versatile mathematician of his generation" and as "combining a deep understanding of analysis with an extraordinary capacity to find unifying concepts". Earlier he was also awarded the Wolf Prize in 1987.

Peter D. Lax was born on 1 May 1926 in Budapest, Hungary. He received his Ph.D. in 1949 from New York University with the leading mathematician and German émigré Richard Courant as his thesis advisor. He was appointed in 1951 as an assistant professor of mathematics at Courant, where he was to spend his entire illustrious career.

Sources:

1. *Nature 642, 568 (2025) doi: https://doi.org/10.1038/d41586-025-01837-y*
2. *https://abelprize.no/article/2025/peter-lax-abel-prize-laureate-dies-99*

3.8.2 RP Bambah, Eminent Mathematician Passes away at 99

Prof. Ram Prakash Bambah, a globally acclaimed mathematician, a towering figure in Indian academia and a Padma Bhushan awardee passed away on 26 May 2025 a few months before completing 100 years.

A scholar of international repute, he was known for his pioneering work in number theory and discrete geometry, especially in lattice coverings and Ramanujan's Tau Function. Among numerous honours, he was also awarded the Srinivasa Ramanujan Medal in 1979 for his work in mathematical sciences. Prof. Bambah, served as Vice-Chancellor of Panjab University from 1985 to 1991 and was president of the Indian Mathematical Society in 1969. Born on 17 September 1925 in Jammu, Prof. Bambah's journey into research in mathematics began at the Government College, Lahore (GCL), where he was deeply inspired by his teacher, *Prof. Sarvadaman Chowla*. It was under Prof. Chowla's guidance that Bambah secured a research scholarship at GCL, setting the foundation for his future achievements. Bambah scored a record 600 out of 600 in his Master's from GCL, in 1946, and went on to earn a Ph.D. from the University of Cambridge, England, in a record two years - an extraordinary academic feat.

He joined the Panjab University (PU) as Reader in 1952. He also held a position as Professor at Ohio State University in the US from 1964 to 1969, before returning to PU. Under his leadership, PU nurtured one of India's first Centres for Advanced Study in Mathematics. He created a school there which became known globally for its contributions to number theory. He was awarded a D.Sc. by Cambridge University in 1970 and was an Emeritus Professor at Panjab University since 1993. In 2016, PU conferred on him a D.Sc. (Honoris Causa) for his exceptional contributions to mathematics.

As Vice-Chancellor of PU from 1985 to 1991, he led the university through a significant period of development and transformation. His contributions to mathematics and higher education were nationally recognized with prestigious honors including the Padma Bhushan and the Ramanujan Medal.

Prof. Bambah remained intellectually active and published significant mathematical papers until long after his retirement in 1993, keeping abreast of ongoing mathematical research. Prof. Bambah inspired countless students, faculty and also administrators. His belief in the transformative power of education remains a guiding light for the academic community. Even during his final years, he had remained deeply invested in mathematics actively keeping track of the new developments in Number theory.

Prof. Bambah leaves behind a towering legacy of academic brilliance and leadership. May his contributions continue to illuminate the path for generations to come[1].

Sources:

1. *https://www.tribuneindia.com/news/chandigarh/mathematics-fraternity-mourns-loss-of-its-great- scholar/*
2. *https://www.hindustantimes.com/cities/chandigarh-news/rp-bambah-eminent-mathematician-former-pu-v- c-passes-away-at-99-101748276412640.html*

3.8.3 Tributes to Padma Vibhushan Prof. Jayant V. Narlikar

Wrangler Dr. Jayant V. Narlikar, a distinguished mathematician and astrophysicist passed away on May 20, 2025[2]. He was a great scientist with profound insights into cosmology, the problems associated with understanding the Universe, its beginning, evolution to its present state and future. He actively engaged in science communication with a view to promote scientific thinking in society.

Dr. Jayant Narlikar was very well known for his work on the Hoyle-Narlikar Steady State Model of the Universe and the hypothesis of Continuous Creation of Matter, attracting attention of the world. When he came to India in 1965 from Cambridge for a short visit after his doctoral work, people were anxious to see him, eager to listen to him and know about the state of the Universe through his talks at places he visited during that visit. Since then Dr. Jayant Narlikar has been a celebrity. His contribution towards promoting - understanding of the nature of the Universe, spreading of science in students and society through literature, talks, radio/tv programs keeping them away from superstitions through a proper understanding of the Universe we live in.

Dr. Jayant Narlikar was born on July 19, 1938 in Kolhapur, received his early education in the campus of the Banaras Hindu University, where his father Wrangler Professor V. V. Narlikar was the Head of the Department of Mathematics of the university. His mother, Sumati Narlikar, was a Sanskrit Scholar. He had a brilliant career in school and later in college education and received his Bachelor Degree in Science from BHU in 1957, following which went to Cambridge for higher studies. He became a Wrangler getting Tyson Medal in Mathematical Tripos with

[1]We at TMC, pay our tributes to the eminent mathematician professor R. P. Bambah and plan to bring out special Issue in April, 2026 in his honor.

[2]The text of this subsection was kindly contributed by Prof. Ramesh Tikekar, Pune; Email: tikekar@gmail.com

degrees in Mathematics, B.A. (1960), Ph.D. (1963), M.A. (1964) and D.Sc. (1976) - specializing in Astronomy and Astrophysics. He received the famous Smith Prize (1962) and Adams Prize (1967) and was a Fellow of King's College during (1963-1972). He was Founder Faculty Member of Institute of Theoretical Astronomy (1966 - 1972) where in collaboration with his mentor Fred Hoyle laid foundations of their research work in Cosmology and Astrophysics.

He returned to India in 1972 and joined Tata Institute of Fundamental Research, taking charge of the Theoretical Astrophysics Group which later expanded and received International standing for its contributions to science and cosmology. Narlikar was well known for his work on the cosmological models alternative to the popularly known Standard Big Bang Model of our Universe in which the galaxies are seen to be moving away from each other. The alternative Hoyle-Narlikar model of the universe adopts the view that, the process of continuous creation of matter is going on with formation of new galaxies which also keep on moving away from others.

Dr. Narlikar's later work pertained to the following areas: (1) Gravity: the interaction between two particles, Mach's principle and inertial and gravitational aspects of mass particles. (2) Quantum gravity and physics of action at a distance. (3) Quasi-stellar objects, Black holes and Gravitational waves.

Dr. Narlikar played a pioneering role in establishing the Inter University Centre for Astronomy and Astrophysics (IUCAA) Pune. He was its Founder-Director and under his leadership IUCAA developed as a world-wide recognized research centre for Theoretical Physics, Astrophysics and Cosmology. The students, teachers and scholars engaged in study of gravity, astronomy, cosmology in India and abroad have been immensely benefited by the activities promoted by IUCAA.

Dr. Narlikar played an important role as promoter of scientific thinking in society, through his writings, science stories, articles and books, lectures and talks on various public institutional platforms, radio/television programs and will be remembered for a very long time. He was a great, prolific science writer and science-populiser. His Autobiography "Char Nagaratale Maze Vishwa" in Marathi was awarded "Sahitya Academy Prize". He was honoured by the Government of India with the Award - Padma Bhushan in 1965 and later with the Award - Padma Vibhushan in 2004. He received Honour from UNESCO and received Kalinga Popular Science Award for popular science work in 1996.

Dr. Narlikar has authored 49 books and 18 edited volumes in different categories of popular science books, books of academic nature and fictions. *The Lighter Side of Gravity, Scientific Edge: The Indian Scientists from Vedic to Modern Times, Seven Wonders of the Cosmos, The Universe: A Beginner's Guide and Cosmic Safari* (co-authored with M. T. V. Raghunathan) are intended for general readers while, *An Introduction to Cosmology, Lectures on General Relativity and Cosmology, and Facts and Speculations in Cosmology* (co- authored with Geoffrey Burbidge) are academic books intended for advanced readers. Fiction books written by Dr. Narlikar are *The Return of Vaman - A Scientific Novel, It Happened Tomorrow, and Black Holes.* Apart from this, Dr. Narlikar has written books in Marathi such as *Dnyaneshwari Ani Vigyan, Tapatraya* (Science fiction), *Antarikshaatil Avakash, Ganitatlya GamatiJamti* and *Phulrani Ani Chandralok, Suryacha Prakop, Yala Jivan Aise Nav* etc..

Dr. Narlikar's death has brought a great loss to the scientific community in general and Astrophysics and Cosmology community in particular, but his invaluable scientific contributions will light up scientific curiosity of future generations for ever.

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4. Dr. S. Balachandra Rao

S. G. Dani
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In the passing of Dr. S. Balachandra Rao, on 14 May 2025, we have lost one of a unique brand of enthusiasts and an erudite educator of classical Indian astronomy and mathematics. Apart from his scholarly research in the area, he has done yeoman service in promoting awareness of ancient Indian heritage in the area, through many of his books, articles, and not to forget, many lively talks on the subject, including in videos, over his career.

Dr. Rao was born at Tyāgarti (also known as Thāgarti), near Sagar, in Karnataka, on 24 December 1944, and had his early schooling at Sagar. In 1956 the family moved to Bangalore, following sad untimely demise of his father. He later studied at the Basavanagudi National College, Bangalore, which cultivated his interest in mathematics and Sanskrit, which were to have a lasting impact on his later works. Motivated by the twin interests he purchased and read with keen interest the books *History of Hindu Mathematics, A Source Book* by B. B. Datta and A. N. Singh (in two parts, published in 1935 and 1938 respectively), and *The History of Ancient Indian Mathematics* by C. N. Srinivasiengar (1967), which have been pioneering works in the subject of ancient Indian mathematics. He noticed that while the development of mathematics in ancient India was intricately linked with the study of astronomy, the latter had nevertheless remained a relatively unexplored topic, compared to the purely mathematical component. This prompted him to focus his attention on astronomy. He also had an exposure to astrology, as a teenager, stemming from observations with the family horoscopes, and he actively pursued it with the help of an English magazine and a book in Kannada, authored by C. G. Rajan, which he found very useful. His interest in astrology waned, however, in the course of his college years. In his autobiographical note [1] he mentions "In retrospect I feel I wasted two years or more studying (but not practising!) astrology. Dr HN's influence, coupled with Russell's rationalistic thinking, plus the outcome of the highest Indian philosophy *Advaita* (non-dualism) made me give up astrology altogether."; "Dr HN" here refers to Dr. H. Narasimhaiah, then Principal of the National College, a Professor of Nuclear Physics who was later appointed Vice-Chancellor of Bangalore University; Dr. Rao is noted to have been very fond of him all through, and referred to him as his mentor. Renunciation of astrology simultaneously led to his studying astronomy seriously; a take-away from the earlier involvement was that he retained keen interest in learning to compute planetary positions, and phenomena like eclipses. During that period he studied Sanskrit canonical works on astronomy, both in the original and through available translations.

He did his Master's degree, in Mathematics, from the Manasa Gangotri University, Mysore, during 1965-67. Following the degree he got an appointment as a Lecturer in Mathematics at the National College at Gouribidanur, about 75 kms from Bengaluru, where he was to spend the next 10 years. At the College he got to teach spherical astronomy, something that particularly suited his temperament. In 1977 he got an opportunity, under the Central Government's Faculty Improvement Program (FIP), to work for Ph.D., with financial support for four years. Availing of it, he worked in Fluid Mechanics, under the guidance of Prof. N. Rudraiah, at the Central College, Bangalore University; Prof. Rudraiah, an applied mathematician of international repute, had been one of his teachers at Manasa Gangotri. He completed the doctoral work in the stipulated 4-year period, and following that, in 1981 he got a transfer of his affiliation to the National College at Basavanagudi, Bengaluru. He worked there for about 21 years, until retiring in 2002; he was the Principal of the College during the final years, starting from 1998. Following his retirement from the College Dr. Rao served as Honorary Director of the Gandhi Centre of Science and Human Values, Bangalore, of the Bharatiya Vidya Bhavan, during 2004–2019, during which his creativity is seen to have taken further leaps. He also served as Honorary Professor at the National Institute for Advanced Studies (NIAS), Bangalore.

He received the Ph.D. degree of the Bangalore University in 1983. Another major development in his career followed soon after. In 1984-85 he got an opportunity of spending one year at the Loughborough University of Technology in the UK, to participate in an advanced training programme in Computer Oriented Mathematics. Here he got introduced to computer programming, during the early phase of the computer era. The initial engagement with the newly learned techniques related to differential calculus, but on return from Loughborough he bought a 'Spectrum' home computer, and from 1986 that kept him busy with computational Indian astronomy. He mentions that programming on the home computer for mathematical algorithms really thrilled him.

He developed one of the early software giving accurately the heliocentric and geocentric planetary positions, including those of Uranus, Neptune and Pluto, and the Indian astronomical features such as the *tithi, nakṣatra, yoga or karaṇa* for any date. He then programmed several algorithms for procedures described in the *Sūryasiddhānta*, the excitement around which is described vividly by him in [1]. He also moved on, in a similar spirit, to other texts like Brahmagupta's *Khaṇḍakhādyaka, Gaṇeśa Daivajñya's Grahalāghavaṃ* and others.

Over his career he has written numerous books. His first book, "*Indian Mathematics and Astronomy– Some Landmarks*", appeared in 1994. The book has subsequently appeared in several editions and reprints, with updates on some topics along the way. The book surveys, in about 300 pages, the development on these topics in India, starting from the Vedic period, through the medieval period, introducing the works of the stalwarts Āryabhaṭa, Brahmagupta, Bhāskara-I, Mahāvīra, Bhāskara-II and Gaṇeśa Daivajña, together with a brief treatment of the Kerala school of mathematics, and concludes with a chapter on Srinivasa Ramanujan. Soon after the first book, he got into a collaboration with the team of researchers working on the topic at Chennai, M. D. Srinivas, M. S. Sriram and K. Ramasubramanian. The endeavor, supported by an assistantship, resulted in his second book *Indian Astronomy - an Introduction*. The book became quite popular. This and his other works on the subject, including especially *Ancient Indian Astronomy- Planetary Positions and Eclipses* have served as textbooks for courses on classical Indian astronomy, especially with the implementation of the New Educational Policy in recent years.

Dr. Rao at Loughborough

Dr. Rao's books

He also collected some medieval unedited and unpublished Sanskrit palm-leaf manuscripts from the Bhandarkar Oriental Research Institute (BORI), Pune, and the Oriental Research Institute (ORI), Mysore, and computerized the algorithms described in them. He also worked on the texts of Ptolemy and Copernicus, and the planetary tables, along with modern astronomical algorithms for the planetary positions, eclipses etc.. Motivated by the work of Kuppanna Sastry and using some of it together with a Tamil manuscript he worked on a project, jointly with Padmaja Venugopal, culminating in two books *Eclipses in Indian Astronomy and Transits and Occultations in Indian Astronomy.*

Among his other notable scholarly works a mention ought to be made of the translated and edited versions, together with mathematical discussions, of the two famous astronomical handbooks (so called *Karaṇa* works), *Grahalāghavaṃ* of Gaṇeśa Daivajña (c.1520 CE) and *Karaṇakutūhalaṃ* of Bhāskara-II (b.1114 CE), jointly with his student S. K. Uma, published by the Indian National Science Academy (INSA) in 2007 and 2008 respectively. The work was earlier serialized in the

INSA Journal *Indian Journal of History of Science*, in 2006 and 2007-08 respectively. Incidentally, most of his research pursuits on ancient mathematics and astronomy, including the last mentioned works, was carried out under projects supported by the Indian National Science Academy, since 1993; he perhaps qualifies to be the one to have made the best use of the provision made by the academy for supporting research in ancient heritage. He also served on the Research Advisory Council, National Commission for History of Science, INSA, and on the Editorial Board, Indian Journal of History of Science.

For many years now he had a team of five students around him, Drs. V. Vanaja, M. Shailaja, S. K. Uma, Padmaja Venugopal and Rupa Raviprasad (K. Rupa). He was supportive of them and engaged them with his pursuits as much as possible. A few years ago I had the opportunity to edit, in collaboration with Dr. S. K. Jain, Ohio University, USA, a volume "Mathematics in Ancient Jaina Mathematics"; the project was a follow up of an international conference in 2020, sponsored by the Jain Centre of Greater Boston and the Academic Liaison Committee of the Federation of Jain Associations of North America. Dr. Rao's team contributed to the endeavor, with a paper "Geometry in Mahāvīrācārya's *Gaṇitasārasaṅgraha*" authored by Dr. Rao together with K. Rupa, S. K. Uma and Padmaja Venugopal. Earlier when I took over the editorship of Gaṇita Bhāratī, in 2010, I was quite apprehensive of getting adequate number of papers to keep the journal going, and had approached various people for help. Prof. Rao's was one of the reassuring voices. Indeed, together with his team he published four papers in Gaṇita Bhāratī in the initial years.

Apart from producing scholarly works he also carried a deep urge, 'as a teacher' as he would refer to it, to reach out to wider audiences through books. In this his focus was on creating awareness about ancient heritage on the one hand, and promoting rationalist thinking on the other hand. His books *Tradition, Science and Society* and *Astrology - Believe It or Not* are notable in this respect. He was staunch in debunking pseudosciences such as Astrology and (the so called) Vedic Mathematics. Having studied astrology systematically he was well equipped to challenge the claims of astrologers. In 2001 there was a move to introduce Astrology and Vedic Mathematics into university curricula. Some of us were involved in a campaign against such unscientific move, and it was a pleasure to have Dr. Rao on board with us, contributing to its success. Reference to the campaign are found in some of his books. He also debunked the so called Vedic mathematics; it was a pleasure to find that he often cited my writings on the topic. In recent years he had also been an active participant in movements like 'March for Science', promoting adoption of scientific temper.

He also wrote many books in Kannada. In Nava Karnataka Publications, Bangalore, he found a welcoming publisher. The reputable publishing house, known for scientific, progressive and rationalistic books, encouraged him to write in Kannada. His books on *Āryabhaṭīya and Līlāvatī* deserve special mention in respect. Many titles published there got reprinted. The Kannada versions of *Tradition Science and Society* and *Astrology - Believe It or Not* won prestigious awards from the Kannada Sahitya Parishat, the highest literary body in Kannada.

His was a dynamic and lively personality, and he remained active almost till the end. He will be missed by enthusiasts of Indian heritage in mathematics and astronomy, and the large community of readers of his informative and persuasive books.

Acknowledgement: It is a pleasure to thank Mr. Karthik Shiraly, son of Dr. Balachandra Rao, for providing material which was helpful in preparing this note, and for sharing the photographs presented here.

Reference

1. S. Balachandra Rao, My pursuit of classical Indian astronomy, Journal of Astronomical History and Heritage, 27(2) (2024), 397–415.

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5. Report on the Compact Courses Conducted by R. Balakrishnan Endowment Trust (RBET) and The (Indian) Mathematics Consortium (TMC)

T. Tamizh Chelvam
President RBET

Professor R. Balakrishnan Endowment Trust (RBET), Tiruchirapalli and The (Indian) Mathematics Consortium (TMC), Pune jointly organized 12 Compact Courses in Mathematics during the year 2024-25, with an aim to provide clear knowledge about basics in Mathematics to the young Undergraduate students in the county. These courses were organised under the guidance of Prof. R. Balakrishnan and Prof. T. Tamizh Chelvam. Prof. S. A. Katre and Prof. Krishnendu Gongopadhyay were TMC Representatives for the compact courses. This activity will also continue during the academic year 2025-26. For the details regarding modus operandi and financial support for organizing such compact courses, Institutions may contact regional coordinators mentioned below or Prof. T. Tamizh Chelvam, President RBET (*tamche59@gmail.com*).

5.1 List of Regional Coordinators for Compact Courses during 2024-25

Sr. No.	Region	Name of the Regional Coordinator	Email and Mobile
1	Delhi, Uttar Pradesh and Haryana	Dr. Deepti Jain, Dept. of Maths Sri Venkateswara College, Uni. of Delhi, New Delhi	djain@svc.ac.in 9871413161
2	Maharashtra and Gujarat	Dr. Chirag M. Barasara Hemchandracharya North Gujarat Uni., Patan, Gujarat	chirag.barasara@gmail.com 9998041029
3	Andra Pradesh, Telangana and Orissa	Dr. Sasmita Barik School of Basic Sciences IIT Bhuvaneshwar	sasmita@iitbbs.ac.in Phone: 0674-7135142
4	Tamil Nadu Additional	Dr. A. Muthusamy Dept. of Mathematics Periyar University, Salem	appumuthusamy@gmail.com 9842035190
5	Tamil Nadu, Kerala and Karnataka	Dr. K. Somasundaram Department of Maths., AMRITA Uni., Coimbatore	s_sundaram@cb.amrita.edu 9443657545
6	Bihar, West Bengal and Assam	Dr. Madhumangal Pal Dept. of Applied Maths, Vidhyasagar Uni., West Bengal	mmpalvu@mail.vidyasagar.ac.in 9832192207

Reports on the three Compact courses held in September, 2024 were published in October, 2024 Issue of the TMC Bulletin. We include here report on the other 9 compact courses held during 2024-25.

5.2 List of Compact Courses During October 2024 (UG colleges)

(1) Region: Tamil Nadu **Dates: October 17-19, 2024**
Institute: Periyar University, Salem, Tamil Nadu.
Local Coordinator: Dr. P. Prakash.
Resource Person: Dr. P. S. Srinivasan, Dept. of Mathematics, Bharathidasan University, Tiruchirappalli.
Topic: Real Analysis: LUB Axiom and its Applications, Series and Sequence of real numbers, Convergence and its properties, Continuity and Differentiation, Pointwise and uniform convergence.

(2) Region: Tamil Nadu, Kerala and Karnataka **Dates: October 18-20, 2024**
Institute: St. Dominic's College Kanjirapally, Kottayam, Kerala.
Local Coordinator: Dr. Prathish Abraham.
Resource Person: Dr. V. Pragadeeswarar, Dept. of Mathematics, Amrita Vishwa Vidyapeetham, Coimbatore.
Topic: Real Analysis: Calculus: limit, continuity, differentiation, integration and other concepts in real analysis.

(3) Region: Bihar, West Bengal and Assam **Dates: October 21-26, 2024**
Institute: Raja N L Khan Women's College (Autonomous), Midnapore, West Bengal.
Local Coordinator: Dr. Biswajit Mondal.
Resource Person: Prof. Sukhendu Kar, Jadhavpur University
Topic: Algebra: Introduction to algebraic structures: Groups, rings, subgroups, normal subgroups, quotient groups, ideals, quotient rings, group and ring homomorphisms.

5.3 List of Compact Courses During February and March 2025 (Engineering Colleges):

(1) Region: Delhi, Uttar Pradesh and Haryana **Dates: February 10-12, 2025**
Institute: Shri Vishwakarma Skill University, Palwal, Haryana.
Local Coordinator: Dr Mohit Kumar Srivastav.
Resource Person: Dr. Sachin Sharma, Assistant Professor, Department of Mathematics, Netaji Subhas University of Technology, Delhi.
Topic: Differential Equations and their Applications in Science and Engineering: Definition of ordinary and partial differential equations, Formation of ODE, order and degree, Solutions of first order differential equations: separation of variables, homogeneous and linear ODE, Application of first order ODE in Engineering, Linear differential equations with constant coefficients and its applications, Euler-Cauchy differential equations, Euler methods, Euler Modified method, Runge-Kutta method, MATLAB program based on the above topic.

(2) Region: Maharashtra and Gujarat **Dates: February 27 - March 1, 2025**
Institute: Shree K. J. Polytechnic Bharuch Gujarat.
Local Coordinator: Mrs. Jyoti D Chaudhari.
Resource Person: Prof. Devbhadra V. Shah, Department of Mathematics, Veer Narmad South Gujarat University, Surat, Gujarat.
Topic: Calculus: Differentiation and its Applications: Concept and Definition and definition of Differentiation, Working rules: Sup, Product, Division, Chain Rule, Derivative of Implicit and Parametric functions, Logarithmic Differentiation, Successive Differentiation up to second order. Concept and Definition of Integration, Working rules and Integral of standard functions, Method of substitution, Integration by parts, Definite Integral and its properties, Simple applications to Area and volume. Concept and Definition, Order and Degree of a differential equation, Solution of differential equations of first degree and first order by variable separable method, Solution of a linear Differential equation.

(3) Region: Tamil Nadu and Kerala **Dates: Dates: March 10-12, 2025**
Institute: Saranathan College of Engineering, Panjappur, Tiruchirapalli, Tamil Nadu.
Local Coordinator: Dr. V. Punitha, Department of CSE.
Resource Person: Dr. Lavanya Selvaganesh, Department of Mathematical Sciences, IIT (BHU) Varanasi, UP.
Topic: Numerical Iterative Methods: Solution of algebraic and transcendental equations - Fixed point iteration method - Newton Raphson method - Solution of a linear system of equations - Gauss elimination method - Gauss Jordan method - Iterative methods of Gauss Jacobi and Gauss-Seidel - Eigenvalues of a matrix by Power method.

(4) Region: Tamil Nadu **Dates: March 10-12, 2025**
Institute: Golaghat Engineering College, Assam.
Local Coordinator: Department of Mathematics.
Resource Person: Prof. Ankur Bharali, Dept. of Mathematics, Dibrugarh University, Assam.
Topic: Linear Algebra: Fundamentals of Linear Algebra - Matrix operations, determinants, and vector spaces, System of Linear Equations Eigenvalues and Eigenvectors and their significance in stability analysis and transformations. Applications in Engineering Practical applications of linear algebra techniques.

(5) Region: Andra Pradesh, Telangana and Odisha **Dates: March 17-19, 2025**
Institute: Gayatri Vidya Parishad College of Engineering for Women, Visakhapatnam, AP.
Local Coordinator: Dr. A. Suseelatha.
Resource Person: Prof. Vasudeva Rao Allu, Dept. of Mathematics, IIT Bhubaneswar, Odisha.
Topic: Differential Equations: Construction of Differential Models and Their solutions, Differential Equations as Mathematical Models. Why must an Engineer know the Existence and Uniqueness Theorems? Modelling with First Order Differential Equations. Modelling with Higher-Order Differential Equations.

(6) Region: Jammu Kashmir **Dates: March 26-28, 2025**
Institute: Government College of Engineering and Technology, Chack Bhalwal, Jammu.
Local Coordinator: Prof. K. S. Charak, Dept. of Mathematics, University of Jammu, Jammu.
Resource Person: Dr. Sarika Verma, Dept. of Mathematics, University of Jammu, Jammu.
Linear Algebra- The Secret behind Technology: Matrix operations (Social networking), Linear dependence and independence, Rank of a matrix (Significance of rank in smartphone selection), Digital image, image processing and compression (Application of rank in image compression).

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6. International Calendar of Mathematics Events

Ramesh Kasilingam
Department of Mathematics, IITM, Chennai;
Email: rameshk@iitm.ac.in

October 2025

- October 3-5, 2025, 2025 Fall Southeastern Sectional Meeting Tulane University, New Orleans, LA. *www.ams.org/meetings/sectional/2328_program.html*
- October 13-17, 2025, AIM Workshop: Flag Algebras and Extremal Combinatorics, American Institute of Mathematics, Pasadena, California.
aimath.org/workshops/upcoming/flagextremal/
- October 14-17, 2025, SIAM Conference on Mathematical and Computational Issues in The Geosciences (GS25), Louisiana State University, Baton Rouge, Louisiana, U.S.
www.siam.org/conferences-events/siam-conferences/gs25/
- October 15-16, 2025, The 1st International Electronic Conference on Games (IECGA 2025) Online with Live Sessions.
sciforum.net/event/IECGA2025?utm_source=AMS&utm_medium=AMScal
- October 18-19, 2025, 2025 Fall Central Sectional Meeting St. Louis University, St. Louis, MO. *www.ams.org/meetings/sectional/2322_program.html*
- October 19-23, 2025, 7th School on Belief Functions and Their Applications Granada, Spain.
www.bfasociety.org/BFTA2025/

- October 20-24, 2025, New Trends of Stochastic Nonlinear Systems: Well-Posedeness, Dynamics and Numerics, CIRM, 163 Avenue De Luminy, Case 916 13288 Marseille Cedex 9, France. *conferences.cirm-math.fr/3374.html*
- October 27-31, 2025, AIM Workshop: Computations in Stable Homotopy Theory, American Institute of Mathematics, Pasadena, California. *aimath.org/workshops/upcoming/compstabhom/*

November 2025

- November 17-21, 2025, Recent Trends in Stochastic Partial Differential Equations, SL Math, 17 Gauss Way, Berkeley CA. *www.slmath.org/workshops/1148*
- November 17-20, 2025, SIAM Conference on Analysis of Partial Differential Equations (PD25), Sheraton Pittsburgh Hotel at Station Square Pittsburgh, Pennsylvania, U.S. *www.siam.org/conferences-events/siam-conferences/pd25/*

December 2025

- December 8-12, 2025, Research at the Interface of Applied Mathematics and Machine Learning, University Of Houston, Houston, TX. *www.math.uh.edu/cbms-amml*
- December 8-13, 2025, Workshop in Harmonic Analysis and Operator Theory (HAOT), Indian Institute of Science Education and Research (IISER) Mohali, India. *web.iisermohali.ac.in/dept/math/events/2025-dmha/#HAOT*
- December 13-16, 2025, The 30th Asian Technology Conference in Mathematics (ATCM 2025), Ateneo De Manila University, Quezon City, Philippines. *atcm.mathandtech.org*
- December 15-19, 2025, Artificial Intelligence & Mathematical Sciences Shkodra, Albania. *www.risat.org/AIMS%202025.html*
- December 16-19, 2025, 19th Discussion Meeting in Harmonic Analysis, Indian Institute of Science Education and Research (IISER) Mohali, India. *web.iisermohali.ac.in/dept/math/events/2025-dmha/*
- December 20-22, 2025, The International Conference of Industrial and Applied Mathematics (ICIAM), Hammamet, Tunisia. *iciam.net*

January 2026

- January 5-9, 2026, Extremal Black Holes and the Third Law of Black Hole Thermodynamics, ICERM/ Brown University, Providence, Rhode Island. *icerm.brown.edu/program/topical_workshop/tw-26-ebh*
- January 11-14, 2026, ACM-SIAM Symposium on Discrete Algorithms (SODA26) Co- Located with SIAM Symposium on Algorithm Engineering and Experiments (ALENEX26) and SIAM Symposium on Simplicity in Algorithms (SOSA26), Hyatt Regency Vancouver, Vancouver, Canada. *www.siam.org/conferences-events/siam-conferences/soda26/*
- January 12-16, 2026, AIM Workshop: Formal Scientific Modeling: A Case Study in Global Health, American Institute of Mathematics, Pasadena, California. *aimath.org/workshops/upcoming/formalmodel/*
- January 12-16, 2026, Nonparametric Bayesian Inference - Computational Issues ICERM/ Brown University, Providence, Rhode Island. *icerm.brown.edu/program/topical_workshop/tw-26-bnp*
- January 12-16, 2026, Nonparametric Bayesian Inference - Computational Issues, Institute for Computational and Experimental Research in Mathematics, Brown University, Providence, RI 2903. *icerm.brown.edu/program/topical_workshop/tw-26-bnp*
- January 20 - May 22, 2026, Geometry and Dynamics for Discrete Subgroups of Higher Rank Lie Groups, SL Math 17, Gauss Way Berkeley CA 94720. *www.slmath.org/programs/365*

- January 20 - May 22, 2026, Topological and Geometric Structures in Low Dimensions, SL Math 17, Gauss Way Berkeley CA 94720. *www.slmath.org/programs/368*
- January 21-23, 2026, Connections Workshop: Topological and Geometric Structures in Low Dimensions & Geometry and Dynamics for Discrete Subgroups of Higher Rank Lie Groups SL Math, 17 Gauss Way, Berkeley CA. *www.slmath.org/workshops/1124*
- January 26-30, 2026, Introductory Workshop: Topological and Geometric Structures in Low Dimensions & Geometry and Dynamics for Discrete Subgroups of Higher Rank Lie Groups SLMath, 17 Gauss Way, Berkeley CA. *www.slmath.org/workshops/1125*

February 2026

- February 2-6, 2026, AIM Workshop: Time-Dependent Bernoulli-Type Free Boundary Problems, American Institute of Mathematics, Pasadena, California. *aimath.org/workshops/upcoming/bernoullievol/*
- February 10-12, 2026, International Conference on Advanced Scientific Computing & Machine Learning (ASCML 2026), BITS Pilani K K Birla Goa Campus, Goa, India. *www.bits-pilani.ac.in/goa/ascml2026/*

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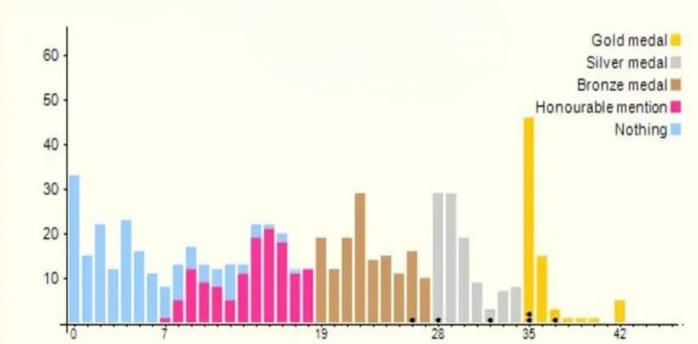
India at 66^{th} IMO-2025



Contestant	P1	P2	P3	P4	P5	P6	Total	Rank		Award
								Abs.	Rel.	
Kanav Talwar	7	7	7	7	7	2	37	9	98.73%	Gold medal
Aarav Gupta	7	7	7	7	7	0	35	27	95.87%	Gold medal
Adhitya Mangudy Venkata Ganesh	7	7	7	7	7	0	35	27	95.87%	Gold medal
Abel George Mathew	7	7	3	7	7	1	32	88	86.17%	Silver medal
Aadish Jain	7	7	0	7	7	0	28	148	76.63%	Silver medal
Archit Manas	7	7	4	7	1	0	26	187	70.43%	Bronze medal
Team results	**42**	**42**	**28**	**42**	**36**	**3**	**193**	**7**	**94.50%**	**G, G, G, S, S, B**

Leader: **Shanta Laishram**
Deputy leader: **Mainak Ghosh**

We congratulate the Indian Team for the excellent performance at IMO-2025.
This year's total score of 193 is the record highest score of the Indian Team.

Some images from “Compact course”, 2024-2025

Periyar University, Salem, Tamil Nadu
October 17-19, 2024

St. Daminic’s College Kanjirapally, Kottayam, Kerala October 18-20, 2024

Shri Vishwakarma Skill Uni., Palwal, Haryana
February 10-12, 2025

Shree K. J. Polytechnic Bharuch Gujarat
February 27 - March 01, 2025

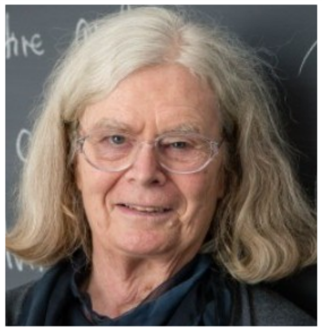
Saranathan College of Engineering, Panjappur, Tiruchirapalli, Tamil Nadu. March 10-12, 2025

Gayatri Vidya Parishad College of Engineering for Women, Visakhapatnam, AP. March 17-19, 2025

Government College of Engineering and Technology, Chack Bhalwal, Jammu.
March 26-28, 2025

Gottfried Wilhelm Leibniz (01 July 1646 - 14 Nov. 1716)

A German mathematician and philosopher. Known as the co-inventor of calculus. Invented the system of binary notation. Invented a better calculating machine than Blaise Pascal had done. Coined the term dynamics for the study of bodies in motion. Solved the problem of the catenary. Known for: Leibniz's Rule, Leibniz's Alternating Series Test, Leibniz's Formula for Pi, Leibniz's Notation for Derivatives, Leibniz Harmonic Triangle etc.



Karen Uhlenbeck (24 Aug. 1942 -)

A founder of modern geometric analysis. A professor emeritus of mathematics at the University of Texas at Austin. Won the 2019 Abel Prize for "her pioneering achievements in geometric partial differential equations, gauge theory, and integrable systems, and for the fundamental impact of her work on analysis, geometry and mathematical physics".

Gerolamo Cardano (24 Sept. 1501 - 21 Sept. 1576)

Italian Renaissance mathematician, physician, astrologer. One of the key figures in the foundation of probability. Made significant contributions to hypocycloids. Well known for his achievements in algebra and for solutions of the cubic and quartic equations. Partially invented several mechanical devices including the combination lock and the Cardan shaft, used in vehicles to this day.

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