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Lecture No. 13: Module 1: Arithmetic, Algebra and Combinatorics

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July 5, 2025

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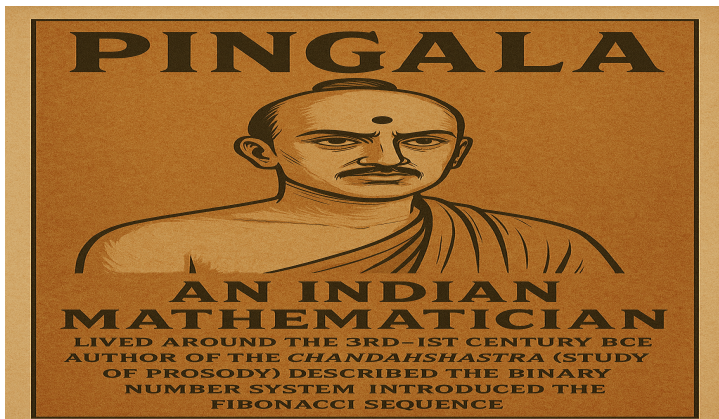
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Combinatorics in Ancient Indian Mathematics

Pingala's Chandaḥśāstra (c. 2nd century BCE):



Combinatorics in Ancient Indian Mathematics

Pingala's Chandaḥśāstra (c. 2nd century BCE):

Context:

- Pingala was a scholar of Sanskrit prosody (Chandas).
- His work Chandaḥśāstra (a treatise on poetic meters) is a binary and combinatoric masterpiece.
- He used short (laghu ↓) and long (guru ↑) syllables in patterns.

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Pingala's Chandaḥśāstra (c. 2nd century BCE):

Core Concepts from Pingala:

Binary Representation (like modern 0 and 1):

- Laghu (short) = 1 (\downarrow)
- Guru (long) = 0 (\uparrow)

So a meter like "laghu-guru-laghu" is represented as 1-0-1 in binary.

Combinatorics in Ancient Indian Mathematics

Pingala's Chandaḥśāstra (c. 2nd century BCE):

Total number of metrical combinations:

For a meter of n syllables, the total number of combinations $= 2^n$

This is the same as in binary strings of length n .

Meru-prastaara (Pascal's Triangle):

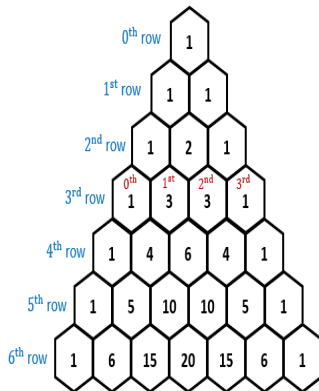
- Pingala gave a recursive method to generate **Meru**, which is equivalent to **Pascal's Triangle**.
- Each row shows the number of ways to arrange k laghus in n syllables (i.e., combinations $\binom{n}{k}$)

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Meru-prastaara (Pascal's Triangle):



Combinatorics in Ancient Indian Mathematics

Pingala's Chandaḥśāstra (c. 2nd century BCE):

Prastāra (Expansion):

- Lists all possible combinations of laghu/guru syllables.
- Equivalent to listing all binary strings of a given length.

Nashta:

- Given a number (say 5), find the binary representation or the corresponding syllable pattern.
- Used in locating the metrical form quickly.

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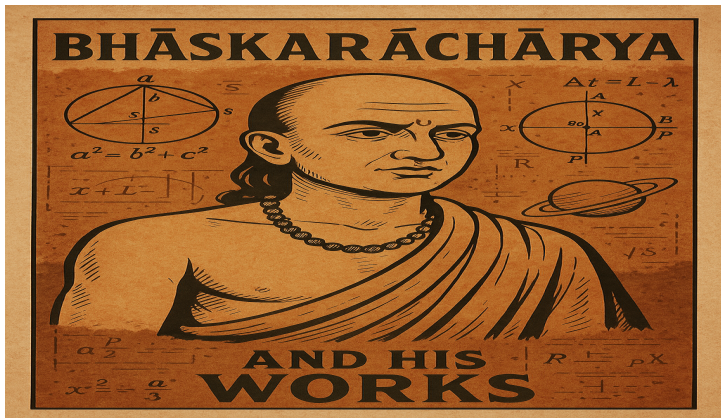
Pingala's Chandaḥśāstra (c. 2nd century BCE):

Uddiṣṭa:

- Given a pattern (e.g., guru-laghu-laghu), find its position in the Prastāra.
- Equivalent to mapping binary strings to integers.

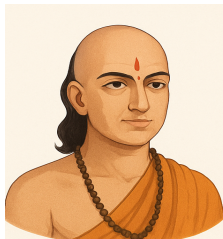
Combinatorics in Ancient Indian Mathematics

Bhaskaracharya's Līlāvātī (c. 1150 CE):



Combinatorics in Ancient Indian Mathematics

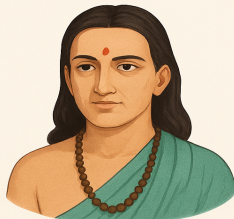
Bhaskaracharya's Līlāvati (c. 1150 CE):



ARYABHATA

(c. 476–550)

Aryabhata was an ancient Indian mathematician and astronomer. In his work 'Aryabhatiya', he wrote about mathematics, astronomy, and the concept of zero. He introduced the place value system in India and made pioneering calculations of



MAHAVIRA

(c. 815–885)

Mahavira was an Indian mathematician who made significant contributions to algebra and geometry. In his major work, 'Ganitashasamgraha', he presented systematic rules for solving quadratic, cubic, and quartic equations.



BHASKARACHARYA

(c. 1114–1185)

Bhaskaracharya was a talented Indian mathematician and astronomer. His renowned works, 'Siddhanta Shiromani' and 'Lilavati', cover topics such as algebra, arithmetic, geometry and planetary mathematics. He also made significant contributions

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Bhaskaracharya's Ankapāśa (in Līlāvātī, 12th century CE):

Ankapāśa = "Net of Numbers" or Grid of Numbers:

- Found in the Līlāvātī section of Bhāskara II's work.
- It is a method for computing the number of combinations and permutations.

Combinatorics in Ancient Indian Mathematics

Bhaskaracharya's Ankapāśa (in Līlāvātī, 12th century CE):

Topics and Concepts:

Permutation (Vikalpa):

- Bhāskara gives formulae for permutations, using terms like:

$$n! = n(n-1)(n-2)(n-3) \dots 3.2.1$$

- Problems include: "In how many ways can ornaments be arranged?" or "How many ways to seat people?"

Combinatorics in Ancient Indian Mathematics

Bhaskaracharya's Ankapāśa (in Līlāvātī, 12th century CE):

Topics and Concepts:

Combination (Saṅkhyā):

- Bhāskara discusses choosing r objects from n without regard to order:

$$\binom{n}{r} = \frac{n!}{r!(n-r)!}$$

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Bhaskaracharya's Ankapāśa (in Līlāvātī, 12th century CE):

Topics and Concepts:

Magic Squares and Number Grids (Ankapāśa proper):

- Constructed magic squares and grid patterns filled with numbers—a type of combinatorial design.
- Used in recreational problems, often with poetic flair.

Combinatorics in Ancient Indian Mathematics

Bhaskaracharya's Ankapāśa (in Līlāvātī, 12th century CE):

Topics and Concepts:

Word Problems in Verse:

Bhāskara included real-world problems using combinations:

"Tell me, clever girl, how many ways can three ornaments be placed on three fingers?"

This is:

$3! = 6$ ways

Combinatorics in Ancient Indian Mathematics

Final Thoughts:

Indian scholars used combinatorics not only for poetry and aesthetics but also in logic, cryptography, and recreational math.

The concept of binary numbers, Pascal's triangle, factorials, and permutations were all present in ancient Indian texts long before they appeared in European mathematics.