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Ritual to Reason: The Origin of Geometry in the Vedic *Śulba* Tradition

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Abstract: *Among the Six ancillary literatures of the Vedas, the Śulba Sūtras (c. 800–200 BCE), subdivision of the Kalpa, represent the earliest preserved expressions of mathematical reasoning in ancient India, emerging from the ritual context of Vedic altar construction (Agnicayana). The word "śulba" itself is used in the sense of the instrument of measurement as well as the science of measurement i.e. geometry. This work explores the transformation "from ritual to reason," arguing that the geometric knowledge embedded in the major Śulba texts namely-Baudhāyana, Āpastamba, Kātyāyana and Maitrāyaṇīya Śulba Sūtras developed as a direct response to the theological demand for precision in sacrificial architecture. The need to construct altars of varying shapes but equivalent areas led to the formulation of systematic geometric procedures.*

At the heart of this study is the so-called "Theorem of the Square" (Baudhāyana Śulba Sūtra 1.48), an early expression of what later became known as the Pythagorean Theorem, as well as techniques for transforming geometric figures, including approximations related to "squaring the circle." The use of the "akṣṇayā rajju" or diagonal cord and the well-known rational approximation of √2 illustrate a computational and constructive approach to geometry. According to the Vedas, altars of specific dimensions had to be constructed for sacrificial rituals (yajñas). These altars took the form of squares, triangles, circles, or complex bird-like shapes. Their construction necessitated precise measurement, as well as the calculation of lengths and areas. This application, rooted in the Vedic literature, subsequently evolved into a systematic geometry within the Śulba Sūtras.

So, the Śulba geometry constitutes a sophisticated and self-contained system of knowledge that integrates ritual symbolism with empirical spatial reasoning. Rather than being merely a precursor to later mathematical developments, the Śulba tradition should be recognized as foundational in shaping the trajectory of Indian geometry and influencing subsequent advancements in trigonometry and algebra. By situating mathematical innovation within its ritual and cultural matrix, this study contributes to a more nuanced understanding of the origins of scientific thought in ancient India.

Keywords: *Concept of Vedic Śulba Sūtras, Vedic Geometry, Ritual Architecture, Baudhāyana Śulba tradition and Pythagorean Theorem, Ancient India.*

1. Historical Background: The Vedic Matrix

All of us more or less know about the Vedas, the oldest monument of Indian Literature. Vedas are divided in four divisions: The *Ṛgveda,* the *Sāmaveda,* the *Yajurveda* and the *Atharvaveda*. Each *Veda* has been sub-classified into four major texts considering its content;

- ***Saṃhitā*** (*mantras* and benedictions),
- ***Brāhmaṇa*** (commentaries on ritual ceremonies and sacrifices),
- ***Āraṇyaka*** (text on rituals, ceremonies, sacrifices and symbolic sacrifices) and
- ***Ūpaniṣad*** (text discussing of philosophy and spiritual knowledge).

The *Vedas* are also known as the *śruti* or 'what is heard' for these are considered as the revelations seen by the ancient seers or *rishi*s after intense meditation and were normally passed from generation to generation through oral tradition. Which means the teacher would

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recite the *Vedas* and the students would repeat whatever the teacher recites. This literature was written down later.

2. The Vedic Toolbox: How the Ritual Connects to the *Vedāṅga*s:

It may seem to us very surprising that how a thousands of year-old literature can survive inspite of its only availability through oral tradition? Behind the correct preservation, recitation, interpretation, and ritual application of the *Vedic mantras* developed the six *Vedāṅgas* or ancillary literature which are called "limbs of the Veda". The word *'anga'* means limb. This *Vedāṅga* literature traditionally compared to the limbs of the human body because they sustain the life of the *Veda*. These ancillary disciplines were regarded as essential supports for understanding and performing the Vedic tradition properly.

The six *Vedāṅgas* are:

Shiksha	*Chanda*	*Vyakarana*	*Nirukta*	*Kalpa*	*Jyotish*
Phonetics and Pronunciation	Metre	Grammar	Etymology and Explanation of Words	Ritual Procedure	Astronomy
for swadhyaya/chanting		for proper meaning of *Vedic mantra*		for knowledge related to *Vedic* rituals	

- ***Śikṣā* (Phonetics and Pronunciation)** Concerned with proper pronunciation, accent, intonation, and articulation of Vedic sounds.
- ***Vyākaraṇa* (Grammar)** The science of Sanskrit grammar. It ensured the correct formation and understanding of words and sentences in the Vedic texts.
- ***Nirukta* (Etymology and Explanation of Words)** Concerned with difficult Vedic words and their meanings. It helped priests and scholars interpret archaic expressions found in the Vedas.
- ***Chandas* (Prosody or Metrics)** Correct metre was necessary for proper chanting and preservation of rhythmic structure.
- ***Jyotiṣa* (Astronomy and Astrology)** Used to determine the correct timing of sacrifices and rituals. Vedic rituals had to be performed according to precise astronomical calculations and calendrical observations.
- ***Kalpa* (Ritual Procedure)** Concerned with ritual instructions and sacrificial procedures.

The *Kalpa Sūtras* are themselves subdivided into four distinct categories:

- ***Śrauta Sūtras*:** Dealing with large-scale public sacrifices using the three sacred fires (*Gārhapatya*, *Āhavanīya*, and *Anvāhāryapacana*).
- ***Gṛhya Sūtras*:** Dealing with domestic rituals and rites of passage (*Saṃskāras*).
- ***Dharma Sūtras*:** Dealing with ethics, law, and social conduct.
- ***Śulba Sūtras*:** Appended as technical supplements to the *Śrauta Sūtras*.

The *Śulba Sūtras* belong explicitly to the ***Kalpa Vedāṅga***. The term ***Śulba*** is derived from the Sanskrit root *śulb*, meaning "to measure" or "to bind." In its primary sense, a *śulba* refers to a measuring cord or rope (*rajju*). Because these ropes were used to map out the sa-

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cred spaces, where the rituals will be performed. The word *Śulba* eventually came to mean the science of measurement itself—what we call **Geometry**.

So, we can see that the *mantras* in the *Vedas* were not written only as hymns or prayers to be read. They were mainly meant to be used in Vedic rituals and sacrifices (*yajñas*). The collection of these mantras is found in the *Saṃhitā* portion of the Vedas. However, the *Saṃhitās* do not explain how the mantras should be used. The details—such as which mantra should be recited, during which ritual, by which priest, and in what sequence—were explained in the *Brāhmaṇa* texts.

Later, as rituals became more complex, special manuals called the *Kalpa Sūtras* were composed to give clear and systematic instructions for performing rituals properly. Thus, the *Kalpa* texts taught how to perform the rituals correctly. Inside the *Kalpa,* there are different manuals. Some deal with domestic family rites, while others deal with large public rituals. The technical appendix attached to these public ritual manuals is called the *Śulba Sūtras*.

3. The Authors and Their Texts: Mapping the *Śulba Sūtras* :

Now, one might wonder: who wrote these manuals, and how are they organized? The *Śulba Sūtras* were not composed by a single person or at a single time. They were compiled by master craftsman-priests between 1000 BCE and 200 BCE. Because different regions and priestly families specialized in different traditions of the Vedas, they created their own distinct manuals. (Because each veda has different schools or Sakhas) Although the names of numerous *Śulba Sūtra* traditions associated with various Vedic schools are preserved in later textual references, only a small corpus survives in extant manuscript tradition. The surviving *Śulba Sūtra* texts include the *Baudhāyana, Āpastamba, Mānava, Maitrāyaṇī,* and *Kātyāyana Śulba Sūtras*. Most of these texts belong to the *Yajurveda*—the *Veda* entirely dedicated to the practical, hands-on mechanics of sacrifice.

Here are the four primary *Śulba Sūtras* that have survived till now:

Text / Author	Vedic School Connection	What Makes It Special
Baudhāyana (c. 1000–800 BCE)	*Kṛṣṇa* (Black) *Yajurveda (Taittariya Samhita)*	**The Pioneer:** This is the oldest, largest, and most mathematically rich text. It is the root source where we find the first statements of the Pythagorean property and the calculation of √2
Āpastamba (c. 600–500 BCE)	*Kṛṣṇa* (Black) *Yajurveda*	**The Practical Guide:** Written slightly later in southern India, this text takes Baudhāyana's complex math and reorganizes it into highly practical, elegant, step-by-step instructions for field workers.
Maitrāyaṇīya (c. 500–400 BCE)	*Kṛṣṇa* (Black) *Yajurveda*	**The Designer:** This manual specializes in highly unique, artistic altar shapes—such as complex variations of the multi-layered bird and square altars—focusing heavily on brick-stacking patterns.
Kātyāyana (c. 300–200 BCE)	*Śukla* (White) *Yajurveda*	**The Logician:** This is the youngest text. It strips away long-winded explanations and presents the geometry in incredibly short, formulaic, and almost algebraic statements.

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4.Connection between *Śulbasūtras* and Vedic Geometry

The Vedic people did not worship in temples. Religious ceremonies were usually performed in the sacrificer's (*Yajamāna*'s) house or on a specially prepared open ground covered with grass. There were mainly four principal classes of sacrifices in *Srauta* literature-i.e.

Homa →Iṣṭi → Paśu → Soma → Satra

For performing those sacrifices, two important structures were required:

a) **Vedi (Sacrificial Platform)** – A raised area where rituals were performed.
b) **Agni or Citi (Fire Altar)** – A specially constructed altar for maintaining the sacred fire.

Types of Fire Altars:

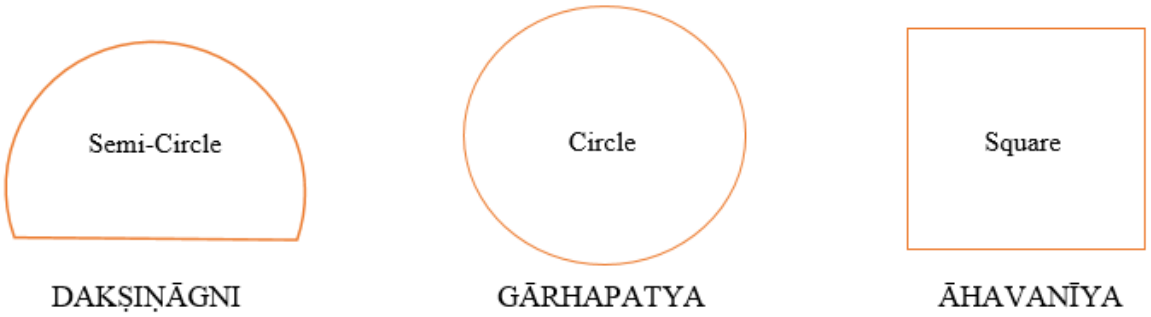
There were two kinds of fire altars:

i) *Nitya Agnis* (Permanent Fires)

These were used in daily rituals of every Vedic householder:

- **Gārhapatya (The Householder's Fire):** Built as a perfect **Circle**. It symbolized the sky, the cyclical nature of time, and the protective, enclosing warmth of the home.
- **Āhavanīya (The Offering Fire):** Built as a perfect **Square**. Located to the east, this fire represented the stable earth and stood as the formal gateway to send offerings up to the deities.
- **Dakṣiṇāgni (The Southern Fire):** Built as a **Semi-circle** (shaped like a half-moon). Placed to the south, this shape was defensively designed to ward off negative ancestral energies and destructive forces.

This daily maintenance of the three sacred fires is not a modern assumption; it is a foundational rule of life codified as the ***Tretāgni*** in the ***Āpastamba Śrauta-Sūtra* (5.1.1)**, ***Baudhāyana Śrauta Sūtra* (2.1))** and deeply spiritualized in the ***Chāndogya Upaniṣad* (4.11–13)**, where these very fires are described as the householder's direct, daily link to balancing the energies of the Earth, the Atmosphere, and the Heavens.



Every Vedic householder was required to maintain three sacred fires daily for general harmony, balance, and duties to nature.

ii) *Kāmya Agnis* (Optional Fires)

These were constructed for specific desires or purposes such as obtaining cattle, food, heaven, victory, or prosperity. Examples include:

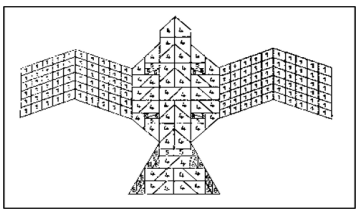
- **Śyenacit (Falcon-shaped Altar)**

The most celebrated of the Vedic altars, constructed for those desiring heaven (*svarga*).

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The geometry requires a highly sophisticated arrangement of square, rectangular, and triangular bricks to perfectly form the wings, torso, and tail while maintaining a strict total area of 7½ square *puruṣas*.

- **Kaṅkacit (Heron-shaped Altar)**



Very similar to the *Śyenacit*, but modeled specifically after a heron or kite (*kaṅka*). The primary difference lies in the configuration of the head and the slightly stylized curvature or elongation of the wings to mimic the distinct silhouette of a heron.

- **Alajacit (Alaja-bird Altar)**

The *Alaja* is another specific bird species mentioned in the texts (often identified as a type of waterbird or osprey). Like the previous bird-shaped altars, it features two wings, a tail, and a body, but it employs its own unique ratio of brick sizes and shapes to define its distinct form.

- **Praugacit (Triangle-shaped Altar)**

An altar shaped like an isosceles triangle or the forepart of a chariot wheel pole (*prauga*). It was traditionally constructed for the destruction of rivals. Geometrically, it showcases early Indian mastery of constructing perfect triangles with precise fractional grid subdivisions.

- **Rathacakracit (Chariot Wheel-shaped Altar)**

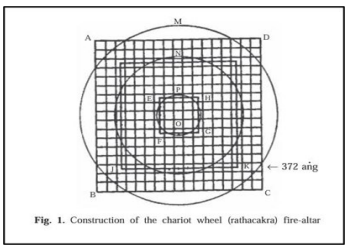


Fig. 1. Construction of the chariot wheel (rathacakra) fire-altar

Constructed for those seeking prosperity or power over enemies. The *Śulba Sūtras* detail two forms: a simple massive circle and a more intricate version with a distinct hub (*nābhi*), spokes (*arāḥ*), and a rim (*felicity/nemira*). This required squaring the circle with remarkable fractional accuracy.

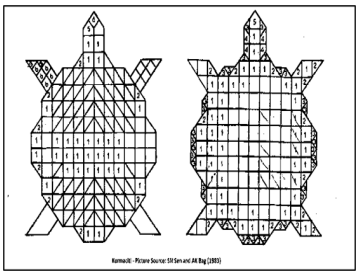
- **Dronacit (Trough or Vessel-shaped Altar)**

Shaped like a square or rectangular trough (*droṇa*) used for holding Soma juice. It was prescribed for those seeking food or abundance. The geometry relies heavily on expanding square fields into concentric layers while preserving absolute area equivalence.

- **Śmaśānacit (Cemetery-shaped Altar)**

A highly specialized, rarely constructed trapezoidal altar where the eastern side is broader than the western side, mimicking the shape of a traditional burial mound. Its geometry relies on precise trapezoidal tiling equations.

- **Kūrmacit (Tortoise-shaped Altar)**



Prescribed for those seeking stable spiritual or material foundations. The *Śulba Sūtras* provide two distinct variations: a naturalistic version with five extended limbs (head, legs, and tail) and a more abstract, rounded form. The brick pattern elegantly curves to suggest the domed shell of a tortoise.

The *Śulba* texts provide information about the shape, size, number of bricks, and ritual significance of the altars.

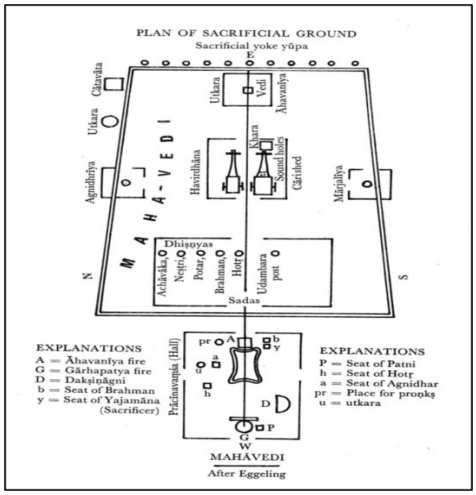
- **Mahāvedi (Great sacrificial Platform)**

One important sacrificial ground for performing the *Kāmya* or Optional rituals was the *Mahāvedi*, which had the shape of an isosceles trapezium.

Its dimensions were carefully fixed according to Vedic rules.

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The construction of a fire altar was called Agnicayana. It was not merely a physical activity but also had deep symbolic and philosophical meaning. The altar represented the universe and the cosmic order. A specialist who knew how to construct fire altars was called an *Agnicit*. The term appears in the *Taittiriya Saṃhitā* and *Maitrayani Saṃhitā.*



So, we can see that *yajñas* (sacrifices) gained importance in the Vedic era and a vast literature dealing with the sacrificial rituals came into vogue in the form of the *Śrautasutra*s. The *Śrautasūtras* give detailed descriptions of these fire altars which are constructed in the form of animals, birds etc. as we discussed before. Since the construction of altars and *citis* is a complex task, the *Śulbasūtras* developed as specialized texts offering systematic and scientific knowledge of mensuration, geometry, and construction techniques. The practical rules for constructing altars were collected in the *Śulbasūtras*, the earliest Indian texts on geometry.

In many cases, the *Sulbasūtras* constitute a special chapter of the corresponding *Śrautasūtras* e.g. the *Baudhāyana Sulba* is the 30th chapter or *praśna* of the *Baudhāyana Śrautasūtra*, the *Apastamba Śulba* is the 30th *praśna* of the *Apastamba sūtra*. Hence the *Sulbasūtras* are the very important part of the ritualistic literature.

5.The Ultimate Rule: Equal Areas, Changing Shapes

The spiritual requirements that sparked the mathematical genius of the Vedic era was a simple but strict rule: **The altar must look different depending on the specific spiritual or worldly goal of the ritual, but its physical surface area must remain exactly the same.**

For a standard household altar, the surface area had to be exactly $7^1/_2$ square *Puruṣas* (a *Puruṣa* was a standard unit based on the height of a man with his arms stretched overhead).

Now, how do you change a flat square into a perfect circle on the ground, using nothing but a piece of rope, without altering its total area? You cannot guess. You cannot approximate blindly. You need **exact mathematical laws**. Ancient Indian mathematicians solved complex geometric algorithms purely through strings/cords (Rajju) and stakes, mapping highly complex non-linear equations visually. The procedure of squaring the circle and vice versa is recorded in mainly *Baudhāyana Śulba Sūtra* I.58 & I.59 and later other *Śulba Sūtra* texts also have done the same sometimes in slightly different way.

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(In *Baudhāyana* I. 59 it is stated that if you wish to turn a circle into a square, divide the diameter into eight parts and one of these eight parts into twenty-nine parts; of these twenty-nine parts remove twenty-eight and moreover the sixth part (of the one part left) less the eighth part (of the sixth part). In modern mathematical notation, starting with *a* circle of diameter *d*, the length of the side of the corresponding square is: length = $d - {}^{d}/_{8} + {}^{d}/_{8x29)}$

6.The Indian Origin of the Pythagorean Theorem

Baudhāyana's Śulba Sūtras dated around 1000 BCE-600BCE are not only the earliest one among the *Śulba Sūtra* texts but are most systematic, logical and represents the subject in detailed manner. It was written centuries before the Greek mathematician Pythagoras was born. In the ***Baudhāyana Śulba Sūtra***, we see the core principle of the right-angled triangle stated beautifully in a single sentence:

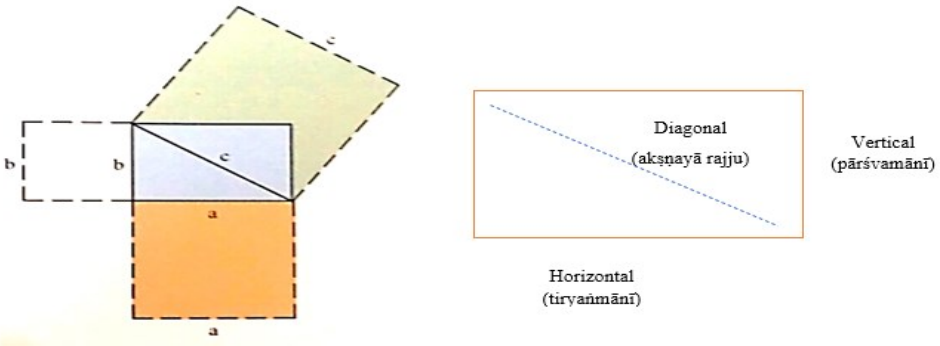
dīrghacaturasrasyākṣṇayā rajjuḥ pārśvamānī tiryaṅmānī ca yat pṛthagbhūte kurutastadubhayaṃ karoti || (BŚS 1.48)

Let's break down this ancient Sanskrit into plain English:

- *Dīrghacaturasra* = A rectangle.
- *Akṣṇayā rajju* = The diagonal rope stretched across the corner.
- *Pārśvamānī* = The vertical side (the flank).
- *Tiryaṅmānī* = The horizontal side (the width).
- *Karoti* = "To make an area" (meaning, to build a square out of that side).

Translated simply: **The square built on the diagonal rope of a rectangle equals the sum of the squares built on its vertical side and its horizontal side.**

In modern math, we write this as: $c^2 = a^2 + b^2$



The Vedic builders used this law practically. They used this concept dynamically to calculate areas and create perfect right angles using "Pythagorean triples" like 3, 4, 5

(Decoding the Text and Image Together

When you read the *Śulba Sūtra* text side-by-side with the geometric layout, every archaic term maps onto a precise component of the drawing:

- **The Rectangle (*Dīrghacaturaśra*):** The central underlying shape formed by the horizontal side (b) and the vertical side (a).
- **The Diagonal Rope (*Akṣṇayā Rajju*):** Represented by the slanted line (c). In practice, a priest stretched a physical cord tightly from the bottom-left corner to the top-right corner of the rectangular brick boundary.

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- **The Sides (*Pārśvamānī & Tiryaṅmānī*):** *Pārśvamānī* is the vertical flanking side (a, flanking the body); *Tiryaṅmānī* is the horizontal transverse side (b, stretching across).
- **"Produces Separately" (*Yat pṛthagbhūte kurutaḥ*):** If you build a square using the vertical rope (a^2, the green square) and another independent square using the horizontal rope (b^2, the yellow square).
- **"Produces Both Combined" (*Tad ubhayaṁ karoti*):** If you swing that diagonal rope out and construct a giant tilted square directly on its length (c^2, the blue square), its complete surface area will perfectly swallow the combined areas of the first two squares.)

Baudhāyana in next sūtra (I. 49) gives example of the same:

tasyodāharaṇāni — ūruprathamā, trikacatuṣke, pañcakadvādaśike, aṣṭakapañcadaśike, dvādaśikapañcatriṃśike, pañcadaśikāṣṭaviṃśike, saptakacaturviṃśike, dvādaśikāṣṭasaptatike, pañcadaśyekonasaptatiketi || 49 ||

Word-by-Word Philological Breakdown

- **Tasya:** Of its / Of that (Referring back to the universal geometric rule declared in verse 1.48).
- ***Udāharaṇāni*:** Examples / Practical illustrations.
- ***Ūruprathamā*:** An introductory phrasing context denoting the fundamental application or the prime wide-based dimensions used in constructing the *Mahāvedī.*
- ***Trika-catuṣke*:** The triad (*trika* = 3) and the tetrad (*catuṣka* = 4). This refers to the side measures 3 and 4, which yield a diagonal of 5.
- ***Pañcaka-dvādaśike*:** The pentad (*pañcaka* = 5) and the dodecadic (*dvādaśika* = 12). Side measures 5 and 12, yielding a diagonal of 13.
- ***Aṣṭaka-pañcadaśike* :** The ogdoad (*aṣṭaka* = 8) and the pentadecad (*pañcadaśika* = 15). Side measures 8 and 15, yielding a diagonal of 17.
- ***Dvādaśika-pañcatriṃśike*:** The twelve-unit measure (12) and the thirty-five-unit measure (35). Side measures 12 and 35, yielding a diagonal of 37.
- ***Pañcadaśika-aṣṭaviṃśike*:** The fifteen-unit measure (15) and the twenty-eight-unit measure (28). Side measures 15 and 28, yielding a diagonal of 32.01 *(often utilized in specific structural modifications)*.
- ***Saptaka-caturviṃśike*:** The heptad (*saptaka* = 7) and the twenty-four-unit measure (24). Side measures 7 and 24, yielding a diagonal of 25.
- ***Dvādaśika-aṣṭasaptatike* :** The twelve-unit measure (12) and the seventy-eight-unit measure (78).
- ***Pañcadaśī-ekonasaptatika*:** The fifteen-unit measure (15) and the sixty-nine-unit measure (69).
- ***Iti* :** Thus / End of the formulation.

Thus, while verse 1.48 of BSS states the universal theorem of the diagonal rope qualita-

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tively, verse 1.49 provides the **quantitative proofs and operational field components**. Baudhāyana is explicitly enumerating integers that solve the equation $a^2 + b^2 = c^2$, making this the world's oldest recorded list of **Pythagorean Triples**.

Since, the diagonal of a unit square equals √2, the need naturally arose to obtain a numerical approximation, which is supplied by the *dvikaraṇī* rule above. So, in the next *sūtra* (1.61–62) of *Baudhāyana* the famous approximation of √2 is stated:

samacaturasrasya dvikaraṇī |
pramāṇaṃ tṛtīyena vardhayet |
taccaturthenātmacatuḥtriṃśonena saviśeṣaḥ ||

samacaturasrasya: of a square
dvikaraṇī: the diagonal producing double area
pramāṇam: the side
tṛtīyena vardhayet: increase by one-third
taccaturthena: then by one-fourth of that
ātmacatuḥtriṃśonena: diminished by one-thirty-fourth of itself
saviśeṣaḥ: yielding a more accurate value.

The diagonal of a square is obtained by increasing the side by one-third, then by one-fourth of that third, and then subtracting one-thirty-fourth of that last addition.

Mathematical Interpretation

If the side of a square is 1, then its diagonal is: √2
Baudhāyana gives: $\sqrt{2} \approx 1 + 1/3 + 1/(3\times4) - 1/(3\times4\times34)$

Step by step calculation:

- Add one-third

  `1 + 1/3 = 1.333333`
- Add one-fourth of the third

  `1/12 = 0.083333`

  `1.333333+0.083333→ 1.416666`
- Subtract one-thirty-fourth of that amount

  `1/3x4x34 =1/408 = 0.002451`

  `1.416666+0.002451→ 1.414215686`

Comparison with Modern Value

Modern value of √2 = 1.41421356237...
Baudhāyana value = 1.414215686
Difference ≈ 0.000002124

Thus the approximation is correct to five decimal places, an astonishing achievement for a text composed many centuries before. This formula was transmitted and reused in later *Śulba* traditions, especially in *Āpastamba (Āpastamba* I.6) and *Kātyāyana (Kātyāyana* II.9).

Conclusion: The Legacy of the Rope

So, it becomes completely clear that the *Baudhāyana Śulba Sūtra* is just the beginning. The entire collection of *Śulba* literature—including the detailed engineering rules of *Āpastamba*, the structural designs of *Maitrāyaṇī*, and the highly refined geometry in *Kātyāyana*—is packed with advanced mathematical ideas. When we look at how these ancient texts manipulate shapes, balance surface areas, and map out space, we can easily see principles that match up perfectly with modern geometry.

To truly unlock the secrets of the *Śulba Sūtras*, we need a partnership between two

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worlds. Those who love modern geometry and mathematics will find a goldmine of spatial logic in these ancient texts. By working together—combining the textual insights of a Vedic scholar with the analytical skills of a modern mathematician—we can show the world that these ancient rituals were the true birthplace of practical geometry.

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