Ritual Application of Mensuration Rules in India: An Edition of Ganesa's *Kundadhyudhahrati* with Mathematical Commentary

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Ritual Application of Mensuration Rules in India: An Edition of Gaṇeśa’s Kuṇḍasiddhyudāhṛti with Mathematical Commentary

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1. INTRODUCTION

1.1. Kuṇḍasiddhyudāhṛti

The Kuṇḍasiddhyudāhṛti is a prose commentary on nine verses (39–47) of

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ABBREVIATIONS

KSU: Kuṇḍasiddhyudāhṛti of Gaṇeśa.
L: Lilāvati of Bhāskara.
MKS: Māṇḍapakundasiddhi of Viṭṭhaladikṣita.

1. INTRODUCTION

1.1. Kuṇḍasiddhyudāhṛti

The Kuṇḍasiddhyudāhṛti is a prose commentary on nine verses (39–47) of

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Vitthaladiksita’s *Mandapakundasiddhi*, and deals with the mensuration of eight kinds of *kundas*. The *KSU* is interesting to the student of the history of Indian mathematics as well as to the student of Hinduism because the work, which contains many citations from the *Lilavati* of Bhāskara, shows us how the traditional mathematics (*ganita*) was employed in a field other than mathematics and astronomy (*jyotisa*).

### 1.2. Author

The *KSU* was written by Gañeśa, son of Śrīdhara, in Nandigrāma1) (Nandod, Gujarat) some time between A.D. 1619, when Vitthaladiksita composed his *KMS* [RAGHAVAN 1968: 182], and A.D. 1836, when the manuscript used for the present edition of the *KSU* was copied (see 1.7. below). We know a Gañeśa, who wrote a commentary called *Śiromaniprakāśa* upon the *Siddhāntasiromani* of Bhāskara in Nandigrāma in the early seventeenth century; but his father was Keśava [PINGREE 1971: 106b–107a, 1981: 126]. Keśava was in turn the grandson of the famous Gañeśa (born A.D. 1507), who wrote no less than ten works on *jyotisa*, including the *Buddhivilāsinī*, a popular commentary on the *L* [PINGREE 1971: 94–106]. The existence of abundant citations in the *KSU* from the *Lilavati* shows that our Gañeśa also was versed well in the traditional mathematics, although we cannot trace his lineage beyond his father.

### 1.3. *Kunda*

*Kundas* are pits on the ground for holding ceremonial fire in religious ceremonies. They are classified into eight according to their shapes: caturasra (square), yoni (vulva), ardhaivalaya (semi-circle) or ardhaacandra (half-moon), tryasra (triangle), vrtta (circle), ṣadasri (hexagon), padma (lotus), and aṣṭāsri (octagon). On a certain ceremonial spot, for example, these eight kundas are arranged on the eight cardinal points surrounding a central vedi (fire-altar). The arrangement in that case starts from the east and proceeds clockwise in the above order; and the ninth kunda, which is either caturasra or vrtta, is placed in the north-east by east [MKS 31–32].

Every kunda has to measure, without regard to its shape, an area determined according to the number of havanas (oblations) in the particular ceremony in which it is used2). A failure in the measurement of kundas is said to cause something unfavourable to the yajamana (sacrificer)3). Thus arises a mathematical problem: to draw those geometrical figures with reasonable exactness in area by means of

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1) See the concluding verse of the *KSU* (p. 110 below).
2) See Sec. 3.0 below.
3) Vitthaladiksita, in commenting upon the irregular hexagonal kunda (*MKS* 43), cites a half *sloka*:

"mānādhikye bhaved rogo mānahime daridratā/
(In the case of excess of area, there will be a disease;
in the case of defect of area, there will be poverty.)
a rope (sūtra) and a pair of compasses (karkata). The nine verses (39–47) of the MKS give a solution to this problem, while Gaṇeśa carries out computations of the areas of the kundas obtained.

1. 4. Place-value system

Gaṇeśa uses a place-value system, in which eight units make the next higher unit, for fractions of the linear measure aṅgula (finger breadth). This simply results from the table of linear measures used in the MKS itself⁴):

\[
\begin{align*}
1 \text{ hasta} & \quad = \quad 24 \text{ aṅgulas}, \\
1 \text{ aṅgula} & \quad = \quad 8 \text{ yavas}, \\
1 \text{ yava} & \quad = \quad 8 \text{ yūkās}, \\
1 \text{ yūkā} & \quad = \quad 8 \text{ liksās}, \\
1 \text{ liksā} & \quad = \quad 8 \text{ bālāgras}, \\
\end{align*}
\]

Similar tables are recorded in various works such as the Bhātanāhitā [VARĀHAMIHĪRA 1968: 57, 1–2], Ganitasārasamgraha [MAHĀVĪRA 1963: 1, 25–31], and the Purāṇas⁵). The MKS takes the above table to be a variable system; that is, the hasta is defined as one-fifth of the total height of an individual yajamāna with his hands stretched upwards⁶). It may be pointed out in this connection that Gaṇeśa does not seem to follow any principle when he obtains approximations of fractions: he sometimes carries out his computations down to the fourth place (bālāgra) below the aṅgula, but is usually satisfied with the second place (yūkā). Again, he seems, in a few cases, to count fractions as a unit when they are no less than half, but usually cuts them without regard to their magnitudes.

1. 5. Quotations

Gaṇeśa’s computations of the areas are based exclusively on the mensuration rules of the Lilāvatī. He cites the following rules:

1) algorithm for squaring a number (L 19) [in Sec. 1];
2) algorithm for taking the square root (L 22) [in Sec. 2];

---

⁴) MKS 3–4:

\[
\begin{align*}
kṛtordhvahōh samabhūgatasya kartuḥ śārāṃśaḥ prapadocchritasya/
yo vā sa hasta 'ṣya jināmśāko 'pi syād aṅgulaṃ tattadibhāṃśakā ye//
yavo yūkā ca liksā ca bālāgram caivamādayaḥ/
kṛtamūṣṭiḥ karo ratnir aratnir akenāṣṭhikā//
\end{align*}
\]

(One-fifth of ‘the total height of’ the sacrificer, who is standing on tiptoes on a plane surface of the earth with his hands stretched upwards, is a hasta (cubit), and a twenty-fourth of it shall be an aṅgula (finger breadth). One-eighth of each of yava, yūkā, liksā, bālāgra, etc. is ‘the measure of’ its succeeding one. A kara (cubit), with the fist clenched, is a ratnir, and a ratnir, without the little finger, is an aratni.)

⁵) Vīyāpurāṇa, chap. 101, 115–127; Maityopurāṇa, chap. 258, 17–18; and [BHOJA 1966: chap. 9, 4–5]. cf. also [KIRFEL 1920: 331].

⁶) See footnote 4 above.
3) sides of a right triangle \((L 136)\),
\[ c = \sqrt{a^2 + b^2} \] [in Sec. 2]
\[ b = \sqrt{c^2 - a^2} \] [in Sec. 8.2];

4) \(āvādhas\) \((L 165)\) and perpendicular \((L 166)\) of a triangle,
\[ a_1 = \frac{[a - (b + c)(b - c)]}{a} \]
\[ a_2 = \frac{[a + (b + c)(b - c)]}{a} \]
\[ h = \sqrt{b^2 - a_1^2} = \sqrt{c^2 - a_1^2} \]
[in Secs. 6.1, 6.2, and 8.1];

5) area of a triangle \((L 166)\),
\[ S = \frac{ah}{2} \] [in Secs. 2, 4, 6.1, and 8.1];

6) area of a rectangle \((L 173)\),
\[ S = ab \] [in Secs. 1, 8.1, and 8.2];

7) area of an equi-perpendicular quadrilateral \((L 173)\),
\[ S = \frac{h(a + c)}{2} \] [in Secs. 6.2 and 8.2];

8) perpendicular of an equi-perpendicular quadrilateral \((L 184)\),
\[ h = \text{perpendicular of the triangle formed by } b, (c-a), \text{ and } d \] [in Sec. 8.2];

9) circumference of a circle \((L 199)\),
\[ c = \frac{3927d}{1250} \] [in Sec. 2];

10) area of a circle,
\[ S = \frac{cd^2}{4} \] [in Sec. 2]
\[ S = \frac{(3927d^2)}{5000} \] [in Sec. 203]
[in Secs. 2, 3, 5, and 7];

11) \(šara\) of a segment of a circle \((L 204)\),
\[ b = \frac{d - \sqrt{(d+a)(d-a)}}{2} \] [in Sec. 6.2];

12) sides of circumscribed regular polygons \((L 206-208)\),
\[ a_3 = \frac{(103923d)}{120000} \] (triangle) [in Sec. 6.1]
\[ a_8 = \frac{(45922d)}{120000} \] (octagon) [in Secs. 8.1 and 8.2].

1.6. Editions of the Mandapakundasiddhi

The \(MKS\) has been published at least six times. In editing the \(KSU\), we consulted 3) and 6). The other editions have not been available to us\(^7\).

2) As the first work in the Kundagrathavimśati. Bombay 1887.
3) With the author’s own commentary and Mahādevamīśra’s Hindi commentary. Kāśi 1908.

\(^7\) The information given here has been obtained from [RAGHAVAN 1968: 182–183] and [GUPTA 1981: 96].
6) With Vayunandamiśra’s Hindi commentary. Under the title, Kundaṃsiddhaṃ-dapasiṃṭhi. Vāraṇa: Master Kheladiśāla Śaṃkṣaṭāprasaśā Śaṃskṛt Pusta-kālaya, 1980 (7th printing; first printing 1936?).

1.7. Manuscript

Government Oriental Manuscripts Library, Madras, D 13403. Title: Kṣetragaṇita. Script: Devanāgarī. Ff. 1–8. Complete. 9 to 10 lines to a page. About 40 aksaras to a line. Paper, 24.5 × 10 cm. Bound in modern book form together with a Tithinirnaya (D 3120). Every leaf is slightly injured by worms, but there is no difficulty in reading. Contains no geometrical figures; but the phrases such as “darśanaṃ”, “darśanaṃ patrapṛṣṭhe”, “darśanaṃ pūrvapatre”, “tatra kṣetradarśanaṃ yathā”, etc. indicate that the original text did have ones. The date of the ms. is known from the colophon, which reads: samvat 1894 āśvina kṛṣṇa maṅgalavāra=2 November 1836.

1.8. Apparatus

In the ms., the nasals standing before a consonant are almost always expressed by the anusvara, and the labial nasal ‘m’ at fullstops also follows the same convention in most cases. We have corrected them without mention. The ms. uses the letter ‘v’ for ‘b’ in the words lamba, bahi, brhat, and subodha; we have given their correct forms in the text. We have also corrected silently the reduplication of consonants after ‘r’, which occurs in the words ardha, iṛdhva, paryanta, varītate, and vardhana. We have also corrected freely irregular samdhī. Other corrections are mentioned in the footnotes. The danda for punctuation is rarely used in the present ms. We have supplied it according to the context.

1.9. Symbols used in the text

⟨A⟩ indicate that A has been supplied by the present editor.
[A] indicate that A is physically damaged or lost.

2. TEXT: KUNDAŚISDDHYUDĀHRTI OF GANEṢA

(1b) śrīgurur jayatitarām/
śrīgaṇeṣaṃ mahālakṣmīṃ natvā kurve samāstah/
ganeṣābhīdhadaivaṃṣaḥ⟨h⟩ kuṇḍasiddh essayāhrtim/
2.1. caturasrakunḍam

dvighnavyāsamsam tri yathā (MKS 39)/
darśanam (See Fig. 1)/
kṣetraphalam adhikṛtyocayate/ tatra
samaśrutau tulyacaturbhujhe ca tathāya(10) tadbhujakotighāta (L 173)
iti bhāskaroṣyā/ prakte samaśrutitulyacaturbhujasyasya bhujakoṭī 24/24/
anayor ghatē bhujavarga eva bhavati(11)/ atas tulyacaturbhujhe bhujavarga eva
kṣetraphalam iti tātparārthaḥ/
sthāpyo 'ntyavarga (L 19)
ityādinā tathā kṛte sati jātam ekahastakṣetraphalam 576)/

2.2. yonikunḍam

atha yonikunḍam āha/
kṣetre jināṁśe purataḥ(12) śarā(m)śān iti (MKS 40)/
atra jināṁśa(13)-24-kṣetrasya śarāṁśā 5 ete svīyaratdāṃśāṅgulādyaṇānena(14)
0/1/2 yutā ekahastayonikunḍe vardhanāṅkaḥ 5/1/2/ ayam eva dvāyāṅgaṇaḥ
san dvāyāṅhaste bhavet/ evam sarvatra/ darśanaṁ yathā (See Fig. 2)/
atra kṣetraphalam/ atra pūrvāṅgṛd āyāṃyottararekhāpṛṇāntadvāyāṅgamasūtra-
dvayottam(15) ekāṁ trīṇibhujaḥ/ bhūmis tu āyāṃyottarekhaiṣva/ tathā āyāṃyot-
tarasūtrāṅgṛt pūrvāṅgarhāpaścīṃṭāntadvāyottam(16) aparantam/ (2a)
vṛttārdhadvāyāṅyam ekāṁ vṛttāṁ ca/ evam kṣetratrayam/
pūrvāṅgarāyāṃyottarekhāsāmpāṭād(17) urdhv(ā)m caturasrapūrvabhujā-
vadhi prāgapaṃparārekhāmāṇam āṅgu(laṇi) 12/ idāṁ vardhanāṅkena 5/1/2 yutaṁ
jāto labdha(b) 17/1/2/
lambuṇaṁ bhūmyardhamāṁ spaṣṭaṁ trībhujhe phalāṁ bhavati(17) (L 166)
bhāskaroṣyā bhūmyardhaṁ 12 lambena nīghnaṁ jātam uparitrasaṇakṣetra-
phalam 205/7(18)/ athādhālaṁṣaṅkṣetrapahalam(19)/ tatra āyāṃyottaraṇaṃprāgapa-
ṛtrasāmpāṭād(20) adhāsaḥcaturasya pascaṁbhujāvadhi pūrvapraṃkarṇāṃ
am(ṅulāṇi) 12/ ayam evaḥdaḥṣṭhāṣya(21) lambaḥ/ bhūmyardhaṁ(22) tad eva
12/ atrāpi
lambuṇaṁ (L 166)
ityādinā kṣetraphalam 144/ atha vṛttārdhadvāyaphalam/ tatra
vṛttakṣetre paridhigunitavyāṣaṅpadāḥ phalam (L 201)
ityādinā phalaṅyaṅaṅaṁ paridhivyāṣajñāṇāya prāgapaṃprāyāṃyottarekha-
sāmpāṭāc(23) caturasasya yāmyabhujāvadhy athavottarabhujāvadhi yāmyotta-
rasūtraṃmanam eko bhujāḥ/ tannāṇāṃ yāmyottarāṣṭrādhatulyam aṅguḷāni
12/ evam ca tasmāt sāṃpāṭācc(24) caturbhujasya pascaṁabhujāvadhi pūrvāpa-

9) nyāsam in the ms. 10) tathāya. 11) nām. 12) tu paraḥ for purataḥ. 13) jināṁśā.
14) -āṅgulāṇāne. 15) -dvāyordham. 16) -dvāyocham. 17) -ṣayāṇād for -sāmpāṭād
18) 20/5/7. 19) athādhaṁsra- for athādhaṁṣṭa-. 20) -sāmpāḍanād. 21) evāḍhasasya.
22) Inserts pari before tad. 23) samyāṇāc. 24) sampannāc.
rarekhāmānan 12 aparō bhujaḥ/ saiva koṭiḥ 12/ vṛttārdhaprāntadvayagā- 
mibhujaṇotpṛantaspṛktyaksūtraṁ karnāḥ/ evam jātaḥ(m) caturbhujāntahpa-
tītṛyasram/ tatra karnajñānā(2b)yā 
tatṛtyor yogapadāṁ karna (L 136) 
iti bhūja-12-koṭi-12-vargayor 144/144 yogoy 'yam 288/ asmāt 
yaktvā(25) (L 22) 
ityādīnā padaṁ jātaḥ karnaḥ 16/7/6/1(26) ayam evoddīṣṭavaṁtakṣetre vyāsaḥ/ 
asmat parīdhyaṇayanaṁ 
vyāsa bhanandāgniḥita(27) (L 199) 
ityādānā/ vyāsaḥ 16/7/6/1/ ayam bhanandāgni-3927-hataḥ 66643/7/4/7(28) 
khabānasūrya(29)-1250-bhakto jātaḥ parīdhīḥ 53/2/4/ atāḥ param kṣetrapha-
nayanaṁ 
 vṛttakṣetre parīdhīguṇitavyāsasāpādaḥ(30) phalam (L 201) 
ityādīnā/ parīdhīnāh gamūtrikāya(31) guṇito vyāsaḥ 904/6/ ayasa caturthāṁ(ō) 
jātam uddīṣṭavṛttakṣetre phalam 226/1/4/ eva(m) trayānāṁ yoge jātam 
 ekaḥastayonikunoḍe kṣetraphalam 576/0/4/ 
thavā 
vyāsasya varge bhanavāgninīghna(33) (L 203) 
ityādīnā vṛttakṣetre phalam/ tatra vyāsaḥ 16/7/6/1/ asya vargaḥ 288/0/0/2 
bhanavāgni-3927-gunaḥ 1130991/2/5/6(34) pañcasahasrabhakto jātam kṣetrapha-
lam tad eva 226/1/4/ 
 atra likhyacatuṣṭayam adhikam tan na dośaya/ utkam ca 
svalpāntaratvād avahūya yogyād 
iti vacanāt/ iti yonikundam/ 

2. 3. ardhacandrakundam 
athārdhavālayam/ 
svāsātāḥ(m) sayuteṣubhāgahīneti(36) (MKS 41)/ 
ātriṣyā jināṃśakṣetrasyasvams(ā)ḥ 4/6/3/1/5/37/ ayam svāsatāṃśena 0/0/3/0/4 
yutaḥ 4/6/6/2/1/ anenaiva dharitrī 24 hinā (3a) 19/1/1/5/7/ anena vyāśārdhena 
“madhyāḥ(n)” nāma pūrvāparadakṣipottāraḥ(sūtra)ṣampātāt “kṛtvāttadale 
grato” “jīvāḥ(m) vidadhātv indudalam” bhavati/ darśanam (See Fig. 3)/ 
vyāśārdham dvighnam(38) jāto vyāsaḥ 38/2/3/3/6/ vyāsasya vargaḥ 1467/ 
1/5/4/3(39) bhanavāgninīghnaḥ(h) 5761740/1/6/4/5/40 ayam pañcasahasrabhakto 
jātam vṛtte phalam 1152/2/6/2/ etad vṛttakṣetraphalam/ asyārdham jātam 
vṛttārdhakṣetraphalam 576/1/3/1/}/ 

2. 4. tryasrakundam 
athā trya(sra)kundam/

25) panktam for tyaktvā. 26) 16/7/6/11, corrected. 27) va- for bha-. 28) 6642/5/5. 
29) -vāna- for -bhāna-. 30) gunitaḥ vyāśāpādaḥ. 31) gamūtrikāyā. 32) 516/0/4. 
33) -hata for -nighna. 34) 1130990/0/5/16. 35) 2/6/1/41. 36) -bhāgeṣy iti. 37) 9 for 6. 
38) dvi in margin. 39) 14/6/7/1/5/4/3. 40) 57/61/740/1/6/4/5. 

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vahnyaṁśaṁ\(^{41}\) purato nidhāyeti (verse 42ab)/ atra kṣetraphalam/ tatra caturvīṁśāṅgulātmake madhyasūtre vahnyaṁśaṁ\(^{41}\) aṣṭāṅgulaṁ\(^{42}\) samyojya jāto lambaṁ 32/ caturasrapaścimabhuje 24 caturth-āṁśadavyaṁ saṣṭāḍangulātmakam samyojya jāta bhūḥ 36/ lambā\(^{43}\)-32-guṇam bhūmyardham \(<1\>8/ spaṣṭam tribhuce phalaṁ bhavattī (L 166)/ jātaṁ kṣetraphalam 576//

2. 5. vrṭtakunḍam

atra vrṭtakunḍam/
vāṃśaṁ svajināṁśaṁsva sahitaṁ iti (MKS 42cd)/ atra caturvīṁśatidhābhaktakṣetrasya trayodaśaṁśaṁ 13/ ete svajināṁśaṁsvaṁ-kenāṅgulādyena\(^{49}\) 0/4/2/5/344) sahita jātaṁ vyāsārdham 13/4/2/5/3/ anena vyāsārdhena sampātāt kṛte vrṭte vrṭtakunḍam\(^{45}\) bhavati/ darśanam (See Fig. 5)/ kṣetraphalam vyāsārdham driguṇam 27/0/5/\(\sqrt{5}\)2/6/ vyāsasya varge 733/4/146) bhanavāgniṁīghne 2880516 paṇcasahasrabhakte jātaṁ kṣetraphalam 576/0/6//

2. 6. 1. viṣamaśaḍāṣṭrakunḍam

atra śaḍāṣṭrakunḍam/
bhakte kṣetre jināṁśaṁ dhr∩(i)mitalavakaiṁ
vākṣiśailāṁśayuktair iti (MKS43)/ atra jināṁśaṅkṣetrasya dhṛtyaṁśaṁ\(^{47}\) 18/ ete svākṣiśailāṁśena 0/2 yutā jātaṁ vyāsārdham 18/248)/ anena vyāsārdhena kṛte maṇḍala “indudiktaḥ”\(^{49}\)/ tenaiwa vyāsārdhamitakarkaṭenendudiktaḥ\(^{50}\) kṛṭaśaṭciḥneṣv ekam ekaṁ hitva sūṭrāṁi dadyat/ madhyāmgaḍaṁśaṁ nāše “netraramyaṁ śaḍasaṁ” bhavati/ tathā kṛte sati darśanam patraprāṭhe (See Fig. 6. 1)/ atra mahattrikonaṁdavyaṁ nispānam/ tad yathā—ekam uttarāgraṁ anyad daksīṇaṁgraṁ/ uttaradikto vahniṁdparyantam\(^{51}\) eko bhūjaṁ/ evam cottaradikto nairṛtīṁ yāvad aparāṁ/ nairṛtīṁ ārābhīyāṁgyey\(\langle i\>\) yāvat tṛṭīyaḥ\(^{52}\) uttarāgraṁ ārābhī thyābhyuparyantadhyāsūtraṁ lambaṁ/ evam eva digvaiṁparyenāparam/

tatraṁ\(^{53}\) vrṭṭāntaṁstrhibhuyaṁ bhujajñaṁ/ vrṭṭavyāṁ 36/4 “tridvyatk-āgninabhāṣācandaire”\(^{154}\) hate 3793189/455) “khakakkhaṁbhāṛaṁbhaṁkhe” (L 206–208) jātaṁ trayāṇāṁ bhujāṁnam mānam 31/4/7/ atra tṛṭīyabhujāṁ

\(^{41}\) vahvyāṁśaṁ. \(^{42}\) lambaṁ. \(^{43}\) -āṅguloddīna. \(^{44}\) 02 for 2. \(^{45}\) vrṛṭamaṁ kṛṇaṁ. \(^{46}\) I for 7. \(^{47}\) dhṛtyaṁśaṁ. \(^{48}\) 180/2/0. \(^{49}\) -dikṣū, corrected in margin. \(^{50}\) -miṭukarkaṭendudikṣū, corrected in margin. \(^{51}\) vahīr- for vahīn-. \(^{52}\) tṛṭīyaḥ. \(^{53}\) Here is mistakenly repeated a long passage, which actually belongs to the next section (2.6.2). The repetition begins: “rekkhādvayaṁ kuryāt”; and ends: “phalaṁ tad eva” . The words, “rekkhā” and “phalaṁ tad eva”, have been encircled. \(^{54}\) -āgnir nabhaṁ-. \(^{55}\) 1793/89/4.
bhúmiṃ prakalpyānau bhujau bhujav iti prakalpya lamba āṇiyate/ "tribhujive bhujayor yogaḥ 63/1/6 tadantaraguṇo 0/0 bhuvā 31/4/7 hṛtaḥ" (L 165) phalam 0/0/ labdhena66 bhūr dvīṣṭ(h)aiṅkatronā 31/4/7 ’nyatra yutā 31/4/7 dalitā jāte67 āvādhē 15/6/3/4/ svāvādhākṛṭ(h) 249<6/2/3/ bhujā-31/4/7-kṛttā 999/1/1/6/158/ antaram 749/2/7/3/159/ mūlaṃ jato lambaḥ 27/3/0/ ayaṃ caturthāṃśono vyāsa eva lamba iti siddham/ lambena 27/3/0 bhūmyārdham 15/6/3/4 guṇitaṃ jā[t]ā(4b)m uddisṭatribhujive kṣetre phalam 432/5/5/ athāṣya mahattribhujysya triṣy api bhujeṣu trīṇi tryasrāṇi bahiḥsāegrāṇy60 eva lagnāni santī/ ekamuttarato ’gnidiggāmbhujalagnam dvitīyam uttarato nirṛtiddiggāmbhujasaktam triṭiyam nairṛtīdikto ’gnidiggāmbhujasamālganam/ tatraikasya tribhujysya phalam āniya trīguṇam vidhāya pūrvaphale maṃyojya kṣetrapalamaṃ syāt/


2. 6. 2. samaśaḍarśikunḍam

atha prakārāntaraṇe śaḍasraṅkunḍam ucye/ athavā jinabhaṅgakunḍamānād iti (MKS 44)/ jinabhaktakunḍamānasa tithibhāga(h) 15 sva-15-khaḥūpā-160-bhāgena 0/0/6 hinaḥ 14/7/2/ jātāṃ vyāśārdaḥmaṃ65) 14/7/2/ anena kṛte (vṛtte) vidhūdiṭaḥ samaśaḍbhūjaiḥ śaḍasraṃ jātaṃ daršanam ca (See Fig. 6. 2)/ atra pūrṇāparam parasparāsanāṅgaṃ viṣamacaturbhumadvayaṃ drṣyate/ atra vyāsaturyā bhūḥ 29/6/4/ mukham tu pūrṇāpararūpaṃ vyāśārdaḥtyaṃ 14/7/2/ yato yena vyāśārdaḥena vṛttam kṛttam tenaiva vyāśārdaḥena vidhūdiṭaḥ samaśaḍbhūjaḥ śaḍasraṃ jātaṃ darśanam ca/ (L 204)/ jyā-14/7/2-vyāsa71)-29/6/4-yoga-44/5/6-ntara72)-14/7/2-ghāṭa-666/4/5-mūlaṃ 25/ 56) dvi before bhūr, corrected. 57) jāto. 58) 991/0/1. 59) 749/2/6/5. 60) -sāṭany. 61) 0/4/2/5. 62) 3 for 2. 63) samatvāna. 64) 3 for 2. 65) māśārdham. 66) vyāśārddhe tulyam. 67) sumukhā. 68) atatha, ta deleted. 69) varhir, first r deleted. 70) -āvadhīr. 71) vyāsaḥ. 72) ntarāb. 207
6/4/ vyāsah 29/6/4 tadūnaḥ 4/0/0 da(5b)litah 2/0/0 śaraḥ syat/ anena śareṇa vyāsārdham 14/7/2 hīmaṃ jāto lambah 12/7/2/ "caturbhujae 'nyatra samānalambbe lambena 12/7<2/2 nighnam ku-29/6/473)-mukhai-(14/7/2-kyya-45/5/6-khaṇḍam" (L 173) 22/2/774) nighnam <2>88/4/5 jātam ekaviṣamacaturbhujasya kṣetraphalam/ dvīguṇam 577/1/1 evam ekahasta ekāṅgula<m>1 ekayaavāś cāntaraṃ patattī sthūlām//

athavordhv(<vlasthabhujasampātadvayād adhaḥ>sthabhujasampātadvayāvadhi pūrvāparam rekhādvayāṃ kuryāt/ evaṃ kṛte sati caturbhujasya yāmyottaram bhujadāvyaṃ pariṃjaya vyāsasya catvāri khaṇḍāni samānāntaraṇī jāyante/ tayo rekhayor yad yāmyottararekhayā saha sampātadvayāṃ tasmād yad yāmyottarabhusampātadvayāvadhi yad vyāsāturakhaṇḍamāṇāṃ sāvādhā 7/3/5/ yāmyottaratavyāsagranīḥṣṭam vyāsārdhamāṇāṃ bhujadāvyaṃ kāṁcaraṇaṃ bhujah 14/7/2/ tataḥ
svāvādāhbujaṃkṛtyor antaramūlam prajāyate lamba (L 166)
ity anenāpi sa eva lambah 12/7/2/ evaṃ lambam āṇīya
caturbhujae 'nyatra (L 173)
ityādīnā phalaṃ tad eva 288/4/5//

2. 7. padmakuṇḍam
atha padmakuṇḍam āha/
aṣṭāṁsāc ca yata iti (MKS 45)/
kṣetrasyaṣṭamāṃṣa(6a)vrddhyā caturasraṃantarāptavṛttacatuṣṭayam75) kuryāt/ paṅcamavṛttāṃ svasyaṣṭatri(ṃ)śaṃṣena76) 0/0/5 ūṇitena pūrvavāyāsārdhena77) 14/7/3 vṛttam kuryāt/ darsanaṃ ca pūrvapatre78) (See Fig. 7)//
atha kṣetraphālanayamam/ tatra caturthavṛttavāsah 2479)/ āsmād vyāsasya varga (L 203)
ityādīnā jatāṃ caturthavṛttiyāṃ kṣetraphalam 452/3/1/ paṅcamavṛttavyāsah 29/6/6/ āsmād api vyāsasya varga (L 203)
ityādīnā kṣetraphalam 699/4/1/ anayor antarārdham 123/4/4 pūrvakṣetraphale yojiṭam athavā paṅcamavṛttakṣetraphale hīnaṃ jatāṃ kṣetraphalam 575/7/5/ yūkāṭrayi namati na dosāya//

2. 8. 1. viṣamaṣṭāṣrikuṇḍam
athāṣṭāṣrikuṇḍam āna/
kṣetre jināṃśa80) iti (MKS 46)/
jināṃsaṃkṣetrayāṣṭādaśaṃśaiḥ81) 18 "svāṣṭadadvibhāgena82) 0/5/1/1 yutaib" 18/5/1/1 anena vyāsārdhena kṛt(ṃ)e "vṛte vidigdiṣor antarato 'ṣṭasūtras triyayuktaib" nāma cihnaṇvāṃ vīhāya triyayuktair arthāc caturthayuktair

73) 2/9/6/4. 74) 22/7/2. 75) caturasramanyāpta-. 76) -āṃṣena, first na deleted. 77) kunitena 2/7/3 yutapīra- for ūṇitena pūrva-. 78) sūrya- for pūrva-. 79) 14. 80) jināṃśa. 81) -daśaṃśa. 82) svaṣṭāsvi- for svāṣṭadvi-. 208
2.8.2. samāṭṭasrikunḍam

“athavāṣṭakoṇaṃ”/
madhye guṇe vedayamair iti (MKS 47)/
sākrāṃṣāh <14>/ ete “nījarṣyabdhi-47-lavena”99) 0/2/3/0 yūkta jātaṃ
yāsārdham 14/2/3/ anena caturasramadhyāt kṛte vṛtte yathoktadiśāṣṭā(8a)sri
syāt/ darśanaṃ patrapṛṣṭhe (See Fig. 8. 2)//
ata “dvidvīnandesūṣāgaraiḥ” “vṛttavyāse 28/4/6 samāhate 1313082/1/4100)
khakhakhāhārākasambhakte” (L 207–208) jātaṃ aṣṭāsribhujāmānom 10/7/4/2/
ata yathāvart101) teṣu bhujēv ekabhujayobyahapraṇāt102) samuḥkāparabhuj-
apraṇādvyām yāvan niyāmānāṃ sūtradvayaṃ kuryāt/ evaṃ kṛta
āyatacaturbhujāṃ pārśvayor viṣamacaturbhujayutam103) āyate/ tattāyataca-
turbhujām tu tribhujadvayastdexceptāṣayogayam104)/ prakṛta āyatacaturbhuj-
asya vṛttavyāsaḥ105) karṇaḥ 28/4/6/ aṣṭāsribhujō bhujāḥ 10/7/4/2/ tatra106)
dohākārnadvarygayoc<1>14 ete nijarsyabdhi-47-lavena 0/2/3/0 yuktajatam
vyāsārdham 14/2/3/ anena caturasramadhyāt kṛte vṛtte yathoktadiśāṣṭā(8a)sri
syāt/ darśanaṃ patrapṛṣṭhe (See Fig. 8. 2)//
3. COMMENTARY

3.0. Introductory remarks

As is stated in the Introduction, the size of a kunda is determined according to the number of oblations to be made in that particular ceremony in which it is used. Table 1 shows the areas of kundas prescribed by Viṣṭhaladikṣita (MKS 35). He also mentions others' opinions (MKS 36).

Table 1

<table>
<thead>
<tr>
<th>Number of oblations</th>
<th>Area of kunda</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1 square aratni</td>
</tr>
<tr>
<td>$10^2$</td>
<td>1 square ratni</td>
</tr>
<tr>
<td>$10^3$</td>
<td>1 square hasta</td>
</tr>
<tr>
<td>$10^4$</td>
<td>2 square hastas</td>
</tr>
<tr>
<td>$10^5$</td>
<td>4 square hastas</td>
</tr>
<tr>
<td>$10^6$</td>
<td>6 square hastas</td>
</tr>
<tr>
<td>$10^7$</td>
<td>8 or 10 or 16 square hastas</td>
</tr>
</tbody>
</table>

The square-shaped kunda is the basis of the construction of kundas of other shapes; in other words, the rule for drawing a kunda, except for the square kunda, is given in terms of the side of the square kunda of the same area. Thus, the rules may be characterized as transformation-rules that keep the areas unchanged, and the rules given in MKS 39–47 can actually be applied to kundas of any size, though Gaṇeṣa only deals with ekahastakundas or kundas of one square hasta, except in one place (Sec. 2.2) where he makes an erroneous statement about yonikundas of other sizes (see Sec. 3.2, Remark 1).

Viṣṭhaladikṣita gives in advance the sides of the square kundas of one square hasta to ten square hastas (MKS 37).

Table 2

<table>
<thead>
<tr>
<th>Area of square kunda</th>
<th>Side (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 square hasta</td>
<td>24 aṅgulas 0 yava</td>
</tr>
<tr>
<td>2 square hastas</td>
<td>34 aṅgulas 0 yava</td>
</tr>
<tr>
<td>3 square hastas</td>
<td>41 aṅgulas 5 yavas</td>
</tr>
<tr>
<td>4 square hastas</td>
<td>48 aṅgulas 0 yava</td>
</tr>
<tr>
<td>5 square hastas</td>
<td>53 aṅgulas 5 yavas</td>
</tr>
<tr>
<td>6 square hastas</td>
<td>58 aṅgulas 6 yavas</td>
</tr>
<tr>
<td>7 square hastas</td>
<td>63 aṅgulas 4 yavas</td>
</tr>
<tr>
<td>8 square hastas</td>
<td>66 aṅgulas 7 yavas</td>
</tr>
<tr>
<td>9 square hastas</td>
<td>72 aṅgulas 0 yava</td>
</tr>
<tr>
<td>10 square hastas</td>
<td>75 aṅgulas 7 yavas</td>
</tr>
</tbody>
</table>

3.1. Square kunda (MKS 39: Fig. 1)

\[ S = a^2 ...(1) \]
3.2. *Kuña* shaped like a vulva (*MKS* 40: Fig. 2)

\[EP = \left(\frac{5a}{24}\right) \times (1 + 1/32) \ldots (2)\]

\[a = 1 \text{ hasta} = 24 \text{ aŋgulas: } EP = 5 + 5/32 = 5;1, 2 \text{ aŋgulas.}\]

(The right-hand side of the semicolon indicates the fractional part in the octonary system. See Sec. 1.4 above.)

\[OP = 12 + 5;1,2 = 17;1, 2 \text{ aŋgulas.}\]

\[SN = 24 \text{ aŋgulas: } S_1 = \triangle PNS = (1/2) \times 24 \times 17; 1, 2 \text{ (L 166)} = 205; 7 \text{ aŋgula}^2.\]

\[OW = 12 \text{ aŋgulas: } S_2 = \triangle WNS = (1/2) \times 24 \times 12 \text{ (L 166)} = 144 \text{ aŋgula}^2.\]

\[d = NW = SW = \sqrt{ON^2 + OW^2} = \sqrt{OS^2 + OW^2} \quad (L 136)\]

\[= \sqrt{12^2 + 12^2} = \sqrt{288} = 16; 7, 6, 0, 7, \ldots \approx 16; 7, 6, 1 \text{ (L 22}).\]

\[c = 3927 \times 1250 \text{ (L 199)} = 3927 \times 16; 7, 6, 1 \times 1250 = 66643; 7, 4, 7/1250 \]

\[= 53; 2, 4, 1, \ldots \approx 53; 2, 4, \text{ aŋgulas}.\]

\[S_3 = \text{sum of the areas of two semicircles NAW and SBW} = cd/4 \quad (L 201)\]

\[= 53; 2, 4; 16; 7, 6, 1/4 = 904; 6, 0, 0, 2, 4/4 \approx 904; 6/4 = 226; 1, 4 \text{ aŋgula}^2; \text{ or}\]

\[S_3 = 3927 \times 1250/5000 \quad (L 203)\]

\[= 3927 \times 16; 7, 6, 1^2/5000 = 3927 \times 288; 0, 0, 2, 3/5000 \approx 3927 \times 288; 0, 0, 2/5000 = 1130991; 2, 5, 6/5000\]
Remarks.
1) Having obtained $EP = 5; 1, 2$ for $a = 1$ hasta, Gañēṣa remarks: ayam eva dvyaṭidigunāḥ san dvyaṭidihaste bhavet/ evaṃ sarvatra/ “This (i.e. 5;1,2), when multiplied by two etc., would be (the value of $EP$) in the cases of (kundaḥ of) two square hastas etc. So is it everywhere (i.e. for kundaḥ of any shape).” This statement is of course wrong because what are doubled, tripled, etc. in kundaḥ of two square hastas etc. are not their lines but their areas.

2) The excess 0;0,4 in the area $S$ is designated “likhyacatustaya (=liksa-)” by Gañēṣa, but it should be “yakacatustaya”. On the other hand, Viṭthaladikṣita, having obtained $S = 576; 0, 4, 5$ ($S_B = 226; 1, 4, 5$ according to him) in his own commentary, correctly remarks:

\[
\text{atra likṣāpañcakaṃ yūkācatuṣṭayaṃ cādhikam}\
\]

Here, the excess is five likṣās and four yūkās.

3) Viṭthaladikṣita in his commentary mentions a sort of proof intended for those who do not know mathematics, and prescribes how to multiply numbers in the octonary system:

\[
yo ganitanabhijrias tena caturasram kundam tanduladina parayitva tan eva tandulān yonyādikunḍeṣu dattvā tattptārau toṣṭavyam iti/ atrāṅgulayavayū-kāliṣāḥ kṛtvā gomūtrikādīrītyā guṇayitvāṣṭhir bhāge grhitē phalē upary upari ca yojyamāne phalāny utpadyante111)/\
\]

One who does not know mathematics should be satisfied when kundaḥ beginning with the one shaped like a vulva are filled with exactly the same grains of unhusked rice and so on that a square kundaḥ (of the same size) has been filled with. Here, when one has multiplied (the numbers) arranged (in the places of) aṅgula, yava, yūkā, and likṣā (severally) in the manner of gomūtrikā (lit. urine of a cow) etc., divided (each product) by eight, and added each quotient to the next higher place, the (true) results (for each place) are produced.

4) Requirement for the transformation. The transformation has to keep the area unchanged:

\[
a^2 = \pi(a/4)^2 + a(a + EP)/2, \quad \text{or } EP = (1 - \pi/4)a.\
\]

Comparing this with (2), we have $\pi = 201/64 = 3927/1250 - 39/40000.$

5) The Śāradātīlaka, 3.53cd–55ab, prescribes:

\[
EP = a/5.\
\]

3. 3. Semicircular kunda (MKS 41: Fig. 3)

\[
t = (a/5)(1 + 1/100) \\
r = OP = OQ = a - t \quad \ldots (3) \\
a = 24 \text{ aṅgulaḥ: } a/5 = 24/5 = 4; 6, 3, 1, 4, 6, \ldots \approx 4; 6, 3, 1, 5.
\]

111) phalādy utpadyate, in the text we have used (see Sec. 1.6 above).
\[ t = a/5 + (a/5)/100 \]
\[ = 4; 6, 3, 1, 5+4; 6, 3, 1, 5/100 \]
\[ = 4; 6, 3, 1, 5+0; 0, 3, 0, 4, 4, \ldots \]
\[ \approx 4; 6, 3, 1, 5+0; 0, 3, 0, 4 \]
\[ = 4; 6, 6, 2, 1. \]

\[ r = a - t \]
\[ = 24 - 4; 6, 6, 2, 1 \]
\[ = 19; 1, 1, 5, 7. \]
\[ d = 2r = 2; 19; 1, 1, 5, 7 \]
\[ = 38; 2, 3, 3, 6 \text{ aₚ₉ₐₙ₉ₐₙ₉ₖₐₙ₃ₖₐₙ₃} \]
\[ d² = 38; 2, 3, 3, 6² \]
\[ = 1467; 1, 5, 4, 3, 0, \ldots \]
\[ \approx 1467; 1, 5, 4, 3. \]
\[ S₁ = 3927d²/5000 \text{ (L 203)} \]
\[ = 3927·1467; 1, 5, 4, 3/5000 = 5761740; 1, 6, 4, 5/5000 \]
\[ = 1152; 2, 6, 2, 1, \ldots \approx 1152; 2, 6, 2 \text{ aₚ₉ₐₙ₉ₐₙ₉ₖₐₙ₃}². \]
\[ S = S₁/2 = 1152; 2, 6, 2/2 = 576; 1, 3, 1 \text{ aₚ₉ₐₙ₉ₐₙ₉ₖₐₙ₃}². \]

**Remarks.**
1) Viṣṭhadikṣita mistakenly obtains \( S₁ = 1152; 2, 6, 4 \) and hence \( S = 576; 1, 3, 2. \)
2) Requirement for the transformation:
\[ a² = \pi r²/2. \]

By assuming \( r = a - t \), we have: \( t = (1 - \sqrt{2}/\pi) a. \) A comparison of this with (3) will give \( \pi = 500000/159201 = 3927/1250 - 182327/199001250. \) See Sec. 1.5 above for \( \pi = 3927/1250. \)
3) Śāradātiśaka 3.55cd-57ab prescribes:
\[ r = a - t, \] \( \text{where } t = a/5. \)

### 3. 4. Triangular kunḍa (MKS 42ab: Fig. 4)

\[ t = AQ = BR = a/4, \]
\[ u = EP = a/3, \]
\[ PW = a + u \]
\[ = 24 + 24/3 = 32 \text{ aₚ₉ₐₙ₉ₐₙ₉ₖₐₙ₃} \]
\[ QR = a + 2t \]
\[ = 24 + 2·(24/4) \]
\[ = 36 \text{ aₚ₉ₐₙ₉ₐₙ₉ₖₐₙ₃} \]
\[ S = \triangle PQR \]
\[ = (36/2)·32 \text{ (L 166)} \]
\[ = 576 \text{ aₚ₉ₐₙ₉ₐₙ₉ₖₐₙ₃}². \]

**Remarks.**
1) The triangle prescribed by Viṣṭha-
ladiksita is not equilateral. If an equilateral triangle be required in this case, one has to satisfy the requirement,

\[ a^2 = \left(\sqrt{3}/4\right)(a+2t)^2, \]

where \( t = AQ = BR \), EP being consequently determined. This equation may be rewritten as:

\[ t = \left(1/\sqrt{3} - 1/2\right)a. \]

2) Śāradatilaka 3.57cd–58 only gives \( t = a/4 \), being silent about the point P. It is not certain whether this implies that the triangle in consideration was equilateral. See Rāghavabhaṭṭa’s commentary on Śāradatilaka loc. cit. for several interpretations.

3.5. Circular kunda (MKS 42cd: Fig. 5)

\[ r = OP = (13a/24)(1 + 1/24) \]

\[ a = 24 \text{ aṅgulas:} \]

\[ r = (13a/24)(1 + 1/24) \]

\[ = 13 + 13/24 \]

\[ = 13 + 0;4,2,5,2,5,... \]

\[ \approx 13;4,2,5,3 \text{ aṅgulas.} \]

\[ d = 2r = 27;0,5,2,6 \text{ aṅgulas.} \]

\[ d^2 = 27;0,5,2,6^2 \]

\[ = 733;4,1,0,0,4,3,4,4 \]

\[ \approx 733;4,1. \]

\[ S = \frac{3927d^2}{5000} (L 203) \]

\[ = 3927 \cdot 733;4,1/5000 \]

\[ = 2880516/5000 \]

\[ = 576;0,6,4,6,5,... \]

\[ \approx 576;0,6 \text{ aṅgula}^2. \]

Remarks.

1) Viṭṭhadaliksita obtains \( S = 576;0,6,5 \text{ aṅgula}^2 \).

2) Requirement for the transformation:

\[ a^2 = \pi r^2; \text{ hence } r = a/\sqrt{\pi} \]...

(5a)

Or, by assuming \( r = a/2 + t \), we may rewrite the equation:

\[ a^2 = \pi(a/2 + t)^2; \text{ hence } t = (1/\sqrt{\pi} - 1/2)a \]...

(5b)

By comparing (5a) with (5), we have \( \pi = 329776/105625 = 3927/1250 - 2569375/13203125. \) The difference amounts to about 1/50. This is twenty times as large as those in the cases of the kundas shaped like a vulva and the semicircular kunda (see Sec. 3.2, Remark 4 and Sec. 3.3, Remark 2 above).

3) Śāradatilaka 3.59 prescribes: \( t = a/18 \).

4) To transform a square into a circle is a traditional problem which can be traced back to the śulbasūtras. Baudhāyana (1.58), Āpastamba (3.2), and Kātyāyana (3.13) prescribe [DATTA 1932: 140–143]: \( t = (\sqrt{2} \cdot a/2 - a/2)/3 = \)
3. 6. 1. Irregular hexagonal kunḍa (MKS 43: Fig. 6. 1).

\[ r = \text{OP} = (18a/24)(1 + 1/72) \]

...(6. 1)

\[ a = 24 \text{ açugas} ; \\
\[ r = 18 + 18/72 = 18 + 0.2 ; \\
\[ = 18.2 \text{ açugas} . \\
\[ d = 2r = 36.4 \text{ açugas} . \\
\[ PR = RU = UP \\
\[ = 103923d/120000 \\
\[ = 103923.36;4/120000 \\
\[ = 31;4,7,0,2,\ldots \\
\[ \approx 31;4,7 \text{ açugas} . \\
\[ RH = [RU \pm (PR + PU) \times (PR - PU)/RU]/2 \\
\[ = RU/2 = 31;4,7/2 = 15;6,3,4 \text{ açugas} . \\
\[ RH^2 = 15;6,3,4^2 = 249;6,2,3,4,2,0 \approx 249;6,2,3. \\
\[ PR^2 = 31;4,7^2 = 999;1,1,6,1. \\
\[ PH = (3/4)PT = \sqrt{PR^2 - RH^2} \\
\[ = \sqrt{999;1,1,6,1 - 249;6,2,3} = \sqrt{749;2,7,3,1} \\
\[ = 27;2,7,3,\ldots \approx 27;3,0 \text{ açugas} . \\
\[ S_1 = \Delta PRU = PH \cdot RH \\
\[ = 27;3,0,15;6,3,4 = 432;5,1,6,4 \approx 432;5 \text{ açula}^2. \\
\[ TH = PT/4 = d/4 = 36;4/4 = 9;1 \text{ açugas} . \\
\[ FG = RU/3 = 31;4,7/3 \approx 10;4,2,2,5,2,\ldots \approx 10;4,2,2 \text{ açugas} . \\
\[ S_2 = \Delta TFG = (FG/2) \cdot TH = (10;4,2,2/2) \cdot 9;1;0 \\
\[ = 48;0,4,2,1 \approx 48;0,4,2 \text{ açula}^2. \\
\[ S = S_1 + 3S_2 = 432;5 + 3 \cdot 48;0,42;0,4,2 = 432;5 + 144;1,4,6 = 576;6,4,6 \text{ açula}^2. \\
\[ Remarks. \\
\[ 1) \ \text{Vičhālaḍākṣita obtains } S_1 = 432;5,1,6 \text{ and hence } S = 576;6,6,4. \ \text{He mentions} \\
\[ \text{that } S \text{ can also be obtained from } S = 12 \cdot S_2. \\
\[ 2) \ \text{Ganēśa says that the geometrical property, } \text{PH} = \text{PT} - \text{PT}/4, \text{ "has been well} \\
\[ \text{established" (iti siddham).} \ \text{He also says that the property, } \text{RF} = \text{FG} = \text{GU}, \text{ is} \\
\[ \text{"observed by means of the direct perception" (pratyakṣato drṣyete).} \ \text{See also} \\
\[ Section 3. 8. 1, \text{ Remark 2}. \\
\[ 3) \ \text{Requirement for the transformation:} \\
\[ a^2 = \sqrt{3} \ r^2, \text{ or } r = \sqrt{3} \cdot \sqrt{3} \ a/3. \\
\[ \]
4) The Śāradātilaka only prescribes for the regular hexagonal kunda. See the next section.

3.6.2. Regular hexagonal kunda (MKS 44: Fig. 6.2)

\[ r = \frac{15a}{24} \left( 1 - \frac{1}{160} \right) \]
\[ a = 24 \text{ aṅgulas}; \]
\[ r = 15 - 15/160 = 15 - 0;0,6 = 14;7,2 \text{ aṅgulas.} \]
\[ d = 2r = 29;6,4 \text{ aṅgulas.} \]
\[ t = GH = \frac{[d - \sqrt{(d+UV)(d-UV)}]}{2} = \frac{d - \sqrt{(d+r)(d-r)}}{2}. \]
\[ (L \, 204) \]
\[ (d+r)(d-r) = 44;5,6;14;7,2 \approx 666;4,5,5,4 \]
\[ t = \frac{(29;6,4 - \sqrt{666;4,5})}{2} \]
\[ = \frac{(29;6,4 - 25;6,4,2,...)}{2} \]
\[ = 4;0,0/2 = 2;0,0 \text{ aṅgulas.} \]
\[ h = OH = r - t = 14;7,2 - 2;0,0 = 12;7,2 \text{ aṅgulas; or} \]
\[ h = \sqrt{PV^2 - PF^2} = \sqrt{d^2 - (d/4)^2} = 14;7,2^2 - 7;3,5^2 \approx 12;7,2. \]
\[ S_1 = \text{area of trapezium } PTUV = h(d+r)/2 \]
\[ = 12;7,2(44;5,6/2) = 12;7,2 \times 22;2,7 = 288;4,4,6,6 \approx 288;4,5 \text{ aṅgula}^2. \]
\[ S = 2 \times S_1 = 577;1,2 \approx 577;1 \text{ aṅgula}^2. \]

Remarks.
1) Vitthaladiksita obtains:
\[ S_1 = 12;7,2 \times 22;2,7 \approx 288;3,1,5 (!) \; \text{and} \]
\[ S = 2 \times S_1 = 577;3,2 \text{ aṅgula}^2. \]
This is not a misprint, because he remarks: “idāṃ likṣādvayaṃ yūkātrayaṃ yavaṣaṭkam adhikam...” In computing \( h \), he uses the second method of Gaṇeśa’s.

2) Requirement for the transformation:
\[ a^2 = 3\sqrt{3} r^2/2, \text{ or } r = \sqrt{2\sqrt{3} a/3}. \]

3) The Śāradātilaka, 3.60–61, prescribes: \( PN = a/8 \).

3.7. Kunda shaped like a lotus (MKS 45: Fig. 7)

\[ r_i = (a/8);i, \text{ for } i = 1,2,3,4; \]
\[ r_5 = (a/8)(5 - 1/38). \]
\[ a = 24 \text{ aṅgulas}; \]
\[ r_4 = 12 \text{ aṅgulas;} \]
\[ r_5 = 15 - 3/38 = 15 - 0;0,5,0,... \]
\[ \approx 15 - 0;0,5 = 14;7,3 \text{ aṅgulas.} \]
\[ d_4 = 2 \cdot r_4 = 24 \text{ ángulas}; \]
\[ d_5 = 2 \cdot r_5 = 29; 6, 6 \text{ ángulas}. \]
\[ S_4 = \frac{3927 \cdot d_4^2}{5000} \quad (L \ 203) \]
\[ = \frac{3927 \cdot 24^2}{5000} \]
\[ = 2261952 \quad / \quad 5000 \]
\[ = 452; 3, 0, 7, 7, \ldots \]
\[ \approx 452; 3, 1 \text{ ángula}^2. \]
\[ S_5 = \frac{3927 \cdot d_5^2}{5000} \quad (L \ 203) \]
\[ = \frac{3927 \cdot 29; 6, 6^2}{5000} \]
\[ = 3927 \cdot 890; 5, 1, 4, 4 / 5000 \]
\[ = 3497580; 1, 7, 7, 4 / 5000 \]
\[ = 699; 4, 1, 0, \ldots \]
\[ \approx 699; 4, 1 \text{ ángula}^2. \]
\[ S = S_4 + \frac{(S_5 - S_4)}{2} \]
\[ = 452; 3, 1 + 123; 4, 4 \]
\[ = 575; 7, 5 \text{ ángula}^2; \text{ or} \]
\[ S = S_5 - \frac{(S_5 - S_4)}{2} = 699; 4, 1 - 123; 4, 4 = 575; 7, 5 \text{ ángula}^2. \]

Remarks.

1) Viṣṭhaladikṣita obtains \( S_6 = 699; 4, 5, 0 \) and hence \( S = 575; 7, 7 \text{ ángula}^2. \)

2) Requirement for the transformation:

\[ a^2 = \left[ \pi (a/2)^2 - \pi r_5^2 \right] / 2, \quad \text{or} \quad r_5 = \sqrt{2 / \pi - 1} \cdot a. \]

By comparing this with (7), we have \( \pi = 184832 / 58825 = 3927 / 1250 + 1369 / 2941250. \)

3) The Śāradatilaka, 3.62–63, prescribes a circle with three inner circles, but without pedals. The size of the outermost circle is the same as that of the circular kunda.

3.8.1. Irregular octagonal kunda (MKS 46: Fig. 8.1).

\[ r = \text{OP}_1 = (18a/24)(1 + 1/28) \]
\[ \ldots (8.1) \]

\( a = 24 \text{ ángulas}; \)

\( r = 18 + 18/28 \)
\[ = 18 + 0; 5, 1, 1, 1, \ldots \]
\[ \approx 18; 5, 1 \text{ ángulas}. \]

\( d = 2r = 37; 2, 2, 2 \text{ ángulas}. \)

\( \text{P}_1 \text{P}_2 = \text{P}_2 \text{P}_3, \text{ etc.} \)
\[ = \frac{45922d}{120000} \quad \text{(L 207–208)} \]
\[ = 45922 \cdot 37; 2, 2, 2 / 120000 \]
\[ = 1712208; 7, 4, 4 / 120000 \]

---

Fig. 7. Lotus-like kunda

Fig. 8.1. Irregular octagonal kunda
$=14;2,1,3,\ldots \approx 14;2,1,1$ an\'gulas.

$P_1Q_2 = P_2Q_3$, etc. $= \sqrt{P_1P_2^2/2} = \sqrt{14;2,1,1^2/2}$

$= \sqrt{203;4,4,0,5,2,1/2} = \sqrt{203;4,4}$

$= \sqrt{101;6,2} = 10;0,5,5,\ldots \approx 10;1$ an\'gulas.

$P_1P_4 = P_1Q_2 + Q_3Q_4 + Q_4P_4 = P_1P_2 + P_1Q_2$

$= 14;2,1,1 + 210;1 = 34;4,1,1$ an\'gulas.

$S_1 = \text{area of rectangle } P_1P_4P_5P_8 = P_1P_4P_8 (L 173)$

$= 34;4,1,1;14;2,1,1 = 492;3,6,6,7,2,1 \approx 492;3,6,7$ an\'gula$^2$.

$P_1R = [P_1P_8 \pm (P_1Q_1 + P_8Q_1)/(P_1P_8)/2 (L 165)$

$= P_1P_8/2 = 14;2,1,1/2 = 7;1,0,4,4 \approx 7;1,0,4$ an\'gulas.

$P_1R^2 = 7;1,0,4^2 = 50;7,0,1,0,2,0 \approx 50;7,0,1.$

$P_1Q_1^2 = 10;1^2 = 102;4,1.$

$Q_1R = \sqrt{P_1Q_1^2 - P_1R^2} = \sqrt{102;4,1 - 50;7,0,1}$

$= 51;5,0,7 = 7;1,3,7,1,\ldots = 7;1,6,4$ an\'gulas (Ga\'n\'esa's value).

$S_2 = \triangle P_1Q_1P_8 - P_1R \cdot Q_1R (L 166)$

$= 7;1,0,4,7;1,6,4 = 51;4,2,7,3,2,0 = 51;4,3$ an\'gula$^2$.

(If we use a more accurate approximation $Q_1R = 7;1,3,7$, we have $S_2 = 51;2,0,1,4,7,4$.)

$S_3 = \text{area of } P_1P_4Q_5P_5P_8Q_1 = S_1 - 2S_2$

$= 492;3,6,7 - 2 \cdot 51;4,3 = 389;3,0,7$ an\'gula$^2$.

$S_4 = \text{area of } P_2P_3Q_4Q_2 = P_2P_3P_4Q_2 (L 173)$

$= 14;2,1,1;10;1 = 144;3,5,3,1 \approx 144;3,5,3$ an\'gula$^2$.

$S_5 = \text{area of } Q_2P_3Q_3Q_4 = S_4 - S_2$

$= 144;3,5,3 - 51;4,3 = 92;7,2,3$ an\'gula$^2$.

$S = \text{area of the kun\'da} = S_3 + 2 \cdot S_5$

$= 389;3,0,7 + 2 \cdot 92;7,2,3 = 389;3,0,7 + 185;6,4,6 = 575;1,5,5$ an\'gula$^2$.

Remarks.

1) Vi\'thaladik\'sita computes, instead of $S_2$, $2S_2 = P_1Q_1^2 = 102;4,0$ (which should be $= 102;4,1$). His value of $S$ is 576;2,0 an\'gula$^2$.

2) Ga\'n\'esa, in computing $P_1Q_2$, uses the geometrical property that $\triangle P_1P_2Q_2$ is an isosceles right triangle, saying that the property $P_1Q_2 = P_2Q_2$ "is observed by means of the direct perception" (pratyak\'sa dr\'ityate). But he does not use the same property in the computation of $S_2$. It seems that, to Ga\'n\'esa, the simpler was not always the better.

3) The word kun\'da occurs three times in this section in the sense of trik\'ona or a triangle.

4) Requirement for the transformation:

$a^2 = 4(\sqrt{2} - 1)r^2$, or $r = \sqrt{\sqrt{2} + 1} \cdot a/2$.

5) The \'S\'r\'avadlitaka does not prescribe for the kun\'da of this shape. See Remark 4 of the next section.
3. 8. 2. Regular octagonal kunda (MKS 47: Fig. 8. 2)

\[ r = OP_1 = \frac{(14a/24)}{(1 + 1/47)} \]

...(8. 2)

\[ a = 24 \] ángulas:

\[ r = 14 + 14/47 \]

= 14;2,3,0,4,...

\[ \approx 14;2,3 \] ángulas.

\[ d = 2 \cdot r = 28;4,6 \] ángulas.

\[ P_1 P_2 = P_2 P_3, \text{ etc.} \]

\[ = 45922d/120000 \]

\[ = 45922.28;4,6/120000 \]

\[ = 1313082;1,4/120000 \]

\[ = 10;7,4,2,3,... \]

\[ \approx 10;7,4,2 \] ángulas.

\[ d = 2r = 28;4,6 \] ángulas.

\[ P_4 P_8^2 = d^2 = 28;4,6^2 \]

\[ = 817;4,6,4,4 \] ángulas;

but Ganeśa obtains:

\[ P_4 P_8^2 = 757;4,6 \] ángulas.

\[ P_1 P_8^2 = 10;7,4,2^2 = 119;5,5,5,6,0,4 \approx 119;5,5,6. \]

\[ P_1 P_4 = \sqrt{P_4 P_8^2 - P_1 P_8^2} \] (L 136)

\[ = \sqrt{757;4,6 - 119;5,5,6} = \sqrt{637;7,0,2} \]

\[ = 25;2,0,3,1,... \approx 25;2,1 \] ángulas (Ganeśa's value).

\[ S_1 = \text{area of rectangle } P_1 P_4 P_8 P_9 = P_1 P_4 - P_1 P_8 \] (L 173)

\[ = 25;2,1 - 10;7,4,2 = 276;3,4,2,0,2 \approx 276;3,4 \] ángula^2.

\[ P_1 Q = [(P_1 P_4 - P_2 P_3) + (P_1 P_2 + P_3 P_4) (P_1 P_2 - P_3 P_4) / (P_1 P_4 - P_2 P_3)]/2 \]

\[ (L 184; 166) \]

\[ = (P_1 P_4 - P_2 P_3)/2 = (25;2,1 - 10;7,4,2)/2 = 7;1,2,3 \] ángulas.

\[ P_2 Q = \sqrt{P_1 P_2^2 - P_1 Q^2} = \sqrt{10;7,4,2^2 - 7;1,2,3^2} \]

\[ = \sqrt{68;3,2,6,2,3,3} = 8;2,1,3,0,... \approx 8;2,3,2 \] ángulas (Ganeśa).

\[ S_2 = \text{area of trapezium } P_1 P_2 P_3 P_4 = P_2 Q \cdot (P_1 P_4 + P_2 P_3)/2 \] (L 173)

\[ = 8;2,3,2 \cdot (25;2,1 + 10;7,4,2)/2 = 8;2,3,2-18;0,6,5 \]

\[ = 150;2,1,3,7,4,2 \approx 150;2,1,4 \] ángula^2.

\[ S = \text{area of the kunda} = S_1 + 2 \cdot S_2 = 276;3,4 + 2 \cdot 150;2,1,4 \]

\[ = 276;3,4 + 300;4,3 = 576;7,7 \] ángula^2; but the manuscript reads:

\[ S = 576;4,3 \] ángula^2.

Remarks.

1) If we use the correct value of \( P_4 P_8^2 = 817;4,6,4,4 \) instead of Ganeśa's erroneous one, we have \( S \approx 577;6,1 \) ángula^2. Probably, Ganeśa deliberately manipulated the first two digits in the correct value of \( P_4 P_8^2 (= d^2) \) in order to
get a better result.

2) Vitthaladiksita’s method (cf. Fig. 8.2). For the computation of $P_1P_2$, he cites a śloka from an unknown source:

\[
\text{candrartunandakṛtibhir vyāśārdhe } <\text{ca}> \text{ samāhate/}
\]
\[
\text{khakhakhāhrāgnisambhakte//}
\]
\[
P_1P_2 \text{ etc.} = 22961r/30000 \approx 10;7,4,2,3 \text{ aṅgulas}.
\]

For the computation of $S_1$ and $S_2$, he utilizes the versed sine:

\[
t = UT = \left[d - \sqrt{(d + P_2P_3)(d - P_2P_3)}\right]/2 \ (L \ 204)
\]

\[
\approx 1,0,5,4 \text{ aṅgulas}.
\]

\[
P_1P_4 = d - 2t = 26;3,3 \text{ aṅgulas}.
\]

\[
S_1 = P_1P_4 + P_1P_8 = 288;4,4 \text{ aṅgula}^2.
\]

\[
P_2Q = r - (P_1P_8/2 + t)
\]

\[
= 7;6 \text{ aṅgulas}.
\]

\[
S_2 = P_2Q \cdot (P_2P_3 + P_1P_4)/2
\]

\[
\approx 144;5 \text{ aṅgula}^2.
\]

\[
S = S_1 + 2S_2
\]

\[
= 577;6,4 \text{ aṅgula}^2.
\]

3) Requirement for the transformation:

\[
a^2 = 2\sqrt{2} \ r^2, \text{ or } r = \sqrt{2}/4 \ a/2.
\]

4) The octagonal kuṇḍa prescribed in the Śūradātīlaka, 3.64–66, is not a regular octagon. See Fig. 8.3, where:

\[
\text{EP} = a/24, \text{ and}
\]

\[
\text{RQ} = RT = (\sqrt{2}/4)a.
\]

This will make the area,

\[
S = (133/144)a^2.
\]

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4. Appendix

Manḍapakunḍasiddhi 31–47 (on Kunda)

prācyāś catuśkoṇabagendukhaṇḍatraiṇoṇavṛttāṅgabhujāmbujāṇī/
aśṭāsriṣakreśvaravas tu madhye vedāśri vai vṛttam uṣānti kūṇḍam//31/
āśeṣaḥkundād ihr paṇcakunḍa cākaṃ yadā paścimasomaśaive/
vedyāḥ sapādena kareṇa yad vā pādāntaṃpahīkulaṃdiṣamstha//32/
viprāc chṛutyasraṃ ca vṛttam ca vṛttādham tryasri syād vedakoṇāṇi vāpi/
sarvāṃ ṣuḥ vṛttārūpāṇi cāṇye yonyākārāṇy aṅganānnāṃ tu tāṇī//33/
sidhiḥ putrāṃ śubhaṃ satrunāśaḥ śantir mṛticchide/
vrṣṭīṛ āgroṣam uktam hi phalaṃ prācyādikunḍāke//34/
śaṭārdeḥ 'ratiṃḥ syāc chat aparimite ratnivataṃ/
sahasre haṃstāṃ syād ayutahavane hastayugalam/
caturhaṃstāṃ lakṣe prayutahavane śaṭkaramitaṃ/
kakubbhīr vā koṭau nṛpakaṃ aḥ prāhur apheres//35/
lakṣaiṇavṛttāṅgādaṇalakṣāṅtāṃ karaṇavṛttāṅgādaṇaḥ haṃstakāṃ ca/
kotyārdaḥdigvistemālalakṣalakṣadāle munīsvartukṛṣānuhaṃstam//36/
vedākṣāṇi yugāngayāḥ saṣṭiyugāḥ asṭābdhyayāḥ trīṣavo/
'ṣṭākṣa vahnirasā rasāṅgakamitā netrāṣyāḥ 'kṣasvarāḥ/
āṅgulyo 'ṭha yavāḥ ḫaṃ abhram iṣavaḥ ḫaṃ paṇca śaṭ sāgarāḥ/
sūṭiḥbhṛṃ caḥ munayas tv amī nigaditā vedaṃrāke bāḥvahāḥ//37/
kunḍatrayiḥ daṃśāvayonir aṁdrīṇaḥ saṃyāgrākāḥ syād itarāṇi paṇca/
paścādṛbhagāṇindradigavṛtāṃ yonir na koṭe na ca yoṅkuṇḍe//38/
dvighnavāsāṃ turyanīhaṃ sapāśaṃ sūtraṃ Şaṅkau paścime pūrvaṃ 'pi/
dattvā karṣet koṇayaḥ pāstāvye syād evam vā vedakoṇāṃ samānaṃ//39/
kṣetre jīnāṃśe puraṭaḥ śarāṃśan samvārdha ca śvīyadāṃśayuktān/
karṇāṅghrimāṇena līkhandukhaṇḍe pratyak puro 'ṅkād guṇāḥ bhagāḥbham//40/
svaśātāṃśayutbhaṅgaḥnaśvadhaiḥtrīmitaḥkāraṇaḥ madhyāḥ/
kṛtvṛttadāle 'grataḥ ca jīvāḥ vidadhātv indudalsya sādhusiddhyai//41/
vahnyaṃśaṃ purato nihāya ca punaḥ śroṇyoḥ caturthaṃśaṃ/
chiṃseṣaṃ triṣu sūtraṇātāta idaṃ syāt tryasri kaṣṭojhitam/
viśvāṃśaśaṃ vjaśāṃśaṃkena sahitāḥ kṣetre jīnāṁśe kṛte/
vyaśārdhena mitena maṇḍalam idaṃ syād vṛttasamjaṇam śubham//42/
ḥakte kṣetre jīnāṁśair dhṛtimalavakaiḥ śvakṣīśailāṃśayuktair/
vyaśārdhān maṇḍale tanmītadhireṇugaṃ kekeṣaṃ cendudiktaḥ/
ṣaṭciṃseṣu pradyād vrasmitagunakaḥ ekam ekam śiḥīvā/
nāṣe sandhyartudoṣaṃ aḥ ca vṛtikṛter netraramyaṃ śaḍaṃsam//43/
athava jinabhaktakunḍamānāt utihēbhāgaiḥ svakhaḥbhupabhāgaiḥāiḥ/
mitakāraṇakąodbhave tu vṛtte viḍhudiktaḥ sāmāśadbhujaḥ śaḍaṃsam//44/
āṣṭāṃśaṣc ca yataḥ ca vṛttasāke tatrādiman kārnīkā/
yugme śoḍaṃksesarāṇi carame svāṣṭātrabhāgonite/
bhakte śoḍaśadhā śarāntaradhāte syuh karkaṭe 'ṣṭau chadāḥ
sarvāṁ tāṁ khana karpikāṁ tyaja nijāyāmoccaṇāṁ syāt kajam 45
kṣetre jināṁśe gajacandraḥbhāgāḥ svāṣṭākṣibhāgāna yutais tu vṛtте/
vīdīgdiśor antarato 'ṣṭasūtraīs tṛtiyayuktair idam aṣṭakonām 46
madhye gune vedayamair vibhakte śakrair nijāryābdhilavena yuktaiḥ/
vṛtte kṛte digvīdiśo 'ntārale gajair bhujaiḥ syād athavāṣṭakonām 47

(This text is based on the two editions we have consulted. See Sec. 1. 6 above.)

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ガネーシャ作クンド設営解説

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ガネーシャ作 Kuṇḍasiddhyudāhṛti「クンド設営解説」は、ヴィッタラディークシンタ作 Maṇḍapakūṇḍasiddhi「マンダパとクンドの設営」(A.D. 1619)の中のクンドに関する9篇に対する、散文による註釈書であり、8種のクンドの面積計算を行なう。

クンドとはある種のヒンドゥー教の宗教儀礼に於て聖火をしつらえるために地面に掘られるくぼみであり、その平面的な形によって8種ある。即ち、正方形、女性生殖器、半円（又は半月）、三辺形、円、六辺形、蓮、八辺形の形をしたクンドがある。しかしすべてのクンドは、その形にかかわらず、個々の儀礼でその火に注される油（havana）の回数に関じてあらかじめ決められた面積をもたねばならない。もしも面積に誤りがあると、祭主（yajamāna）に不幸が起こるといわれる。かくて数学的問題が生ずる。即ち、ロープ（śūtra）とコンパス（karkaṭa）を用いて、決められた面積をもつそれらの図形を描くこと。ヴィッタラディークシンタは Maṇḍapakūṇḍasiddhi 39-47でその作図法を与える。一方ガネーシャは、バースカラが Lilāvatī (A.D. 1150)で与えた数学公式を用いて、それら得られた図形の面積を詳細に計算し、ヴィッタラディークシンタの作図法の妥当性を例証する。

このように Kuṇḍasiddhyudāhṛti は、インドの伝統的数学（gaṇita）が数学や天文暦学以外の分野に応用された極めて興味深い例を我々に提供してくれる。

Text は A.D. 1836 に写された写本（Government Oriental Manuscripts Library, Madras, D 13403）に基づく。また Commentary では、ガネーシャの面積計算を逐次追跡し、若干の注を加えた。