

## NOTES

### A NOTE ON THE SINE TABLE IN ANCIENT INDIA

AMULYA KUMAR BAG

National Commission for the Compilation of History of Sciences in India,  
Indian National Science Academy,  
1 Park Street, Calcutta 16

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In course of a correspondence with the author, Sri T. S. Kuppanna Sastry has drawn attention to the fact that the radius (*trijyā*) used by Varāhamihira in his *Pañcasiddhāntikā* should be 120' and not 120' 1" which follows from the emended version of the text of *Pañcasiddhāntikā*, edited by Thibaut and Sudhākara.<sup>1</sup> I have further looked into the matter and find that Thibaut and Sudhākara have made some wrong emendations in some portion of the original Sanskrit terms.<sup>2</sup> Due to this emendation, some errors have crept in the results of *jyā*-lengths given in my previous published paper.<sup>3</sup>

The relevant Sanskrit verses run as follows:

7	15	3	11	18	20
<i>meṣajyāḥ svaratithayaḥ guṇaśivadhṛtibhiḥśca viṃśatiḥ sahitā  </i>					
45	50	3		60	
<i>pañcanarakam śatārdham trisametam ṣaṣṭhiriti lptāḥ   </i>					
1	50	40	25	4	
<i>saikā'je pañcāśat pañcāṣṭakapañcavargavedāśca</i>					
34		56	5	0	
<i>triṃśaccaturbhiradhikā ṣaṭpañcāśaccharāḥ sūnyam   </i>					

(*Pañcasiddhāntikā*, ch. 4, v. 6-7)

*English translation:*

The sine (or *jyā* values) in the Aries expressed in minutes are: 7, 15, 23, 31, 38, 45, 53, 60. With that (add) 51, 40, 25, 4, 34, 56, 5, 0 (seconds).

Hence the 1st eight sines are 7' 51", 15' 40", 23' 25", 31' 4", 38' 34", 45' 56", 53' 5", 60' 0".

Two other verses run as follows:

6	13	19	$3 \times 8$	30
<i>ṣaṭkatrayadasaikonavimśatistryaṣṭakonyatastrimśat  </i>				
0	5	9	3	1
<i>yuktāmbara pañcanavāgnihimagubhirliptikā vṛṣabhe   </i>				
40	3	7	50	1
<i>catvāriṣṭadrāma munayo'rdhaśatam ca saikam  </i>				
13	12	60	14	5
<i>itigati dvādaśa ṣaṣtirhīnā manuvīṣayai* bṛṣe vikalāḥ   </i>				

(*Pañcasiddhāntikā*, ch. 4, v. 8-9)

*English translation:*

The sines in Taurus are: 6', 13', 19', 24', 30', 35', 39', 43'. The seconds in these are: 40, 3, 7, 51, 13, 12, 46, 55.

In the above verses, the term *viṣayai* (meaning 5) marked by asterisk appearing in the original version has been wrongly emended by Thibaut and Dvivedī in their edition by the term *sāgarai* (meaning 4). Evidently *ṣaṣtirhīnā manuvīṣayai* means  $60 - 14 = 46''$  and  $60 - 5 = 55''$ . Thibaut and Sudhākara have further read *itigati* (vide above verse line—4) as *dvirati*. The more plausible and correct version of *itigati* appears to be *atigati* and not *dvirati* as used by Thibaut and Sudhākara. To get the values of the actual  *jyā* -lengths, the eight values given under Taurus, namely 6' 40", 13' 3", 19' 7", 24' 51", 30' 13", 35' 12", 39' 46", 43' 55" are to be added to the last sine of the Aries, i.e. 60' 0".

Hence the actual values of the next eight  *jyā* -lengths are: 66' 40", 73' 3", 79' 7", 84' 51", 90' 13", 95' 12", 99' 46", 103' 55".

The next two verses run thus:

3	6	9	12	13	$3 \times 5$	16
<i>guṇarasanavakadvādaśa viśve dvistribhūtabhūpāntarajāḥ  </i>						
<i>jyāpīṇḍyā pīṇḍyādyā dvitīyarāśyantato vikalāḥ   </i>						
18	3	18	60	0	52	3
<i>dhr̥tiguṇadhrti parihīnā ṣaṣṭiḥ śūnyam satārdhamanalonam  </i>						
4	49	5				
<i>vedā vyekārdhaśatam pañceti tadantarajyāḥ syuḥ   </i>						

(*Pañcasiddhāntikā*, ch. 4, v. 10-11)

*English translation:*

The  *jyā*  values (of the Gemini) are: 3, 6, 9, 12, 13, 15, 15, 16 in minutes. The (corresponding) seconds are: 42, 57, 42, 0, 47, 4, 49, 5.

These eight values, namely 3' 42", 6' 57", 9' 42", 12' 0", 13' 47", 15' 4", 15' 49", 16' 5" must be added to the last sine, i.e. 103' 55" obtained in Taurus to get the subsequent  *jyā*  values.

Hence the corresponding actual sines are: 107' 37", 110' 52", 113' 37", 115' 55", 117' 42", 118' 59", 119' 44", 120' 0". Since the last sine, i.e. 103' 55", is to be added, every one of the results given by Thibaut and Sudhākara is wrong due to their faulty emendation of the term *viṣayai*.

The 24th *ḡyā* value ( $R$ ) is 120'. This shows that Varāhamihira selected the radius of the circle as 120'. This he has already admitted in ch. 4, v. 1, where he expressed the diameter (or *viṣkambha*) of the circle by the term *aṃśacatuṣka*, i.e.  $4 \times 1^\circ = 240'$ . The twenty-four sines are given at every intervals of  $3^\circ 45'$  (i.e. *rāśyaṣṭabhāgajyāh*, ch. 4, v. 1).

Now the following Table will show to what extent the values given by Varāhamihira when changed from minutes and seconds to degrees and minutes agree to those given by Ptolemy.

Serial No.	Varāhamihira's values of $R \sin \theta$	Ptolemy's values of $R \sin \theta$	Serial No.	Varāhamihira's values of $R \sin \theta$	Ptolemy's values of $R \sin \theta$
1	7° 51'	7° 50' 54"	13	90° 13'	90° 13' 15"
2	15° 40'	15° 39' 47"	14	95° 12'	95° 12' 9"
3	23° 25'	23° 24' 39"	15	99° 46'	99° 46' 35"
4	31° 4'	31° 3' 30"	16	103° 55'	103° 55' 23"
5	38° 34'	38° 34' 22"	17	107° 37'	107° 37' 30"
6	45° 56'	45° 55' 19"	18	110° 52'	110° 51' 52"
7	53° 5'	53° 4' 29"	19	113° 37'	113° 37' 54"
8	60° 0'	60° 0' 0"	20	115° 55'	115° 54' 40"
9	66° 40'	66° 40' 7"	21	117° 42'	117° 41' 40"
10	73° 3'	73° 3' 5"	22	118° 59'	118° 58' 25"
11	79° 7'	79° 7' 18"	23	119° 44'	119° 44' 36"
12	84° 51'	84° 51' 10"	24	120° 0'	120° 0' 0"

In this connection, it would not be out of place to mention here that in the 6th column of the previous paper (vide *IJHS*, vol. 4, p. 80), 5th, 13th and 22nd values of  $R \sin \theta$  given after Brahmagupta's *Brāhmasphuṭasiddhānta* have been misprinted. They would be 1051', 2459', 3242' respectively. Moreover, the value of *ḡyā* 60° in p. 81 and 83 (in four places) has been erroneously printed as  $\sqrt{\frac{3}{2}} R$ . The correct value would be  $\frac{\sqrt{3}}{2} R$ .

#### ACKNOWLEDGEMENT

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## REFERENCES

- <sup>1</sup> *Pañcasiddhāntikā* of Varāhamihira, edited by G. Thibaut and Sudhākara Dvivedi, 1930; Second edition, Chowkhamba Publication, 1968.
- <sup>2</sup> In the above text both original and emended version of the *Pañcasiddhāntikā* are given by Thibaut and Sudhākara.
- <sup>3</sup> Bag, A. K. The sine table in ancient India, *Indian Journal of History of Science*, 4, 80, 1969.