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WATER CLOCK AND STEELYARD IN THE JYOTIṢKARAṆḌAKA

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for Professor Nalini Balbir
in friendship and admiration

0 Introduction

Mahāvīrācārya, the great Jain mathematician who flourished in Karnataka in the ninth century, at the beginning of his mathematical work *Gaṇitasārasaṃgraha,* pays homage to Jina Mahāvīra who illuminated the entire universe with *saṃkhyā-jñāna*, the science of numbers. [1] Indeed, *saṃkhyā-jñāna* plays an important role in Jainism which seeks to comprehend the entire universe in numerical terms. In this process, the Jains conceived of immensely large numbers, making a very fine and subtle classification of transfinite numbers and operating with laws of integral and fractional indices and some kind of proto-logarithms.[2]

Kāla-jñāna or *kāla-vibhāga* is an important part of the *saṃkhyā-jñāna*, for time too needs to be comprehended in numbers. Jains measured time from the microscopic *samaya,* which cannot be sub-divided any further,[3] to the macroscopic *śīrṣa-prahelikā,* a number indicating years which is said to occupy 194 or even 250 places in decimal notation.[4]

But for *vyāvahārika* or practical purposes, especially for the calendar, the early Jain literature makes use of a five-year cycle or *yuga*. The basic problem in astronomical time-measurement is that the apparent movements of the two great luminaries who determine the passage of time, namely the Sun and the Moon, do not synchronize. The lunar year falls short of about eleven days in comparison to the solar year and does not keep step with the passage of seasons. In order to compensate for this shortage, intercalary months (*adhika-māsa*) are added

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[1] Mahāvīra, *Gaṇitasārasaṃgraha,* 1.2:
saṃkhyājñānapradīpena jainendreṇa mahātviṣā |
prakāśitaṃ jagatsarvaṃ yena taṃ praṇamāmy aham ||

[2] Cf. Among others, Datta 1929, Kapadia 1937 and Singh 1991.

[3] JKM 8: *kālo paramaniruddho avibhajjo taṃ tu jāṇa samayaṃ tu*. In ordinary Sanskrit, *samaya* is a synonym of *kāla*, 'time'.

[4] Cf. Datta & Singh 1935 I: 12: "Another big number that occurs in the Jaina works is the number representing the period of time known as *Śīrṣaprahelikā.* According to the commentator Hema Candra (b. 1089), this number is so large as to occupy 194 notational places (*aṅka-sthānāni*); Kapadia 1937: xviii-xix: "*Jyotiṣkaraṇḍaka* strikes altogether a different note in this connection; for, according to it (v. 64-71) *Śīrṣaprahelikā* is the name of the 250th place and not of the 194th place."

to the lunar months. The five-year *yuga* is the smallest period in which, by adding two intercalary months to sixty lunar months, the mismatch between the solar and lunar counts are minimized. This is the basis of the so-called 'luni-solar calendar' which is followed in India by the Hindus, Buddhists and Jains.

The earliest work that speaks of the five-year cycle is the *Vedāṅga-jyotiṣa* (also called *Vedāṅga-jyautiṣa,* or *Jyotiṣa-vedāṅga*) which is variously placed between the twelfth century and the fifth century B.C. The Jain canon, especially the *Sūriyapannatti* (*Sūryaprajñapti*) and related texts, broadly follows this five-year cycle and provide diverse kinds of astronomical parameters for this period.

A related Jain text *Joïsakaraṇḍaga* (*Jyotiṣkaraṇḍaka,* henceforth JK) introduces an interesting variation into the time measurement; it speaks of the 'volume'[5] (*mejja*) and 'weight' (*dharia*) of time. This is not as absurd as it sounds. Suppose we take a vessel with a hole at the bottom and fill it with water, which has a volume of *a* and a weight of *b.* If the water flows out of the vessel in time *t,* then the volume of the water *a* and the weight *b* can be treated as functions of time *t.*

In this context, the JK describes two instruments of measurement, a water clock and a steelyard, i.e. a weighing balance with a single pan. Such descriptions of instruments are rare in Indian literature, and therefore they deserve proper interpretation. In the following pages, we shall attempt a cultural study of these two measuring instruments.[6]

0.1 Jyotiṣkaraṇḍaka

The JK is available in two recensions. The longer one (= henceforth JKP) consisting of 405 *gāthā*s, together with a Prakrit gloss by Vācaka Śivanandī, was published from Bombay in 1981. The shorter version (JKM) of 376 *gāthā*s was published earlier in 1928 from Ratlam, together with a very extensive and learned commentary by Malayagiri who flourished in the twelfth century.[7] The JKM lacks the first six introductory verses and the very last verse which declares that *Pālittaka* (= Pādalipta-ka) is the author.[8] Also 22 verses in between are missing.

[5] Volume is the three-dimensional space occupied by a substance. But the volume of water cannot be measured directly; it must be placed in a container and the space occupied by the water in the container is measured. In other words, the volume of water is measured in terms of the space it occupies in a container, or in terms of the 'capacity' of the container. Therefore, it would be more correct to speak of the capacity of water rather than its volume. But since the term 'capacity' has several other connotations, we use 'volume' in this article.

[6] But no attempt will be made here to discuss such questions as the earliest occurrence of these two instruments in different civilisations.

[7] Malayagiri composed *Śabdānuśāsana* during the reign of Kumārapāla and commentaries on the *Sūryaprajñapti, Candraprajñapti, Jambūdvīpaprajñapti, Kṣetrasamāsa* and *Jyotiṣkaraṇḍaka*; cf. Pingree 1981: 359-62.

[8] JKP 405:

puvvāyariyakayāṇaṃ karaṇāṇaṃ jotisammi samayammi |
pālittakeṇa iṇamo raïyā gāhāhiṃ parivāḍī ||

Malayagiri was of the view that the redaction of the JK was done in the first council at Valabhī, which took place in the latter half of the fourth century, between AD 360 and 373.

> Then, when the famine had subsided, and food was once more abundant, an assembly of the [Jain] community was convened at two places, namely one at Valabhī and another at Mathurā. There in the compilation of the canon, differences occurred in readings (*vācanābheda*). While recollecting and compiling the [long] forgotten passages of the canon, differences in reading are bound to occur; there is nothing unusual in it. [Consequently] the currently available [version of the] *Anuyogadvāra* is in accordance with the recension of Mathurā. The author of the *sūtra*s of the *Jyotiṣkaraṇḍaka* is a venerable teacher of Valabhī (*ācāryo vālabhyaḥ*). Therefore, one should not doubt the numerical statements here [in the *Jyotiṣkaraṇḍaka*], because they do not correspond with the numerical statements of the *Anuyogadvāra*; these are [indeed] in accordance with the recension of Valabhī.[9]

In his introduction to the JKP, Amritlal Mohanlal Bhojak avers that Malayagiri had access only to the shorter version and therefore was not even aware that Pādalipta was the author of the work.[10] Malayagiri, on the other hand, refers to Pādalipta Sūri as a commentator (*ṭīkākāra*) on the JK and cites a sentence from that commentary.[11] Elsewhere he cites from what he calls the *mūla-ṭīkā,* 'original commentary.'[12] It is seems likely that Pādalipta has also written a commentary on the JK which was available to Malayagiri and he may be referring to this commentary by the expression *mūla-ṭīkā.* However, no manuscript of this commentary by Pādalipta seems to be extant. Vācaka Śivanandī, who also wrote a commentary on the JK at an uncertain date, does not refer to this earlier commentary by Pādalipta.

Be that as it may, Pādalipta's date is also uncertain. Bhojak states that Pādalipta Sūri flourished in the first century AD.[13] As in the case of most of the canonical and semi-canonical

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[9] JKM, p. 41: *tato durbhikṣātikrame subhikṣāpravṛttau dvayoḥ saṅghamelāpako 'bhavat, tad yathā— eko vālabhyām eko mathurāyāṃ tatra sūtrārthasaṅghaṭanena parasparaṃ vācanābhedo jātaḥ, vismṛtayor hi sūtrārthayoḥ smṛtvā smṛtvā saṅghaṭane bhavaty avaśyaṃ vācanābhedo, na kācid anupapattiḥ, tatrānuyogadvārakam idānīṃ pravarttamānaṃ māthuravācanānugataṃ, jyotiṣkaraṇḍaka-sūtrakartā cācāryo vālabhyaḥ, tata idaṃ saṃkhyāsthānapratipādanaṃ vālabhya-vācanānugatam iti nāsyānuyogadvāra-pratipādita-saṃkhyāsthānaiḥ saha visadṛśatvam upalabhya vicikitsitavyam iti.*

[10] JKP, Introduction, 27f.

[11] JKM, p. 52: *tathā cāsyaiva jyotiṣkaraṇḍakasya ṭīkākāraḥ pādaliptasūrir āha, 'ee u sasamādayo addhāvisesā jugāiṇā saha pavattaṃte jugaṃteṇa saha samappaṃti'.* A manuscript copy of the *vṛtti* on the JK by Pādaliptācārya is said to be at Jaisalmer, cf. Pingree 1981: 203.

[12] JKM, p. 121: *evaṃrūpā ca kṣetrakāṣṭhā* ***mūlaṭīkāyām*** *api bhāvitā, tathā ca tadgranthaḥ 'sūrassa paṃcayojanasayā dasāhiyā kaṭṭhā, sacceva aṭṭhahiṃ ekaṭṭhibhāgehiṃ ūṇiyā caṃdakaṭṭhā havaï' iti;* p. 237: *kevalaṃ* ***mūlaṭīkāyāṃ*** *parvāyanamaṇḍala-prastāro 'kṣa[ra]tāḍitaḥ kṛta ity asmābhir api vineyajana-sukhāvabodhāya sa kriyate* […].

[13] JKP, Introduction, 30.

texts of the Jains, it is, however, difficult to date the JK with any degree of certainty. All that can be said at present is that the astronomical and calendrical material presented in this text has close relation to texts belonging roughly to a period of a few centuries before Christ, namely the *Vedāṅga-jyotiṣa* (= VJ), Kauṭilya'a *Arthaśāstra* (= AS) and the *Sūryaprajñapti.*[14] In fact, the JK expressly declares, at the beginning[15] and at the end,[16] that it is a restatement of the *Sūryaprajñapti*. The *Sūryaprajñapti* is divided into twenty-three chapters (*pāhuḍa,* Sanskrit *prābhṛta*) each of which is devoted to a particular topic. The JK also treats the same twenty-three topics in the same sequence.[17]

The version of the JK which was available to Malayagiri in the twelfth century is not only short by 29 *gāthā*s, it also differs substantially from the JKP in respect of the phonology. For example, JKP has generally retroflex *ṇ* in the place of dental *n* in JKM. In JKP *t* is often retained while it is generally elided in JKM, eg. *kātavva, havati* (JKP); *kāyavva, havaï* (JKM). The unit of weight *karṣa* becomes *kaṃsa* in JKP while it remains closer to Sanskrit as *karisa* in JKM.

More specifically, in the portion which deals with the two measuring instruments, viz. JKP 7-35 = JKM 1-29, *nālikā,* the term denoting the unit of time as well as the vessel or instrument which measures this unit, becomes in JKP *ṇāligā* (16, 33, 34) or *ṇāliyā* (17-20), while in the JKM it has as many as four different variations *nālikā* (10-16), *nāligā* (11-17; 27-33), *nāḍiyā* (12-18;13-19), *nāliyā* (14-20; 28-34). The aperture in the vessel (*chidra*) becomes *chiḍḍa* in JKP, while it is *chidda* in JKM.

In the present article, we follow the text of the JKM. For the convenience of the readers, the text of JKM 10ab-14; 20-24 which deals with the water clock and the steelyard is given in the Appendix, together with an English translation.

[14] Credit goes to R. Shamashastri for recognizing that there are several parallel passages in the VJ, AS and *Sūryaprajñapti.* In his Sanskrit commentary of the *Vedāṅga-jyotiṣa,* he cites the common passages from the *Sūryaprajñapti* and provides a Sanskrit *chāyā*; cf. VJ-RS: 5, 6, 7 et passim.

[15] JKM 1 (= JKP 7):

> *suṇa tāva sūrapannattīvaṇṇaṇaṃ vitthareṇa jaṃ niüṇaṃ* |
> *thoguccaeṇa tatto vocchaṃ ullogamettāgaṃ* ||

[16] JKM 376 (= JKP 404):

> *kālaṇṇāṇasamāso puvvāyariehi āṇio eso* |
> *diṇakarapaṇṇattīo sīsajavibohaṇaṭṭhāe* ||

[17] These topics are enumerated in JKM 2-5 (= JKP 8-11).

1.0 The Water Clock

In his monumental work *Science and Civilisation in China*, Joseph Needham classifies the ancient water clocks into three types:[18] (i) outflow water clocks, i.e. vessels from which a certain quantity of water flows out in a specific time interval through a hole at the bottom; (ii) inflow clocks, where water from an overhead reservoir flows into a vessel and fills it in a specific time span; and (iii) sinking bowl type. In India, the first and the last type were used, not simultaneously but one after the other.

The outflow water clock used in India was called *nālikā-yantra. Nālikā* is a diminutive of *nala,* which term denotes, among others, a reed or a tube, or a hollow cylinder.[19] Accordingly the *nālikā-yantra* must have been generally of cylindrical shape (Fig. 1). A perforation was made at the bottom of the vessel so that the water in it flowed out in twenty-four minutes or one-sixtieth part of the day-and-night (*ahoratra*). This span of time was also known as *nālikā / nālī* or *nāḍikā / nāḍī.*

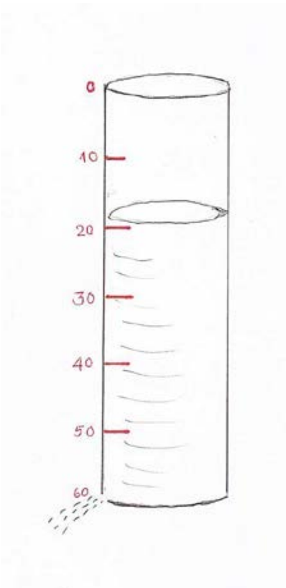

Fig. 1. Outflow Type of Water Clock (*Nālikā-yantra*)

Sometime about the fifth century AD, this *nālikā-yantra* was replaced by the sinking-bowl type which consists of a hemispherical copper bowl with a small perforation at its bottom. When it is placed on the surface of water in a larger basin, the water enters the bowl from below through the perforation. As soon as the bowl is full, it sinks to the bottom of the basin (Fig. 2). The weight of the bowl and the size of the perforation are so adjusted that the bowl sinks also

[18] Needham 1959: 315; see also Turner 1984: 1.

[19] Astronomical texts of the late medieval period speak also of a *nalaka-yantra,* which is different from the present *nālikā-yantra.* It consists of a sighting tube, to view planets and stars, used like a telescope without lenses; cf. Sarma 2009a: 16-18.

in 24 minutes. In Sanskrit, the bowl is called *ghaṭī* or *ghaṭikā* and these two terms designate also the duration of time measured by this device. The whole apparatus was accordingly called *ghaṭī-yantra* or *ghaṭikā-yantra.*[20]

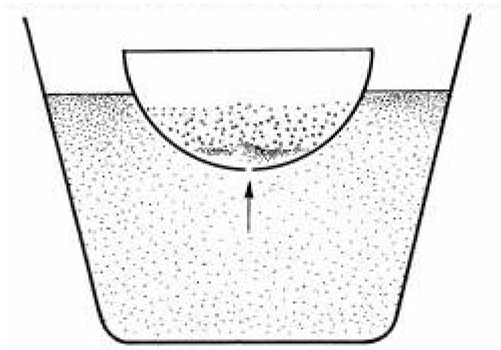

Fig. 2. Sinking Bowl Type of Water Clock (*Ghaṭikā-yantra*)

Thus, though the *nālikā-yantra* and *ghaṭikā-yantra* designate two separate types of water clocks, the periods measured by the two are the same, viz. 1/60 part of the *ahorātra,* that is 24 minutes. Even after the *nālikā-yantra* became obsolete, the terms designating this period in the two systems of measurement, namely *nālikā / nālī* or *nāḍikā / nāḍī* and *ghaṭikā / ghaṭī* were used often indiscriminately as synonyms.

The outflow water clock is described in the *Vedāṅga-jyotiṣa*, Kauṭilya's *Arthaśāstra* and in the *Divyāvadāna.* The descriptions are rather brief and use occasionally the same wording. Therefore, these should be studied together to obtain a coherent picture. This was done by John Faithful Fleet in an important paper "The Ancient Indian Water Clock".[21] It was Fleet who clearly saw that these texts describe an outflow water clock which is different from the sinking bowl variety occurring in the later texts.[22] Fleet did not have access to the description of the outflow water clock in the JK*,* which was published for the first time in 1928.

1.1 Aperture in the Water Clock

The JK describes the water clock in four terse *gāthā*s, stating that the vessel called *nālikā* should be made of metal (*loha*) in the shape of a pomegranate flower (*dālima-puppha*), with an aperture at its bottom. About this aperture, the following instructions are given: "Take ninety-six hairs from the tail of a three-year-old female elephant calf (*gaya-kumārī*; Sanskrit: *gaja-kumārī*);

[20] Sarma 1994.

[21] Fleet 1915.

[22] Fleet 1915: 213-214.

straighten them and bundle them together, and with this make the hole. Or take twice [the previous number] of hairs (i.e. 192) from the tail of a two-years-old female elephant, and with them make the hole."[23] What the text means is that the hole must be such that ninety-six hairs from the tail of a three years' old female elephant calf, or twice that number from the tail of a two years' old female elephant calf can pass through it.

This prescription should not be considered very unusual or funny. The English expression 'hair's breadth' shows that the breadth of a strand of hair is regarded to be a micro-unit in linear measurement in other cultures also. In Jain literature, hair's breadth or the magnitude of the tip of the hair is employed frequently in micro-measurement.[24] Though logical, such a micro-measurement with tail hairs of an elephant or cow is not a very practical proposition. Even if the calf agrees, plucking so many hairs from the young calves would surely be against the fundamental creed of non-violence of the Jains.

More practical would be the third alternative prescribed by the JK, viz. that the aperture should be such that a gold needle of 4 *māṣaka*s weight and 4 *aṅgula*s length can pass through it. The AS also defines the aperture in the same manner.[25] Gold is a pliable metal and there existed from earliest times the technique of drawing gold into a wire of uniform diameter. On the face of it, this sounds like a very scientific method of micro-measurement. Even when the outflow water clock was replaced by the sinking bowl water clock, the dimension of the aperture was defined in a similar manner.[26] Therefore, Harry Falk has taken the trouble of estimating that such a gold needle will have a diameter of 1.448 mm.[27] Goldsmiths of that time may have been able to draw fine grades of gold wire, but whether they could draw a wire measuring exactly eight *aṅgula*s from a lump of gold weighing exactly one *pala* is open to question. But

[23] JKM 12-13; see Appendix.

[24] E.g., see JKM 79 ff, p. 45. Similar specification is mentioned by al-Bīrūnī (*Al-Beruni's India,* vol. 1, 334) who quotes the following from an unidentifiable book by Bhaṭṭotpala of Kashmir: "If you bore in a piece of wood a cylindrical hole of twelve fingers' diameter and six fingers' height, it contains three manâ of water. If you bore in the bottom of this hole another hole as large as six plaited hairs of a young woman, not of an old one nor of a child, the three manâ of water will flow out through this hole in one *ghaṭî*."

[25] AS 2.20.35: *suvarṇa-māṣakāś catvāraś catur-aṅgulāyāmāḥ kumbhacchidram āḍhakam ambhaso vā nālikā.* Kangle (AS, II, 139) translates it as follows: "Or, a hole in a jar (with a dimension) of four *māṣaka*s of gold made four *aṅgula*s in length, (with) an *āḍhaka* of water (running though it) measures one *nālikā.*"

[26] Sarma 2004.

[27] Falk 2000: 118: "The text tells us that the measure of 4 *suvarṇa-māṣakas* of gold should be rolled until the gold is 4 *aṅgulas* long. The diameter of the thread obtained is equivalent to the diameter of the hole in the pot. […] A certain amount (1 *āḍhaka*) of water running through this hole needs half a *muhūrta* (*nālikā*, i.e. 24 minutes). With a density of 19.3 kg per dm^3, a s*uvarṇamāṣaka* of 2.248 gr […] we get a volume of 116.477 mm^3 for the gold. A cylinder of this volume with a length of 70.8 mm (at an *aṅgula* of 17.7 mm) will have a diameter of 1.448 mm." Kulkarni 1988 computed the area of the aperture to be 0.016 cm^2; this would lead to much smaller diameter of the aperture, namely 0.050909. The difference is apparently due to the fact that while Falk considered the gold needle to be a hollow tube, Kulkarni treated it as a solid wire.

this does indicate that the process of drawing gold wire was probably known in Kauṭilya's time.[28]

1.2 Size and Shape of the Water Clock

While the JK provides as many as three alternate methods of micro-measurement of the hole of the vessel which constitutes the water clock, it is entirely silent on the other dimensions of the vessel. But, without these, just the size of the hole will be of no use in constructing the water clock. [29] The AS is also silent on this aspect. It merely states that the volume of water discharged in one *nālikā* is one *āḍhaka.*[30] The JK*,* on the other hand, states that the volume of the water in the *nālikā* vessel is 2 *āḍhaka*s.[31] This would mean that the vessels used by the JK and AS are of different dimensions.

Now we come to the shape of the vessel. The AS calls the vessel *kumbha*. It is not clear whether the word *kumbha* denotes just any vessel or specifically a spherical[32] or hemi-spherical[33] pot. The JK clearly states that the vessel should be shaped like a pomegranate flower. On the other hand, as mentioned already, the name *nālikā* suggests a cylindrical shape. A cylindrical vessel has the advantage that its height can easily be divided to show the water level at various subdivisions of a *nālikā.* Therefore, a cylinder can be graduated with a scale so that not only *nālikās* can be measured but also parts thereof with the outflow water clock (Fig. 1). Or one can have a large cylindrical vessel to measure, not one, but several *nāḍikā*s.

The earliest reference to such a large outflow clock of 24 hours' duration occurs in the *Āryabhaṭa-siddhānta* of Āryabhaṭa, who was born in 476.[34] Here Āryabhaṭa speaks of calibrating the vessel in equal divisions to indicate the *nāḍikā*s. That the vessel is shaped like a

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[28] On the history of drawing gold wire by means of drawing plates, see Oddy 1997. In India, this technical process is mentioned and a draw-plate (*shafshāhang*) was illustrated in the Persian dictionary *Miftāḥu'l Fuẓalā* dated 1469; cf. Habib 2012: 47.

[29] In actual practice, it is doubtful whether any water clock was ever prepared, by measuring the hole in this manner. In an earlier article, I have examined the specifications given in different texts for the sinking bowl variety and showed that Bhāskara II dismisses these specifications as illogical (*yukti-sunya*) and impossible to implement (*durghata*); Sarma 2004: 151f. Yet, the definition of the aperture of the water clock in terms of the diameter of a gold needle has become almost a sacred formula and repeated also in non-scientific works like the *Purāṇa*s.

[30] See n. 25 above.

[31] JKM 28ab: *udagassa nāliyāe havaṃti do āḍhagā u parimāṇaṃ* |

[32] Kulkarni 1988 takes the word literally as a perfectly spherical vessel and discusses its use for time measurement. But there would be practical difficulties in operating with such a spherical vessel.

[33] In connection with the sinking bowl type of water clock, the bowl is frequently described as *kumbhārdhākāra,* "having the shape of half a pot," i.e. hemi-spherical.

[34] This work is no more extant, but its chapter on instruments survives in quotations in the commentaries on the *Sūryasiddhānta* by Mallikārjuna Sūri (AD 1178), Rāmakṛṣṇa Ārādhya (1472) and Tamma Yajvan (1599). The chapter has been extracted and studied in Shukla 1967.

cylinder becomes evident by the use of the word *stambha,* ‘pillar,’ in the present context ‘hollow pillar’.

> Construct a pillar with an excellent (cylindrical) cavity inside. Fill up the cavity with water (and then open the hole at the bottom of the pillar so that the water may flow out. By the time (in *ghaṭī*s) taken by the water to flow out completely, divide the whole length of the pillar. From this (can be calculated) the measure of an *aṅgula* (which corresponds to a *ghaṭī*). On the pillar, mark the *aṅgula*s corresponding to each *ghaṭī.* The water corresponding to one *ghaṭī* flowing out from the hole (at the bottom of the pillar) in the level of the ground, completely fills a *ghaṭikā* vessel in one *ghaṭī.*[35]

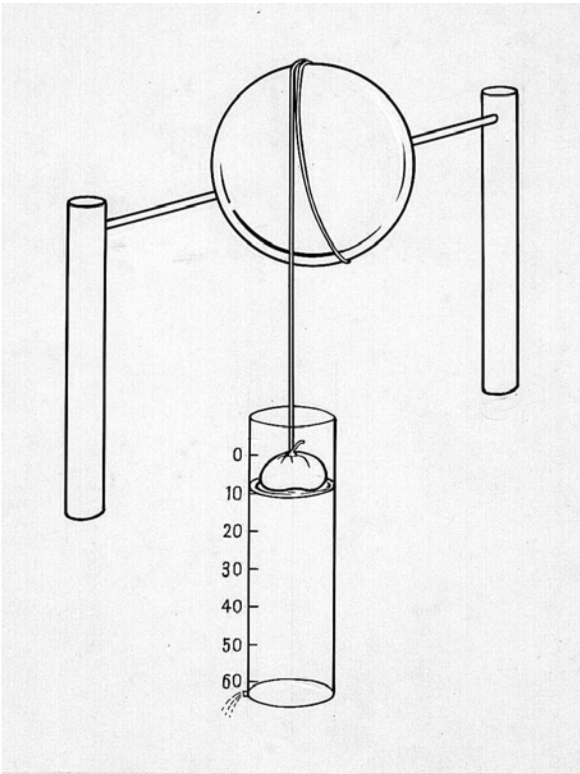

Fig.3. Āryabhaṭa’s model to demonstrate the daily rotation of the earth globe (reconstruction)

Upon this graduated cylindrical vessel, a wooden globe is set up which is made to rotate around its axis at the rate of one rotation per 24 hours by means of a weighted float resting on the surface of water in the cylindrical vessel. As the water flows out of the vessel through the

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[35] *Āryabhaṭa-siddhānta* 18-19 (Shukla 1967):

stambhaṃ sadbilasampūrṇaṃ toyam randhre tu yojayet |
tanmukta-kāla-saṃbhājyaḥ stambhāyamo ’ṅgulātmakaḥ ||
aṅgulānāṃ mitiḥ stambhe pratināḍīṃ tu yantrake |
nāḍyākhyāt bhūtalacchidrāt pūryād ambughaṭītalam ||

The translation cited above is by Shukla.

hole at the bottom, the surface of the water goes down, indicating the time on the graduations marked on the vessel. The float resting on the surface of water also goes down, which process makes the wooden globe turn on its axis[36] (Fig. 3). In other words, this apparatus is powered by an outflow type of water clock which empties itself in 60 *ghaṭikā*s. Based on this design, Āryabhaṭa mentions the creation of several automata with the moving figures of a man, a peacock or a monkey.

In the seventh century, Brahmagupta elaborates on this construction briefly hinted at by Āryabhaṭa. Brahmagupta describes such large outflow vessels, which he calls *nalaka* and makes these the basis for several ingenious automata. He suggests that the length of the cylindrical jar should be calibrated into 60 equal divisions, each one denoting a *ghaṭikā*. Then, an empty shell of a dried gourd filled with mercury is made to float on the surface of the water in the cylindrical jar. To this gourd is attached a long narrow strip of cloth, in which 60 knots are tied at distances equal to the divisions marked on the cylinder, and the knots are numbered serially. Then, as the float goes down it pulls the strip of cloth with the knots downwards, and the passage of each knot beyond a certain point indicates the passage of a *ghaṭikā*.[37]

With this basic design, Brahmagupta devises several models. For example, in a model called *Vadhū-vara-yantra,* two dolls, a bride and bridegroom, are set up, and as the water level goes down in the vessel, at the completion of each *ghaṭikā* a numbered knot issues out from the bridegroom's mouth and passes on to the bride's mouth[38] (Fig. 4).

All these ingenious devices are based on the erroneous assumption that the water level in the vessel falls by equal distances in equal time intervals. But the vessel used here is a regular cylinder called *stambha* by Āryabhaṭa and *nalaka* by Brahmagupta. The outflow of water from these cylindrical vessels cannot be uniform because, as the level of water falls, the water pressure changes and consequently the rate of flow also changes. Therefore, the *ghaṭikās* indicated by these devices will not be of a uniform duration; they will be shorter at first and then become longer and longer gradually.

[36] See also Āryabhaṭa I, *Āryabhaṭīya,* Golapāda 22 and Sūryadeva Yajvan's commentary on it, pp. 129f.

[37] Brahmagupta, *Brāhmasphuṭasiddhānta,* 22. 46-48 (cf. Sarma 1986-87).

nalako mule viddhas tatsrutighaṭikoddhṛtaḥ samucchrāyaḥ |
labdhāṅgulais tu tair nāḍikā kriyā yantrasiddhir ataḥ ||46||
ghaṭikāṅgulāntarasthais cīrir guṭakair ghaṭīdhrutair aṅkyā |
upari naro 'dhaḥ suṣiras tiryak kilo 'sya mukhamadhye ||47||
kīloparigāminyāṃ cīryāṃ dhṛtapāram alāvu tasmin |
sravati jale kṣipati naro guṭikāṃ kūrmādayas caivam ||48||

[38] Ibid., 22.50; cf. Sarma 1986-87.

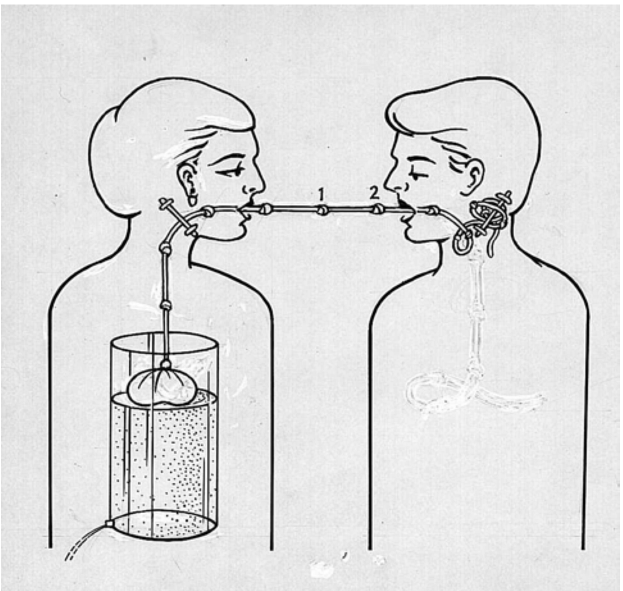

Fig. 4. Brahmagupta's *Vadhū-vara-yantra* (reconstruction)

This problem is raised for the first time only towards the beginning of the sixteenth century by Nīlakaṇṭha Somasutvan in his commentary on the *Āryabhaṭīya.* Commenting on *Āryabhaṭīya, Golapāda* 22, he remarks that, if the cylinder has the same circumference at the top and the bottom, the outflow will be faster at the beginning and then will be slower gradually. Consequently, the equal divisions on the scale will not indicate equal time periods.[39]

1.3 Vessel with Sloping Sides

Nīlakaṇṭha, however, does not state how the upper and lower diameters should vary. The ancient Egyptians tried to regulate the water pressure by adopting a vessel with sloping sides. Bucket-shaped water clocks, whose upper diameter was about twice the lower diameter and whose sides are graduated in equal divisions are attested from the end of the sixteenth century B.C. in Egypt.

It is possible that when the JK prescribes that vessel of the water clock must have the shape of a pomegranate flower (*dālimapupphāgārā*), it may have in mind a vessel with sloping sides as in Egypt. For the pomegranate flower, when seen from the side, looks conical. Or the JK may even be suggesting, not a truncated cone like the Egyptian water clock, but a full cone. A cone cannot rest on the ground, but an appropriate stand can be made to support the conical

[39] Cf. *Āryabhaṭīya-bhāṣya,* Part III, 38: *kālasamatvāya nalakasyordhvādhaḥ pariṇāhabhedaḥ kartavyaḥ. sāmye tu jalādhikye tadgauravād ativegena jalasrvaṇāt* […] *madhyāhnāt prāg eva golacaturdhabhramaṇaṃ syāt. punaḥ punaḥ krameṇa māndyaṃ ca.* "The diameter at the top of the cylinder and that at its bottom should be made different, so that [the water level in the cylinder falls by] equal [intervals of] time. But if [the diameters are] the same, when there is much water [in the cylinder], owing to its greater weight (i.e. pressure), the water flows out very swiftly […] and the globe completes one-fourth of its rotation even before the noon. And then gradually slowness [will occur in the flow of water]."

vessel. If this was so, this seems to be the only case of outflow water clock with sloping sides. Soon this knowledge was forgotten. By the time of the commentator Malayagiri, even the knowledge of the outflow water clock was completely lost.

1.4 Malayagiri's Confusion

We have mentioned earlier that the outflow water clock was replaced by the sinking bowl water clock in the fifth century. Āryabhaṭa at the turn of the fifth and sixth centuries and Brahmagupta in the seventh century prescribe the sinking bowl for time measurement, even though they still employ the outflow vessel for their automata. Thereafter outflow water clocks are not mentioned at all.

By the twelfth century, when Malayagiri was writing the commentary on the JK, the outflow water clock became completely obsolete and was totally forgotten. Therefore, while explaining the passage on the *nālikā-yantra,* Malayagiri consistently misunderstands it as the sinking bowl water clock which is prevalent in his time.[40] In the place of *niḥsarati* (in the sense of water flowing out of the vessel), he uses *praviśati* (in the sense of water entering the vessel). Explaining the word '*chiḍḍa*' he says: "*chidra* means the hole at the bottom through which the water enters the *nālikā*-vessel," whereas the JK uses it in the sense of the hole through which the water goes out the vessel.[41] Again, commenting on the quantity of water for filling the vessel, he observes: "the dimension of the hole through which the water enters the *nālikā* and fills it […]."[42] Nevertheless, Malayagiri's commentary is valuable; it explains lucidly the many numerical expressions and computational procedures; it is also erudite with frequent references to and citations from other works.

Before closing the discussion of the outflow water clock, it must be added that the JK also lays down certain specifications about the quality of water to be used in the water clock. The water must be either filtered with a cloth, or one should use clear rain water, or clear water collected from mountain streams in autumn.[43] Needless to say that this is an ideal case; in practical life it would be impossible to collect and carry such quantities for the constant use in the water clock in all parts of India.

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[40] R. Shamasastry also confuses between the two varieties when describing the outflow water clock mentioned in the *Vedāṅgajyotiṣa.* Cf. VJ-RS, English tr., p. 1: "Verse 7 refers to a cup of thin plate of brass or copper capable of holding a Prastha of water weighing 12 ½ Palas. It had a small hole at the bottom, through which water entered into the cup when it was floated on water contained in a bigger vessel. When the cup was filled with water, it sank in the water of the bigger vessel making a noise." This is repeated on ibid: 24f.

[41] JKM, p. 6: '*chidram' vivaram adhobhāge yenodakaṃ nālikāmadhye praviśati*.

[42] JKM, p. 12: *yāvatpramāṇacchidreṇa praviṣṭena nālikā paripūrṇā bhavati tāvatpramāṇasya nālikodakasya meyapramāṇacintāyāṃ dvāv āḍhakau parimāṇāṃ bhavati*.

[43] JKM 28-29; see Appendix.

2.0 The Steelyard

After discussing the outflow water clock, the JK proceeds to describe the steelyard for measuring the weight of the water which flows out of the water clock. In this connection, the text also gives a list of units of weight.[44]

But first a few words on the two traditional weighing devices, namely the double-pan balance and the steelyard. It is difficult to trace the exact place of origin and the path of diffusion of the two types of weighing balances. In India, however, the earliest traces are of the double-pan balance. Its existence with a well-developed system of weights in the Indus valley civilization (ca. 3300-1300 B.C.) is attested by the remains of metal scales and ~~a~~ large numbers of weights.[45]

The single pan balance or steelyard[46] is technically more sophisticated in that it does not require standard weights to measure the weight of an object; it shows the weight on the scale engraved or marked on the beam. This balance consists of a straight beam from one end of which is suspended a pan to hold the object to be weighted. To the other end is attached a counterweight or poise.

Fig. 5. Roman Steelyards and counterweights in the shape of human heads.
Römisch-Germanisches Museum, Cologne (photo by S. R. Sarma)

[44] JKM 15-19; cf. Appendix, Table 2.

[45] Habib 2002: 36-37: "Another craft involving precision was the making of measures of weight in the form mainly of chert cubes, that have been found in large numbers at Mohenjo Daro and Harappa. Excluding a few fractional pieces, and counting from a basic unit of 13.63 grams (=1), the scale runs in the ratio of 1, 2, 4, 10, 20, 40, 100, 200, 400, 500, 800, while the fractions are 1/16, 1/8, 1/4 and 1/2. The heaviest weight known was about 10.0 kilograms and the lightest 85.1 centigrams. A workshop at Chanhu Daro with unfinished products shows how the weights were cut to achieve fair accuracy." See also Sharma & Bharadwaj 1989: 329f., and Petrusco 2011: 47-50.

[46] It is commonly called 'steelyard' after the main trading base of the Hanseatic League in the fourteenth century London which was known as the Steelyard, i.e., the steel market.

The steelyards are again of two kinds. In one variety, the counterweight slides along the scale on the beam to counter-balance the load and thus indicates the weight of the load. The many surviving Graeco-Roman steelyards are of this type (Fig. 5).

In the second type, it is the fulcrum or the handle with which the beam is suspended and which is moved along the scale of the beam (Fig. 6).[47] This variety with the movable fulcrum was known in India from the earliest times (see 2.3 below); the other variety with the movable counterweight is attested only in the medieval period (see 2.10 below).

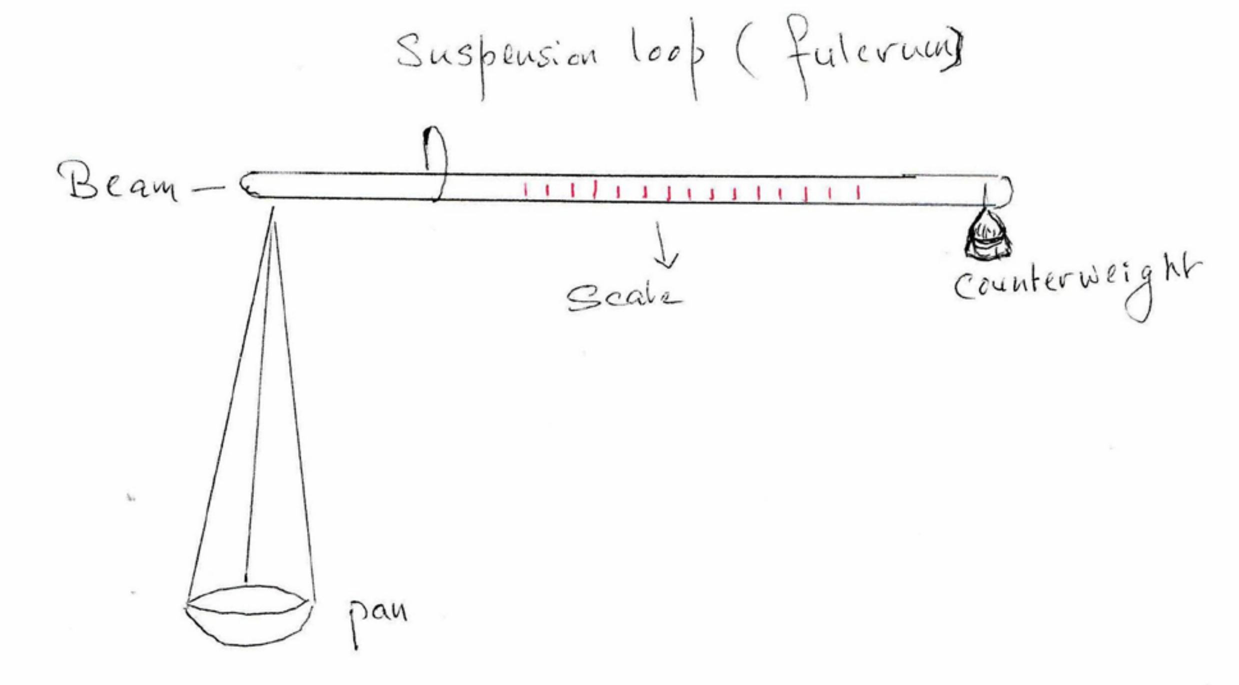

Fig. 6. Steelyard with the movable fulcrum (sketch)

2.1 The Arthaśāstra on the Steelyard

The steelyard is described in two Indian sources, namely in the AS and the JK. Regulating the weights and weighing devices is an important function of state, and the AS devotes an entire chapter (2.19) for this. Here it mentions both the double-pan balance and the single-pan balance. The former is designated as *ubhayataḥ-śikya* (that which has pans on both sides), but there is no special term for the steelyard; it is merely referred to as *tulā,* which term denotes both the varieties. The AS enumerates as many as ten different kinds of balance beams — their lengths ranging from 6 to 72 *aṅgula*s and weights from 1 to 10 *pala*s —, to be used both in the double pan and the single pan varieties.

[47] Steelyards with movable handle are occasionally called Danish steelyards or by the Danish term *bismar.* Such designations are anachronistic because steelyards with the movable fulcrum existed long before existence of Denmark. It is less ambiguous to call the two types respectively as the steelyard with the movable counterweight and the steelyard with the movable fulcrum.

Thereafter, the AS describes in greater detail a single-pan balance called *samavṛttā.*[48] Its beam is made of an unspecified metal (*loha*); it is 72 *aṅgula*s long and weighs 35 *pala*s. After attaching a counterweight (*maṇḍala*) of 5 *pala*s to one of its ends, a mark is made on the beam for the zero weight and thereafter graduation marks (*pada*) for different weights from 1 *karṣa* up to 100 *pala*s.[49] The AS mentions one more variety of steelyard, named *parimāṇī,* which has a beam 70 *pala*s in weight and 96 *aṅgula*s in length for measuring weights up to 200 *pala*s.[50]

2.2 The Jyotiṣkaraṇḍaka on the Steelyard

The JK mentions just one variety, namely the one designated as *samavṛttā* in the AS, with the same specifications and almost with the same wording.[51] Both the texts agree on the length and weight of the beam and also on the weight of the counterweight, which is termed *maṇḍala* in the AS and *dharaṇaga* in the JK. But neither text explains clearly which part is the movable one, whether it is the counterweight or the loop with which the beam is suspended.

2.3 Steelyard in Buddhist Sculpture and Painting

Fortunately, the steelyard is depicted in Buddhist sculpture and painting several times and these depictions would help us answer the question. These depictions deal with the episode of king Śibi.[52] This episode narrates that in one of his previous births, the Buddha was born as a king named Śibi. One day when he is holding court, a dove flies into his lap and seeks his protection. The dove is soon followed by a hawk which demands that the king give him the dove because it is his legitimate food. The king refuses to give the dove because it sought his protection, for it is the king's duty to protect those who seek his refuge. It is also the king's duty, retorts the hawk, to see that nobody in his kingdom is deprived of his legitimate food; hence the king must

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[48] AS 2.19.12-16: *pañcatriṃśat-pala-lohāṃ dvisaptaty-aṅgulāyāmāṃ samavṛttāṃ kārayet. tasyāḥ pañcapalikaṃ maṇḍalaṃ badhvā samakaraṇaṃ kārayet. tataḥ karṣottaraṃ palaṃ palottaraṃ daśapalaṃ dvādaśa pañcadaśa viṃśatir iti padāni kārayet. tata āśatād daśottaraṃ kārayet. akṣeṣu nāndīpinaddhaṃ kārayet.* Kangle's translation (AS, II: 154-155): "He should cause *samavṛttā* (balance) to be made of metal thirty-five *palas* (in weight) and seventy-two *aṅgulas* in length. Fixing a ball (of metal) five *palas* in weight (at one end), he should cause the level to be secured (for marking zero). From that (point) onwards, he should cause markings to be made for one *karṣa*, increased by a *karṣa* up to one *pala*, then increased by a *pala* up to ten *palas*, then for twelve, fifteen and twenty *palas*. Thereafter, he should cause markings to be increased by ten up to one hundred *palas*. In the 'fives' he should cause it to be covered with *nāndī* (the *svastika* mark)." See also Kangle 1960.

[49] Four *karṣa*s make one *pala*; cf. AS 2.19.4: *catuṣkarṣaṃ palam*; JKM 19a: *kaṃsā cattāri palaṃ.*

[50] AS 2.19.17-18: *dviguṇalohāṃ tulām ataḥ ṣaṇṇavaty-aṅgulāyāmāṃ parimāṇīṃ kārayet. tasyāḥ śatapadād ūrdhvaṃ viṃśatiḥ pañcāśat śatam iti padāni kārayet.*

[51] JKM 20-24 (Appendix); compare this with AS 2.19.12-16 in footnote 48 above.

[52] On the different versions of the Śibi episode and its depiction in art, see Parlier 1991.

give him the dove. Finally, the king offers to give his own flesh, of the same weight as that of the dove. Therefore, a balance is brought to weigh the king's flesh against the dove.

The hawk and the dove, however, are not real birds but gods Indra and Viśvakarma who wish to test the king's perseverance (*kṣānti*) in this manner. When the king reconciles his two mutually conflicting duties — the protection of those who seek his refuge on the one hand and the obligation to see that nobody in the kingdom is deprived of his food on the other — by offering his own flesh to the hawk in lieu of the dove, Indra and Viśvakarma assume their original forms and praise the king.

This scene is depicted very vividly in a sculptural panel from Gandhāra of about the second century AD (Fig. 7). The king is seated on a throne on the left and a servant, kneeling at the king's feet, is cutting flesh from the king's left calf. The queen is holding the king in support. Next to the queen stands a servant with the steelyard; he is suspending the beam with the right hand and supporting the one end of the beam with the left hand. From the other end hangs a basket-like pan which is being filled with the king's flesh; when the flesh is equal to the weight of the dove, the beam will automatically come into a horizontal position.

On the right of the panel are two figures, taller than the rest, and their divinity is indicated by the halos behind the heads. The first is Indra, holding with his left hand the hour-glass-shaped *vajra,* which is his emblem, and next to him Viśvakarma. After testing the king, they have resumed their original form and are commending the king for his perseverance.

Figure 7. King Śibi offering his flesh equal to the weight of the Dove,[53] British Museum (OA 1912.12-21.1)

[53] © Marie-Lan Nguyen / Wikimedia Commons / CC-BY 2.5.

The whole composition is imaginatively conceived. The placement of the figures, their postures and their facial expression convey most vividly the emotional and dramatic aspect of the episode. The king's bent head and his facial features clearly suggest that he is bravely enduring the severe pain of flesh being cut off from the body. The queen's posture of holding the king with her outstretched arms shows her concern for the king's health. Indra and Viśvakarma raise their right hands as gestures of commendation for the king's perseverance and also as gestures of benediction. Even the placement of the birds is significant. The hawk is hovering just above the pan with the king's flesh, as if it is carefully watching that the correct amount of flesh goes into the pan. Unfortunately the upper surface of the figure of the hawk is chipped off, but its outlines are well-preserved. The dove is seated at the foot of the king's throne; its position suggests the security it feels under the king's protection. Above all, the servant holding the steelyard at the centre of the composition shows the centrality of the weighing device in this episode. As Schlingloff rightly remarks, the balance, especially the steelyard, becomes the characteristic iconographical feature in the depiction of the story of the King Śibi in sculpture and mural painting.[54]

Figure 8. King Śibi, Mathura Museum[55]

[54] Schlingloff 1977: 68: "[…] die Waage ist ein ikonographisches Charakteristikum dieser Geschichte; sie findet sich in allen Śibi-Darstellungen, sonst jedoch nirgendswo."

[55] © Photo Dharma from Penang, Malaysia / CC BY 2.0.

The Śibi episode is depicted also on a pillar at Mathura of the same period in two panels. The upper panel shows the king seated on the throne, in a characteristic posture with one leg folded on the throne and the other leg touching the ground. The hawk is perched on a pillar and is demanding his legitimate food.[56] The panel below shows the king cutting flesh by himself from his upper right thigh, while a servant on the left is holding the steelyard (Fig. 8). The pan is filled with much flesh, even so the beam is still tilted; more flesh is needed to bring it into equilibrium.

The episode is depicted thrice in the Buddhist *stūpa* at Amaravati in Andhra Pradesh in the same century. In the first one, kneeling on the ground, the king himself is cutting flesh from his right upper thigh, while a servant is holding the steelyard.[57] The second depiction is not completely preserved; it shows the dove seated on the lap of the king.[58] The third one shows, unusually, a double-pan balance and the king stepping into it with his right leg in a pan.[59] This scene depicts another version of the Śibi episode, according to which the king places the dove in one pan. As he is placing the flesh from his body in the other pan to balance the weight of the dove, the dove begins to grow heavier and heavier. Finally, the king offers his entire body and steps into the pan.

Fig. 9. King Śibi, Nagarjunakonda[60]

In the third century Buddhist monuments at Nagarjunakonda, also in Andhra Pradesh, the scene occurs a few times. In one of these panels (Fig. 9), the king is kneeling on the ground

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[56] Cf. Schlingloff 1977: 65, Fig. 5; Parlier 1991: 151, Pl. II.

[57] Parlier 1991, Pl. III.

[58] Schlingloff 1977, Fig. 4.

[59] Schlingloff 1977, Fig. 6.

[60] © Biswarup Ganguly / CC BY 3.0.

and cutting the flesh from his right upper thigh, exactly in the same manner as at Amaravati, while the servant with the steelyard stands on the right. On the left is a servant, slightly bending and watching the king with concern. Between him and the king is a dwarf paying homage to the king by folding his hands above his head. On the extreme right is Indra, with a halo (?), commending the king by raising his right hand.

Again, in the mural paintings in Ajanta caves, we encounter the story of the *Śibi-jātaka* once with the single-pan balance and once with the double-pan balance (Fig. 10).

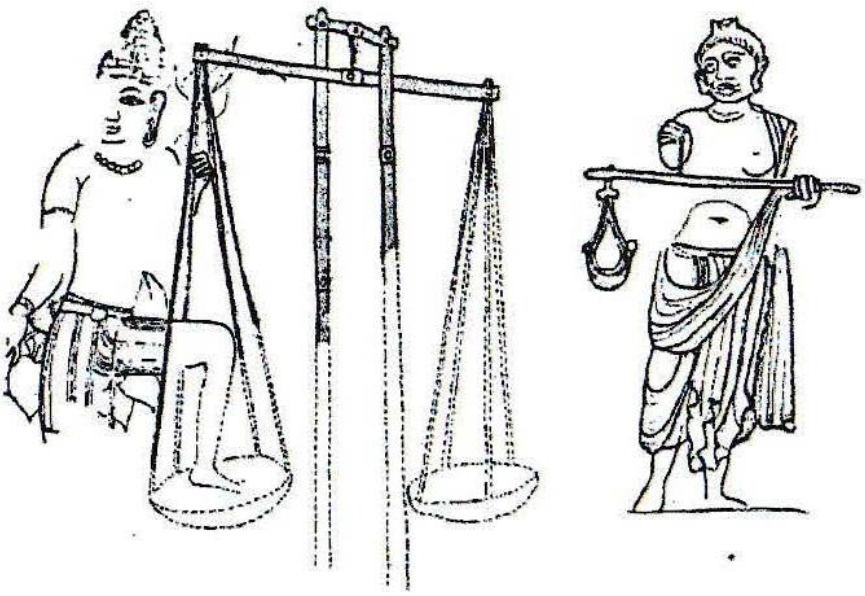

Fig. 10. Two types of balances at Ajanta (from Schlingloff 1977, Fig. 10)

In all these depictions, there is some variation in the style of narration—in some the king himself cuts the flesh from his body, in others a servant does the job— there is also variation in the composition, but there is no variation in the steelyard with which the king's flesh is weighed. The single pan is suspended from one end of the beam, and the loop is closer to that end. There is no counterweight which is prescribed both in the AS and in the JK; in its place the other end of the beam ought to be thicker than the end with the pan. This the sculptors did not clearly delineate in these panels. Be that as it may, the absence of a movable counterweight shows that it is the loop which must be moved along length of the beam until the beam rests in a horizontal position. Then the weight of the object in the pan can be read off from the position of the loop on the scale of the beam. Dieter Schingloff studied the various depictions of the *Śibi-jātaka* meticulously in an article entitled "Der König mit dem Schwert" and concluded that here it is the loop which is movable and that therefore this steelyard is different from the Graeco-Roman steelyards.[61]

[61] Schlingloff 1977: 70: "Die früheste archäologische Beleg einer solchen Waage aus Sirpur stammt aus dem 7. bis 8. Jahrhundert n. Chr. Wie unsere Darstellungen unterscheidet auch diese Waage von den Schnellwaagen der griechisch-römischen Antike dadurch, dass sie kein

2.4 Graduation Marks on the Scale of the Beam

Now we come to the specifications given by the AS and the JK about graduations to be marked in the scale on the beam. Both texts state that the beam should first be suspended with the empty pan at one end and the counterweight at the other end and that the fulcrum should be moved slowly until the beam rests horizontally; then the position of the fulcrum should be marked as the zero-weight mark. This process is called *samakaraṇa* or *samāyakaraṇa.*[62] Thereafter graduation marks should be drawn along the length of the beam up to the other end, presumably at equal intervals.

About the graduation marks, we may begin with the JK, because this text is clearer. JK 22-23 states that in the scale there will be altogether 25 marks to indicate different weights:

> [There will be lines at] the place of equilibrium (*samakaraṇa*), at ½ *karṣa,* thereafter 4 [lines] at each *karṣa,* then [lines] at each *pala* up to 10 [*palas*], at 12, 15 and 20 [*palas*], thereafter 8 [lines] at each 10 *pala*s. Thus, in short, [there will be] 25 lines.

These 25 marks from ½ *karṣa* up to 100 *pala*s are shown in the table below.

The AS (2.19.12-16), on the other hand, states that from the zero point onwards, marks should be placed at each *karṣa* up to 1 *pala*; then at each *pala* up to 10 *pala*s; then at 12, 15, 20 *pala*s; then at each 10 *pala*s up to 100 *pala*s.[63] This is exactly the same as in the JK, with the difference that here the first mark at ½ *karṣa* is omitted. Thus there are 24 marks, as shown in the table below.

Now both the two texts desire that certain marks of graduation be highlighted for easy recognition. The JK states very clearly that "the lines [indicating] 5, 15, 30 and 50 *pala*s should be endowed or decorated with *ṇandī.* The rest will be straight lines (*ujugalehāo*)."[64] Accordingly, in the table above these four marks are shown in bold font. Apparently this *ṇandī*

Laufgewicht besitzt. Das Fehlen eines Laufgewichts bedeutet, dass der Haken, an dem die Waage gehalten wird, nicht starr mit dem Balken verbunden werden darf, sondern längs der Skala so lange verschoben werden muss, bis die waagerechte Stellung des Balkens das genaue Gewicht anzeigt."

[62] AS 2.19.13: *tasyāḥ pañcapalikaṃ maṇḍalaṃ badhvā samakaraṇaṃ kārayet*. JKM 20cd: *paṃcapala-dharaṇagassā ya samāyakaraṇe tulā hoï.* Malayagiri (JKM, p. 9) explains it thus: *tataḥ samāyakaraṇe dharaṇake tulāyāṃ saṃyojite sati yatra pradeśe tulā dhriyamāṇā samā bhavati naikasminn api pakṣe 'grataḥ pṛṣṭhato vā natonnatā vā bhavati tatra pradeśe 'samāyakaraṇe' samatāsaṃgama-parijñānāna-nimitta-rekhā-karaṇe tulā paripūrṇā bhavati.*

[63] Cf. footnote 48 above.

[64] JKM 24; Malayagiri explains that these numbers refer to *pala*s*,* that is to say that there will be *ṇandī* symbols at 5 *pala*s*,* 15 *pala*s*,* 30 *pala*s*,* and 50 *pala*s. The remaining 21 markings will be simple straight lines: cf. JKM, p. 11: *pañca-pala-parimāṇa-sūcikā pañcadaśa-pala-parimāṇa-sūcikā triṃśat-pala-parimāṇa-sūcikā pañcāśat-pala-parimāṇa-sūcikā, etāś catasro rekhāḥ* <u>*phullaḍikā*</u>*-yuktāḥ, śeṣā ekaviṃśatisaṃkhyā ṛjavaḥ.*

which is to be placed at these four graduation marks is a special mark to facilitate the reading on the scale. Its possible nature will be discussed in the next section.

	JK	AS
1	½ *karṣa*	---
2	1 *karṣa*	1 *karṣa*
3	2 *karṣa*s	2 *karṣa*s
4	3 *karṣa*s	3 *karṣa*s
5	4 *karṣa*s (= 1 *pala*)	4 *karṣa*s (= 1 *pala*)
6	2 *pala*s	**2 *pala*s**
7	3 *pala*s	3 *pala*s
8	4 *pala*s	4 *pala*s
9	**5 *pala*s**	5 *pala*s
10	6 *pala*s	6 *pala*s
11	7 *pala*s	**7 *pala*s**
12	8 *pala*s	8 *pala*s
13	9 *pala*s	9 *pala*s
14	10 *pala*s	10 *pala*s
15	12 *pala*s	12 *pala*s
16	**15 *pala*s**	**15 *pala*s**
17	20 *pala*s	20 *pala*s
18	**30 *pala*s**	30 *pala*s
19	40 *pala*s	40 *pala*s
20	**50 *pala*s**	50 *pala*s
21	60 *pala*s	**60 *pala*s**
22	70 *pala*s	70 *pala*s
23	80 *pala*s	80 *pala*s
24	90 *pala*s	90 *pala*s
25	100 *pala*s	100 *pala*s

The corresponding statement in the AS (2.19.16: *akṣeṣu nāndīpinaddhaṃ kārayet*) is difficult to interpret, especially the term *akṣa.* The translator Kangle consulted the commentaries for the significance of the two words *akṣa* and *nāndī*. An unspecified commentary states that *akṣa* is a multiple of five: 5, 10, 15, etc.[65] Apparently, the commentary

[65] Kangle (AS II: 135).

invests the word *akṣa* with the numerical value of 5 for the following reason. One of the several meanings of the word *akṣa* is *indriya,* 'sense organ'.[66] Since there are 5 organs of sense according to Indian tradition, the word *indriya* or its synonym carries the numerical value of 5 in the system of numerical notation commonly known as *bhūta-saṃkhyā.* [67] Kangle accepts this interpretation and translates the sentences as "In the 'fives' he should cause it to be covered with *nāndī*". If we take that 'five' refers to every fifth mark in the scale, then these will be 2, 7, 15 and 60 *pala*s. This set is quite different from that of the JK, except for 15 *pala*s.[68]

Since all other specifications in the JK and AS about the steelyard match perfectly, including the expressions *nāndīpinaddha* in AS and *ṇandīpiṇddha* in the JK, the specification about the placement of these special marks should also match. This does not happen if we treat *akṣa* as the *bhūta-saṃkhyā* notation indicating 'five'. Therefore, *akṣa* cannot be interpreted in this manner. Moreover, the AS abounds in numerical expressions throughout, but in none of these places the *bhūta-saṃkhyā* system is employed; it would be highly unusual that it is employed in this one single case.

But how else to interpret *akṣa* to yield a result that matches with JK? There is another intriguing feature. In all the steelyard scales illustrated by Roth which will be discussed in the next section, whether they are from Malabar, Burma, Malay Peninsula or China, the special marks are placed at uniform intervals. But this is not the case with the JK. We are unable to resolve these two issues.

2.5 The Special Mark of Nāndī or Ṇandī

As mentioned above, this *nāndī* or *ṇandī* appears to be a special mark, placed at certain intervals on the scale, for easy recognition of the graduations. Kangle states that *nāndī* is explained as *svastika* by the Sanskrit commentary *Pratipadapañcikā* of Bhaṭṭasvāmin, as "a mark of a crow's foot" by a fragmentary Sanskrit commentary (cj) and as a "mark of the wedge" by the anonymous Malayalam commentary (cb). Kangle accepts the first meaning *svastika*; this meaning would suit the JK in so far as the *svastika* is one of the eight auspicious symbols of the Jains (*aṣṭa-maṅgala*).

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[66] *Amarakoṣa,* III, *Nānārthavarga* 221: *athākṣam indriye.* In their respective Sanskrit-English dictionaries, Monier-Williams and V. S. Apte list "the beam of the balance" as one of the meanings of the term *akṣa*, apparently on the basis of its use the AS. However, in the AS, *akṣa* does not denote the beam itself, but certain special marks on the scale of the beam.

[67] On this system of notation, cf. Sarma 2009b, where it is shown that this system is first employed a few times in the *Vedāṅgajyotiṣa* and about a hundred times in the *Chandaḥsūtra* of Piṅgala.

[68] Or if we take 'five' as referring to the weights 5, 10, 15 … etc., then 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 *pala*s should endowed with *nāndī;* this means practically every mark after 15 *pala*s!

Another possibility is that *nāndī* stands for *nandyāvarta,* another symbol among the eight auspicious symbols, which is a kind double *svastika.*[69] However, it would occupy too much space on the narrow surface of the beam. *Nandyāvarta* also refers to the small white flower of the shrub *Tabernaemontana coronaria*[70] (Fig. 11).

Fig. 11. Nandyāvarta Flower

In a similar context, Bhoja employs the terms *puṣpa* and *puṣpaka.* In the *Samarāṅgaṇa-sūtradhāra,* he provides another rare description of a measuring tool, namely, a linear scale called *hasta*. This scale, says he, should be 24 *aṅgula*s long. Half of it is divided into 12 *aṅgula*s and the other half into 4 *parvan*s of 3 *aṅgula*s each. The three lines dividing the *parvan*s should be decorated with *puṣpaka* and in the remaining *aṅgula* lines *puṣpas* should be placed.[71] Bhoja does not enlighten us as to how he distinguishes *puṣpaka* from *puṣpa*. The two must be some kind of stylized flowers or floral designs, perhaps not much different from the marks on the Malabar steelyards, which are described by Edgar Thurston thus:

> The graduation marks, which are not numbered, are small brass pins let into the upper surface of the yard along the middle line, and flush with it. The principle graduations are each made of five pins disposed in the form of a small cross, and single pins serve for the intermediate graduations.[72]

[69] Cf. von Hinüber 1972.

[70] In Hindi it is called *chāndnī* (lit. moonlight). The South Indian names are closer to Sanskrit: Tamil *nandiar vaṭṭai,* Kannaḍa *nandibaṭṭalu,* Telugu *nandi-vardhanamu,* Malayalam *nandiarvattom.*

[71] Bhoja, *Samarāṅgaṇa-sūtradhāra* 9.7:
tasyāgre parvarekhāḥ syus tisraḥ puṣpaka-bhūṣitāḥ |
śeṣāsv aṅgularekhāsu puṣpāṇi vidadhīta na (!) ||

[72] Thurston 1907: 561.

In a comprehensive and well-illustrated study entitled “Oriental Steelyards and Bismars,” H. Ling Roth describes several steelyards from Malabar, Burma, Malay Peninsula and China, which are preserved in the Bankfield Museum of Halifax, UK. He states that not only in Malabar, but also in other parts of South-East Asia, graduations on the scales of the steelyards are marked with diverse patterns of dots, instead of numerical symbols.[73] Thus marking the divisions on the scales with patterned dots seems to be a practice widely spread in Asia, as can be seen in Fig. 12.

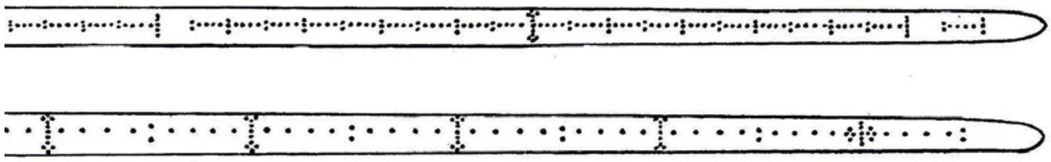

Fig. 12. Graduation Marks on Chinese Steelyards (from Roth 1912, pl. xxiv)

This practice is still followed in Japan, e.g. in a modern Japanese linear scale of 30 cm made of bamboo, where every fifth cm is marked with a thick dot and every tenth with a pattern of four dots (Fig. 13).

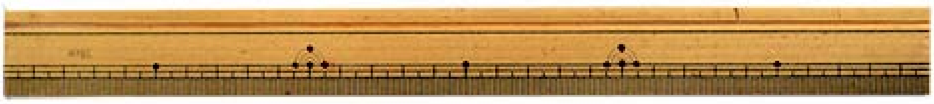

Fig 13. Japanese Linear Scale (courtesy Prof. Takao Hayashi, Kyoto)

Therefore, it is quite likely that the *nāndī* of the AS and the *ṇandī* of the JK were some kind of flower-like symbols made of dots.

2.6 Steelyard Scale Marks as a Poetic Motif

The fact that the divisions on the steelyard scale are generally marked with symbols and not with letters (*akṣara*) is attested also in a poetic motif, which conceives the steelyard (*nārāca*) as ‘unlettered’ (*nirakṣara*).[74] In the *Gāthāsaptaśatī,* an illiterate upstart who is receiving honour, or a courtesan without real talents who is receiving fame, is censured in the guise of the goldsmith’s balance which is without letters or unlettered (*ṇirakkhara*):

ciraḍiṃ pi aāṇanto loā loehiṃ goravabbhahiā |

[73] Roth 1912: 201: “The beams of nearly all the smaller steelyards are of bone, ivory, cane, or bambu; they are thicker at the fulcrum end, tapering down to the other end, and are marked with one or more lines of dots for indicating the weight, but not numbered.”

[74] Dikshit 1961.

soṇāratule vva ṇirakkharā vi khandhehiṃ ubbhaṃti ||[75]

Persons who do not know even the alphabet (*ciraḍi*) are plied with honour by people, just as the goldsmith's balance, though unlettered, is carried on one's shoulders.[76]

In his Prakrit drama *Karpūramañjarī,* Rājaśekhara elaborates on the theme by building up a dichotomy between the 'unlettered' steelyard (*nārāca*) on the one hand and 'lettered' balance (*tulā*) on the other. In the opening scene of the drama, the king and his court engage in reciting verses in praise of spring. Here the king's jester Vidūṣaka and the queen's maid Vicakṣanā compete with each other in displaying their poetic talents and in running down the other's versification.[77] After listening to the jester's clumsy composition, Vicakṣaṇā teases him, saying that even though he is unlettered, he receives all honour, just as the steelyard (*nārāca*) without letters is employed in weighing such precious things as gems; whereas Vicakṣaṇā, though well-endowed with literary talent, is not assigned finer tasks, in the same manner as the common balance (*tulā*), though endowed with letters, is not employed in weighing gold:

kā tumhehi samaṃ amhāhaṃ paḍisiddhī. jado tuvaṃ nārāo viva ṇirakkharo vi raäṇatulāe ṇiuṃjīyasi. ahaṃ puṇa tula vva laddhakkharā vi ṇa suvaṇṇatolaṇe viṇiuṃjīāmi.[78]

Lanman translates the passage thus: "for you, though unlettered as the iron beam of a goldsmith's balance, are employed [in a, *that is*] as part of a [still finer] balance for weighing jewels; while I, though lettered like a [common] balance, am not employed in weighing gold."[79]

Here *nārāca* is employed in the sense of a small balance used for weighing gold and gems and *tulā* in the sense of a large balance. It is said that the *tulā* is endowed with letters (*labdha-akṣarā*) but the *nārāca* is not. Lanman attempts to explain this distinction in the following manner: "Presumably, the beam of the common balance, for bulky things like cotton,

[75] *Gāthāsaptaśatī* 2.91.

[76] The commentators who did not know about the convention of marking the divisions on the steelyard scales with symbols and not letters, had difficulty in explaining *ṇirakkharā* in the *Gāthāsaptaśatī.* Mathurānātha tries to explain the term by saying that the goldsmith's balance cannot weigh anything heavier than one *akṣa*, which is a unit of weight equal to 16 *māṣaka*s (*suvarṇakāra-tulā akṣato 'dhikam atolayantyaḥ* [*nirakṣaṃ rāntīti nirakṣarāḥ*] *api gauravābhyadhikāḥ dattādhikagauravāḥ skandhair nīyante sāvadhānaṃ nīyante. ṣoḍaśamāṣakair akṣa ity amaraḥ*).

[77] In an illustrated manuscript of the *Karpūramamañjarī,* dated 1478 AD, there is a fine miniature painting depicting the Vidūṣaka and Vicakṣaṇā competing in the recital of poems on the spring; cf. Sarma 1993: 47, Fig. 5.

[78] Dikshit 1961, treats it as verse and prints it in two lines. But Lanman and also the commentator Vāsudeva treat it correctly as prose.

[79] Lanman 1901: 232.

had its divisions marked by letters (*akṣaras*); while the beam of the balance for weighing gold or finer objects was not lettered."[80]

In the light of the previous discussion, we know, however, that the divisions on the scales on the steelyards are marked with symbols and not letters. Therefore, the steelyard is 'unlettered' (*nirakṣara*). But how can the larger balance, i.e. the double-pan balance, be 'endowed with letters'? Lanman thinks that the beams of larger balances are marked with letters. What is more likely is that the weights (*pratimāna* or *pratīmāna*) used in the double-pan balance are marked with letters to indicate their weight or marked with the royal seal for authenticity.

The AS declares that it is the prerogative of the state to produce the balances and weights and that people should buy these from the superintendent of standardization; otherwise they would be fined to pay 15 *paṇas*.[81] It goes on to state that the superintendent should stamp the weights and measures for authenticity.[82] The *Manusmṛti* enjoins that all the balances (*tulā*), measures (*māna*) and weights (*pratīmāna*) must be examined every six months and duly marked (*sulakṣita*) for authenticity.[83] Commenting on this verse, Medhātithi explains that *sulakṣita* means that these should be marked with royal symbols (*rājacihna*).[84] The symbols could be in the form of letters. Moreover, the weights would also carry some letters indicating the quantum of the weight.[85] Thus the double-pan balances are 'lettered.'

Although both the AS and JK conceive of the steelyard as a rather large balance with a beam of 72 *aṅgula*s, it is possible that the goldsmiths too made use of smaller versions of steelyards which they carried on their shoulders when visiting the customers' houses.[86] It may be noted that the AS and JK do not have any special name for the steelyard, but in later times it came to be called *nārāca* or *nārācī* from which the modern term *nārji* is derived.[87]

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[80] Lanman 1901: 232, n. 3.

[81] AS 2.14.15-16: *tulā-pratimāna-bhāṇḍaṃ pautava-hastāt kṛṇīyuḥ. anyathā dvādaśapaṇo daṇḍaḥ.*

[82] AS 2.19.40: *caturmāsikaṃ prātivedhanikaṃ kārayet.* Kangle (AS II, p. 137): "He should cause a stamping (of weights and measures) to be made every four months." Note. "*Prātivedhanikam,* i.e. stamping as well as inspection regarding stamping."

[83] *Manusmṛti* 8.403:

tulāmānaṃ pratīmānaṃ sarvaṃ ca syāt sulakṣitam
ṣaṭsu ṣaṭsu ca māseṣu punar eva parīkṣayet.

[84] Medhātithi: *tulā prasiddhā. mānaṃ prastho droṇa ity ādi. pratīmānaṃ suvarṇādīnāṃ paricchedārthaṃ yat kriyate. sarvatobhāge tat sulakṣitaṃ rājacihnair aṅkitaṃ kāryaṃ. svayaṃ pratyakṣeṇa paricchidya svamudrayā. parīkṣayet ṣaṭsu ṣaṭsu māsesu punaḥ parīkṣāṃ kārayed āptair adhikāribhir yathā na vicālayanti kecit.*

[85] There are some extant specimens of weights with engraved inscriptions of symbols. Srinivasan 1979: 95-96 mentions two iron weights stamped with the date and the weight on one side and the royal emblem on the other.

[86] But the goldsmith's balances are not always steelyards. The *Mānasollāsa* (2.4.457-468, p. 70) of the Cālukyan monarch Someśvara contains a detailed description of the goldsmith's balance which is a double-pan balance, where it is merely called *tulā*.

[87] *Amarakoṣa* (348. 32): *nārācī syād eṣaṇikā;* on this the commentator Bhānuji Dīkṣita remarks that these two are the names of the goldsmith's balance (*dve suvarṇatulāyāḥ*).

2.7 Symbolic Power of the Double-Pan Balance vis-à-vis the Steelyard

Leaving aside the practical advantages of the steelyard vis-à-vis the double-pan balance, we may digress for a moment and discuss their symbolic power in the depiction of the Śibi episode. Here the balance with two pans would have had a more dramatic effect than the balance with a single pan. When the dove is placed in one pan and the king's flesh in the other, all the onlookers can see at one glance that the hawk is getting the flesh of precisely same weight as that of the dove — neither an ounce more nor less, as Portia would have said in the *Merchant of Venice*.

With a steelyard, on the other hand, the process involves several steps. First the dove is placed in the pan and its weight is noted by moving the fulcrum to the correct mark. Then holding the fulcrum firmly at that mark, the dove is removed, and the king's flesh is added into the pan until the beam becomes horizontal. Here giving the equal amount of flesh by the king will not appear visually as striking as with a double pan balance to the onlookers.

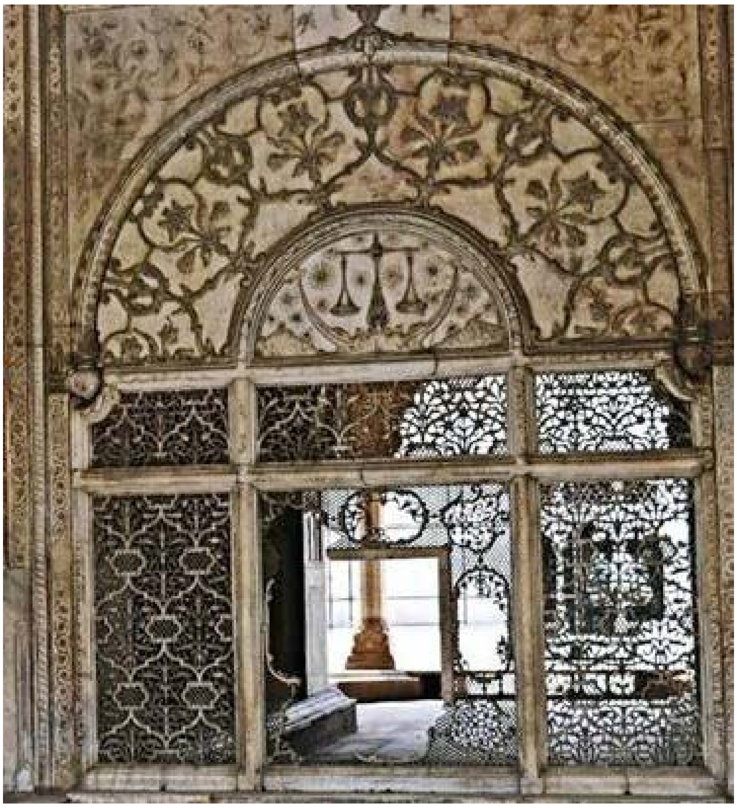

Fig. 14. *Mīzān-i ᶜAdl* (Balance of Justice) at Red Fort, New Delhi (photo by Debasish Das, Gurgaon)

That the notion of justice is visually represented more effectively by the double pan balance is evident also from the iconography of Justitia or the Lady of Justice, holding a balance with two pans, or by the double-pan balance, named appropriately in Persian *Mīzān-i ᶜAdl* (balance of justice), painted above a delicately pierced marble screen in the Red Fort at Delhi, as the royal insignia of the Mughal emperor Shah Jahan (Fig. 14).[88]

Why did then the sculptor of Gandhāra employ a steelyard in the scene depicting the Śibi episode and not the double-pan balance with the dove in one pan and the king's flesh in the other pan?[89] Did he know of only a single-pan balance? Or was it the case that just as the iconography of the Gandhāra sculpture was influenced by the Graeco-Roman style, the choice of the steelyard was also influenced by the Graeco-Roman steelyards? In that case, the steelyard with movable counterweight should have been depicted. And why was the same practice followed at Mathura, and at the distant Amaravati and Nagarjunkonda, to such an extent that the steelyard became the mark of identification for the *Śibi-jātaka*? It has been mentioned above that the double-pan balance is depicted in two cases where the king himself steps into the balance. Does it mean that the steelyard was intended to be employed to weigh smaller objects like the dove and the double-pan balance to weigh larger objects like the king?

2.8 Extant Specimens of the Steelyard in India

As mentioned above, the AS and the JK mention that a counterweight is attached to one end of the beam of the steelyard, but these counterweights are not depicted in the Buddhist depictions. However, two specimens with counterweights, belonging to 7th-8th centuries, were found by Moreshwar G. Dikshit in archaeological excavations. He describes the first one as follows:

> The specimen reproduced in this paper (Pl. I) was obtained at Ārang, a well-known place of archaeological interest, situated on the banks of the Mahānadī in Madhya Pradesh. … Its beam consists of a horizontal bar of iron, about 47 centimetres in length, with the knob-end being about 3 ½ cms. in diameter. The weight of this iron beam is about 120 tolas, i.e. 1 ½ seers. There are 31 graduation marks which start at a distance of 30 cms. from the pan-end, a little over 7 centimetres away from its centre. The marks cover only a portion of the rod and are placed roughly at an intervening space of ¾ of a centimetre in between each mark. These are graduated to weigh any object from about 2 tolas

[88] In the late eighteenth century, when the British India Company was permitted by the Mughal Crown to issue their own coinage, the Company incorporated on some of their coins the same motif, viz. double pan balance with *ʿadl* written between the two pans.

[89] In the ninth century temple at Borobodur, a double-pan balance is used in the depiction of the Śibi episode; cf. Phuoc 2010:199, Fig. 6.31. In China also, the depictions of the Śibi episode have double-pan balances. Cf. Needham 1962: 26: "The equal-armed balance is frequently depicted in the frescos of the cave-temples at Tunhuang;" footnote h: "Generally it hangs from a bar supported on two posts forming a stand like those used for bells and chime-stones. A bird is often perching on the bar; this is the dove [sic! it should read 'hawk'] waiting for the flesh donated by Śivi [sic! Śibi], one of the previous incarnations of the Buddha, and the flesh is being weighed. I have noted this in caves nos. 138 (late Thang), 98 (Wu Tai, *c.* +950), and 61 and 146 (early Sung, before +1000)."

up to 4 seers. Their accuracy has been tested by putting standard weights in the pan […].[90]

About the second steelyard, Dikshit reports thus:

> In 1956, while excavating in the township site of Sirpur (ancient Śrī-pura, the capital of the Pāṇḍava kings of Dakṣina Kośala) Dist: Raipur in Madhya Pradesh, I came across a long beam of iron having a solid knob at one of its ends and which was described to me by my workers as a "Naraji."[91]

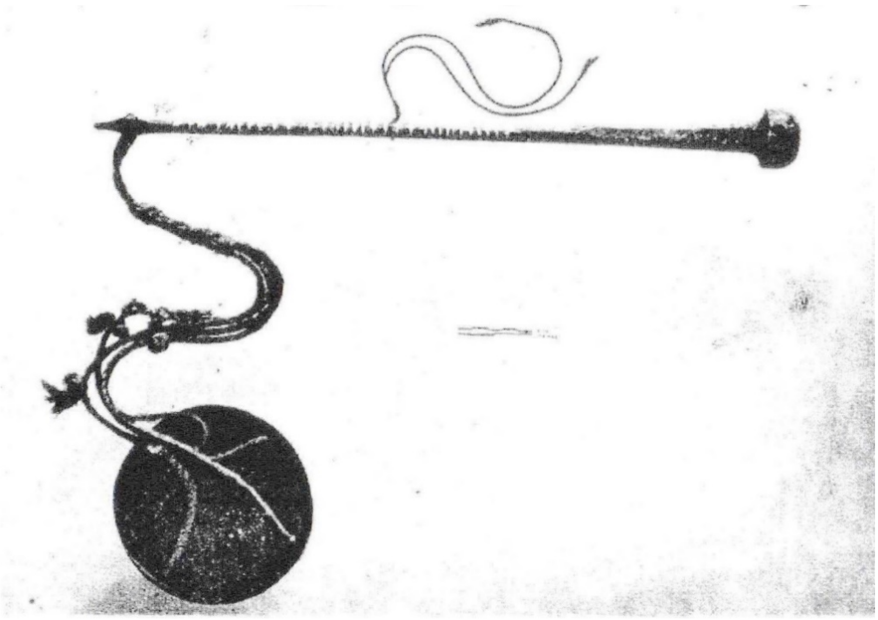

Fig. 15. Steelyard excavated at Ārang (Dikshit 1957, pl. I)

Here the graduation marks are incised into the thickness of the beam

Dikshit writes that itinerant copper-smiths, who go from village to village to buy old vessels and other scrap, carry such steelyards. He also adds that "Naraji as a balance is quite well-known among the aboriginal tribes of Bastar in Chattisgarh and in Orissa, but further enquiries have revealed that it is used in East Bengal, Birbhum and Dhalbhum, and in the Midnapur districts also."[92]

While Dikshit's report concerns the state of affairs at the middle of the twentieth century in central and eastern India, the ethnologist Edgar Thomson writes about the steelyards used in

[90] Dikshit 1957: 6. The excavated specimen is shown in Plate I, and the Plate II shows "A kasera (Smith) weighing with Naraji."

[91] Dikshit 1961: 189f.

[92] Dikshit 1961: 190; see also Chaudhuri 1916, who reports about the use of steelyards in Orissa, where the scales are marked by "ring-marks."

Tamil Nadu and Kerala at the beginning of the twentieth century. From him we learn that steelyard was known in Tamil as *tūkku-kol,* lit. weighing rod. The steelyard or *tūkkukol* used in Madras by shopkeepers and hawkers had a tapering beam of 19 inches in length. "The fulcrum is simply a loop of string, which can be slid along the bar. … The graduations are rough notches cut in the bar and not numbered, but as there are only seven of them including the zero mark, they are probably well known to both purchaser and seller."[93] A specimen of the *tūkkukol* from Madras is preserved in the Bankfield Museum (Fig. 16). It resembles quite closely the steelyards depicted in the Buddhist sculpture.

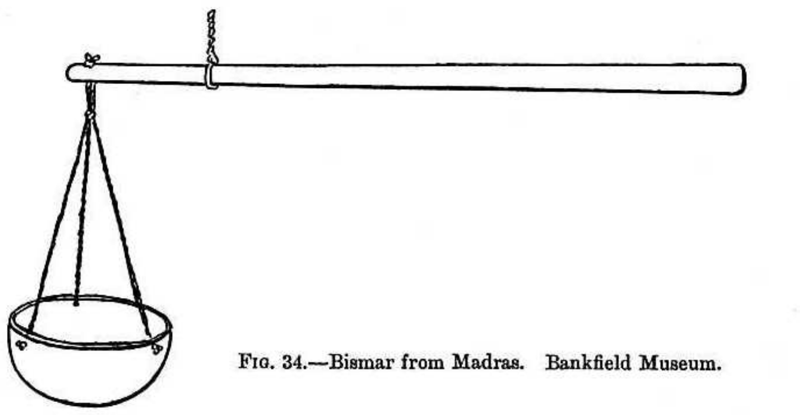

Fig. 16. Steelyard from Madras, Bankfield Museum (from Roth 1912: 223)

The steelyard from Malabar has a much longer beam of about 4 feet. Thurston states that "[i]t is finished off at the heavy end with a loaded brass finial simply ornamented with concentric rings, and the hook end terminates in a piece of ornamental brass work, resembling the crook of a bishop's pastoral staff. The sliding fulcrum is simply a loop of string."[94] The Pitt Rivers Museum of Ethnography at Oxford owns a splendid specimen of a steelyard from Malabar which matches Thurston's description (Fig. 17). Like the beam of the steelyard named *samavṛttā* in the AS, the beam of this one is also graduated to weigh 1 *pala* to 100 *pala*s.[95] There is also a similar specimen at the Bankfield Museum.[96]

[93] Thurston 1907: 560.

[94] Thurston 1907: 561. Thurston adds the following: "In a more simple form of weighing beam, used by the native physicians and druggists in Malabar, the bar is divided into kazhinchi (approximately tolas) and fractions thereof, and the pan is made of coconut shell."

[95] The museum label reads: "Acc. No. 1920.55.26 Weighing beam (of the bismar type). The sliding fulcrum will be a mere coir loop. The brass pins along the upper surface indicate the weight in *palams* (each of about 14 *tolas*) graduated from 1 to 100 *palams* (c. 35 lbs). The 100 *palam* mark is on the brass and has a brass pin projecting. Malabar, S. India. Pres[ented] by F. Fawcett, 1920. Length 1171 mm, crown 144 mm, handle 182 mm."

[96] Roth 1912: 221, Fig. 32.

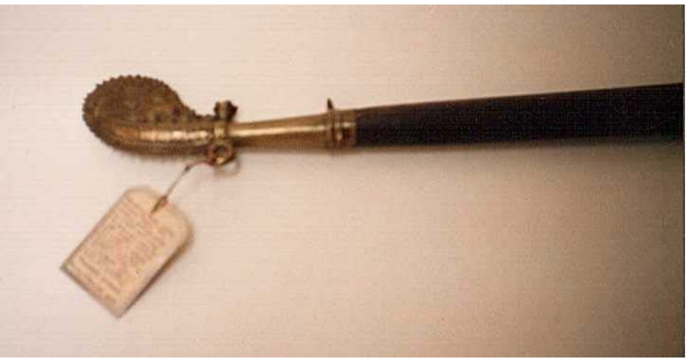

Fig. 17. The Two ornate ends of the steelyard from Malabar, Pitt Rivers Museum, Oxford
(photo by S. R. Sarma)

Dikshit published a photo of a kansera (smith) weighing with naraji (steelyard) in the middle of the twentieth century in central India.[97] It is also being used at the present time by vegetable sellers of the Chakma tribe in Arunachal Pradesh, in north-eastern India (Fig. 18). About the earliest use of the steelyard in India, while the textual evidence is provided by the AS and the JK, there is also some numismatic evidence. The steelyard is depicted on some coins of the second century B.C. found at Ayodhya and on the coins of the first century B.C. found at Taxila.[98] These coins may have been issued by some merchant guilds.

Thus it seems certain that the steelyard has been in use in India throughout the centuries, from at least the second century B.C. up to the present times, in almost all parts of India. It may be noted that all these specimens in sculpture, painting, or actual specimens, are of the type where the weight of an object is determined by moving the suspension rope or fulcrum along the beam. This supports our view that the specimens described briefly in the AS and JK also must be of the same type. There is, of course, variation in the beam; either it is tapering so that one side is heavier than the other, or it is shaped like a club by the addition of a counterweight at one end.

[97] Dikshit 1957, Pl. II.

[98] Sharma & Bharadwaj 1989: 332 and the illustrations (which are too dark to show any details).

Fig. 18. A vegetable seller with a steelyard in Arunachal Pradesh in 2017
(photo courtesy Dr Senthil Babu, Pondicherry)

2.9 Steelyard in Nepal

Another place where a balance is used symbolically is in the depiction the Zodiac sign *Tulā* or Libra. The pictorial representations of Libra in European, Islamic and Indian paintings and astronomical instruments invariably show the double-pan balance. In 1989, M. L. B. Blom submitted to the University of Utrecht an interesting dissertation on *Painters' Model Books in Nepal.*[99] These manuscript copies are meant to teach aspiring painters how to depict various themes. Here all the illustrations of the zodiac sign *tulā* show the steelyard. In the two illustrations (Figs. 19-20) reproduced below, the beam of the steelyard is shaped like a club. It is likely that the steelyard was widely prevalent in the milieu of the painters who prepared these model books.

[99] Blom 1989: 63-65; Figs. 78-80.

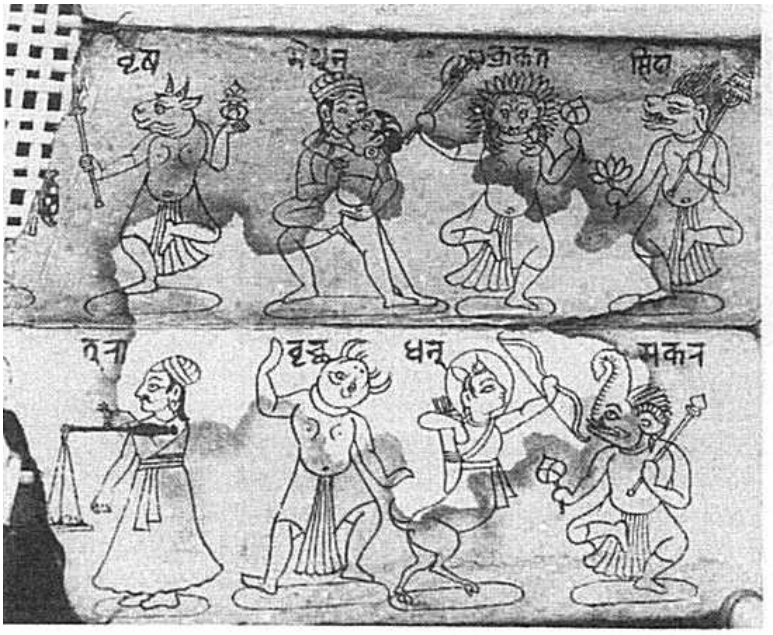

Fig. 19. Zodiac Signs in a Model Book from Nepal (Blom 1989: 65, Fig. 80). Upper register: Taurus (*vṛṣa*), Gemini (*mithuna*), Cancer (*krakata*!) and Leo (*siṃgha*); lower register: Libra (*tulā*), Scorpio (*vṛśca*!), Sagittarius (*dhanu*) and Capricorn (*makara*)

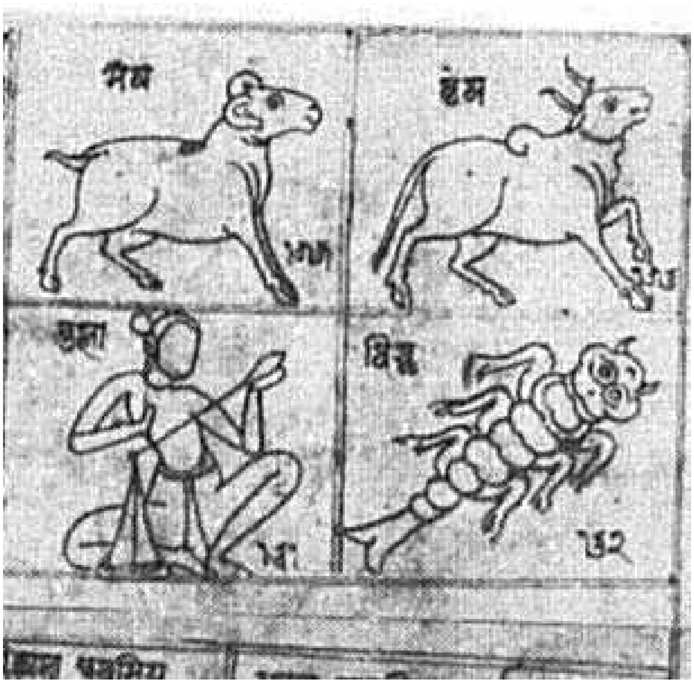

Fig. 20. Zodiac Signs in a Model Book from Nepal (Blom 1989: 64, fig. 78); above: Aries (*meṣa*) and Taurus (*vṛṣa*); below Libra (*tulā*) and Scorpio (*vriśca*!)

2.10 Steelyard with the moveable Counterweight in India

While the variety of the steelyard with sliding fulcrum is known in India since at least the time of the *Arthaśāstra*, the other variety with the sliding counterweight in attested from the fourteenth century.[100] It was probably was introduced from the Islamic world which inherited it from the Graeco-Roman Antiquity. [101] In a valuable article, Mohammed Abattouy discusses the Arabic science of weights (*ᶜilm al-athqal*), the various Arabic treatises on this subject and the double-pan balance and the steelyard (*qarasṭūn, qaffān,* or *qabbān*) used in Arab countries.[102] About the steelyard, he states as follows:

> The *qarasṭūn* or steelyard with a sliding weight was largely used since Antiquity. It is mentioned in Greek sources by its ancient name *charistion,* and was employed extensively in Roman times. Composed of a lever or beam (*ᶜamūd*) suspended by a handle that divides it into unequal arms, the centre of gravity of this instrument is located under the fulcrum. In general the shorter arm bears a basin or scale-pan in which the object to be weighed is set, or suspended from a hook. The cursor weight, *rummāna* in Arabic, moves along the longer arm in order to achieve equilibrium. … The advantage of the steelyard is that it provides an acceptable precision in weighing and allows heavy loads to be supported by small counterweights. In addition, it can be carried around easily.[103]

He enumerates several medieval specimens preserved in different museums and states that it is still employed in some places, especially in Egypt.

In India, this variety of steelyard is was known in by the Persian terms *qappān* or *qabbān.*[104] It was mentioned for the first time in the dictionary entitled *Farhang-i Qawwās* of 1342-43. The dictionary *Miftā'ul Fuẓalā*, which was compiled in Malwa in 1469, describes and illustrates it (Fig. 21).

The Chinese navigator Ma Huan saw its use at Calicut at about 1433:

> The fulcrum of [their] steelyard is fixed at the end of the beam, and the weight is moved along to the middle of the beam, when [the beam] is raised to the level that is the zero position; when you weigh a thing, you move the weight forward;

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[100] Cf. Habib 2012: 72.

[101] Cf. Wulff 1966: 64-65: "Balance with Unequal Lever and Moving Weight (Steelyard): The principle underlying this type of balance was already known to Aristotle (384-322 B.C.), who evolved the theory of it in his 'Mechanical Problems'. Vitruvius mentions it as useful apparatus in Chapter 1 of his *De Architectura,* which was written about 16 B.C. Many Roman steelyards have been unearthed in most parts of Imperium that are almost identical with the types now in use in Persia and it is safe to assume that they have been the same since Roman times."

[102] Abattouy 2008.

[103] Abattouy 2008: 84, 86.

[104] For this and the following references to the use of this variety of steelyard in India, I am highly obliged to Prof. Irfan Habib (Aligarh Muslim University).

and, according as the thing is light or heavy, so you move the weight forward and backward.[105]

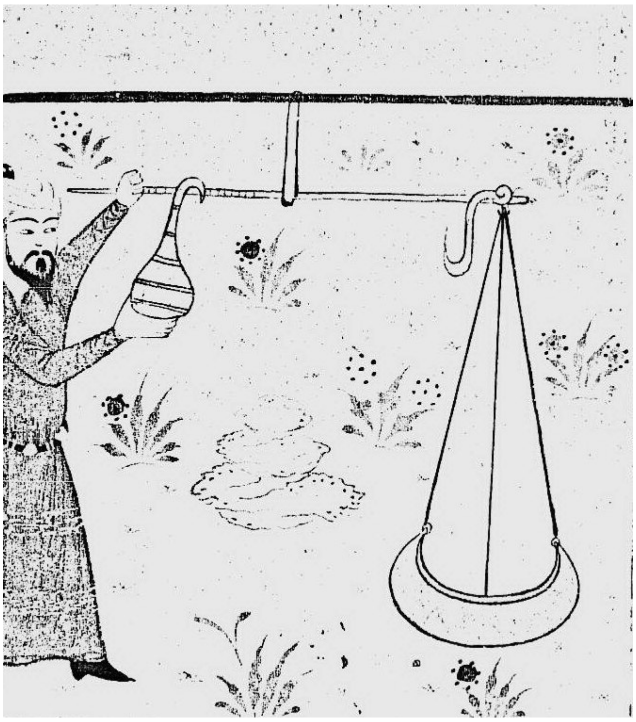

Fig. 21. Steelyard with a movable counterweight as illustrated in the *Miftā'ul Fuẓalā*
(courtesy Prof. Irfan Habib)

It is also mentioned in the dictionary *Bahār-i 'Ajam* by Tek Chand 'Bahār', which was completed in Delhi 1740. Muḥammad 'Alī Khān in his history of Gujarat, the *Mir'āt-i Aḥmadī* (1761), states that it was used in the ports of Gujarat. Finally, the French jeweller Jean-Baptiste Tavernier, who travelled in India during 1640-67, describes a steelyard used in Tippera (Tripura) thus:

> They (the Tippera merchants) each had scales made like steelyards. The arms were not of iron, but of a kind of wood as hard as bresil [Brazil wood], and the ring which held the weights, when put in the arm to mark the livres was a strong loop of silk.[106]

But no specimens seem to be extant today.

[105] Ma Huan 1970: 142.

[106] Tavernier 2001 II, p. 214.

APPENDIX

Vallabhīyācāryīyaṃ **Śrījyotiṣkaraṇḍakaṃ** Prakīrṇakaṃ, Śrīman-Malayagiry-ācārya-kṛta-vṛtti-yuktaṃ, Ratlam 1928, *gāthā*s 1-31, pp. 1-12.

suṇa tāva sūrapaṇṇattīvaṇṇaṇaṃ vitthareṇa jaṃ niuṇaṃ ǀ
thoguccaeṇa tatto vocchaṃ ullogamettāgaṃ ǀǀ1ǀǀ

1. Listen now to [the division of time, *kāla-vibhāga*] which has been described in detail and lucidly in the *Sūryaprajñapti.* Extracting small portions (*thoguccaeṇa* = *stokasya uddharaṇena*) from that [source], I shall tell [so that you can have] a small glimpse (*ullogamettāgaṃ* = *ālokamātraṃ*). [107]

Topics

kālapamāṇaṃ 1 māṇaṃ 2 nipphatti ahigamāsagassavi 3 ya ǀ
vocchāmi omarattaṃ 4 pavvatihīṇo samattiṃ ca 5 ǀǀ2ǀǀ
nakkhattaparīmāṇaṃ 6 parimāṇaṃ vāvi caṃdasūrāṇaṃ 7 ǀ
nakkhattacaṃdasūrāṇa gaïṃ 8 nakkhattajogaṃ ca 9 ǀǀ3ǀǀ
*maṃḍalavibhāgam 10 ayaṇaṃ 11 āuṭṭī 12 maṃḍale muhuttagaī 13*ǀ
uü 14 visuva 15 vaīvāe 16 tāvaṃ 17 vuḍḍhiṃ ca divasāṇaṃ 18 ǀǀ4ǀǀ
avamāsapuṇṇamāsī 19 paṇaṭṭhapavvaṃ 20 ca porisiṃ 21 vāvi ǀ
vavahāranayamayeṇaṃ taṃ puṇa suṇa me aṇannamaṇo ǀǀ5ǀǀ

2-5. [The topics I shall discuss are as follows]:[108]

(1) measure of time (*kālapamāṇa* = *kālasya samayādi-ghaṭikā-paryantasya pramāṇa*) (*vv.* 1-9),
(2) length of the years (*māṇa* = *pramāṇaṃ saṃvatsarāṇāṃ*) (*vv.* 10-90),
(3) constitution of the intercalary months (*nipphatti ahigamāsagassa*) (91-93),
(4) conclusion of the *parvatithis* (94-106),
(5) omitted lunar days (*omaratta* = *avamarātra*) (107-115),[109]

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[107] In the translation English equivalents are generally used for all technical terms and the Prakrit term and its Sanskrit equivalent as given by Malayagiri are shown in parentheses in this order. Where there is no appropriate English equivalent, the Sanskrit term is used in the translation and the related Prakrit term is shown in parentheses.

[108] Malayagiri (p. 3) states these are twenty-one topics: *iha sūryaprajñapti-satkā adhikārā ekaviṃśatiḥ upaprābhṛta-vinibaddhāḥ*; but the JKP treats nos. 4 and 19 as two topics each and thus achieves twenty-three topics.

[109] Malayagiri (p. 3) notes that the sequence of these items is interchanged for the sake of metre: *tadantaraṃ cālpavaktavyatvād gāthoktaṃ kramam ullaṅghya caturthe parvatithisamāptiṃ vakṣye, pañcame 'vamarātraṃ, gāthāyām anyathānirdeśaḥ chandovaśāt*.

(6) measure of the lunar mansions (*nakkatta-parīmāṇa*) (116-142)

(7) measure of the orbits of the moons and suns (*parimāṇaṃ vāvi caṃdasūrāṇaṃ*) (143-144),

(8) motion of the lunar mansions, moons and suns (*nakkhatta-caṃda-sūrāṇaṃ gaï*) (145-148),

(9) junction of the lunar mansions (*nakkhattajoga*) (149-172),

(10) division of the orbits (*maṇḍalavibhāga = jambūdvīpe candrasūryāṇāṃ maṇḍalavibhāga*) (173-220),

(11) solstices (*ayana*) (221-230)

(12) revolutions (*āuṭṭi = āvṛtti*) (231-253),

(13) measure of the motion of the *muhūrta* in the orbits of the moon and sun (*candrasūryāṇāṃ māṇḍale muhūrtagatiparimāṇam*) (254-259),

(14) seasons (*uü = ṛtu*) ()260-278,

(15) equinoxes (*visuva*) (279-290),

(16) *vyatīpāta*[110] (291-293)

(17) measure of the areas illuminated by the luminaries (?) (*tāva = tāpakṣetraṃ*) (294-304),

(18) increase [and decrease] in the length of the day (*vuḍḍhiṃ ca divasāṇaṃ = divasānāṃ vṛddhy-apavṛddhī*) (305-313),

(19) new moon and full moon (*avamāsa-puṇṇamāsī = amāvāsyā-paurṇamāsī*) (314-359),

(20) determination of the unknown *parva* (*pranaṣṭa-parva*) (360-367) and

(21) man's shadow (*pauruṣī*) (368-376).

These will be told from a practical point of view [and not in a theoretical manner] (*vyavahāra-naya-matena na niścaya-naya-matena*). Listen with a concentrated mind.

logāṇubhāvajaṇiyaṃ joïsacakkraṃ bhaṇaṃti arihaṃtā ।
savve kālavisesā jassa gaïvisesanipphannā ।।6।।

6. The Arhats state that the circle of luminaries (*joïsacakka*) arose out the perception of the people [and not created by an Īśvara].[111] All the features of time (*candramāsa-sūryamāsa-nakṣatramāsādikāḥ)* arose from its motion.

[110] A malignant aspect which occurs when the sun and the moon are on the same side of the equator with equal declinations, but the sum of their longitudes amounts to 180°.

[111] Malayagiri (p. 4): *lokānubhāva-janitam anādikālasantatipatitayā śāśvataṃ veditavyaṃ neśvarādikṛtam.*

saṃkheveṇa u kālo aṇāgayātītavaṭṭamāṇo ya |
saṃkhejjam asaṃkhejjo aṇaṃtakālo u nidditto ||7||

7. In short, time is [threefold as] future (*aṇāgaya*), past (*atīta*) or present (*vaṭṭamāṇa*). [It is] also stated to be numerable (*saṃkhejja = śīrṣa-prahelikā-paryantaḥ saṅkhyeyaḥ*), innumerable (*asaṃkhejja = palyopamādikaḥ*) and infinite (*aṇaṃta = anantotsarpiṇy-avasarpiṇyādikaḥ*).

kālo paramaniruddho avibhajjo taṃ tu jāṇa samayaṃ tu |
samayā ya asaṃkhejjā havaï hu ussāsanissāso ||8||

8. Time which is very minute (*parama-niruddho* = *parama-nikṛṣṭo*) and indivisible, know that to be the "*samaya*."[112] Innumerable (*asaṃkhejja*) "*samaya*s" constitute the out-breath and the in-breath.

Numerable Time

ussāso nissāso yado (duve)'vi pāṇutti bhannae ekko |
pāṇā ya satta thovā thovā vi ya satta lavam āhu || 9 ||
aṭṭhattīsaṃ tu lavā addhalavo ceva nālikā hoi |[113]

9. One out-breath and one in-breath make one *prāṇa*. Seven *prāṇa*s are one *stoka*, and seven *stoka*s are said to be one *lava*.
10. Thirty-eight and half *lavas* make one *nāḍikā* (*nāliyā*).[114]

[112] Malayagiri (p. 5): *sa ca samayo duradhigamaḥ* (that *samaya* is imperceptible).

[113] Here Malayagiri concludes the first chapter with the colophon: *iti śrīmalayagiri-viracitāyāṃ jyotiṣkaraṇḍa-ṭīkāyāṃ kālapramāṇa-nāmā prathamo 'dhikāraḥ.*

[114] The JKM employs three phonetic variants, *nāligā, nāliyā* and *nāḍiyā,* but in the translation we shall use the Sanskrit form *nāḍikā* throughout.

TABLE 1: UNITS OF TIME[115]

Innumerable *samaya*s	=	1 in-breath and/or 1 out-breath	
1 in-breath + 1 out-breath	=	1 *prāṇa*	= 0.70408 seconds[116]
7 *prāṇa*s	=	1 *stoka*	= 4.92286 seconds
7 *stoka*s	=	1 *lava*	= 34.5 seconds
38 ½ *lava*s	=	1 *nālikā*	= 24 minutes

Water Clock

tīse puṇa saṃṭhāṇaṃ chiḍḍaṃ udagaṃ ca vocchāmi || 10 ||
dālimapupphāgārā lohamayī nāligā u kāyavvā |
tīse talaṃmi chiddaṃ chiddapamāṇaṃ ca me suṇaha || 11 ||
channaüyamūlavālehiṃ tivassajāyāe gayakumārīe |[117]
ujjukayapiṃḍiehi u kāyavvaṃ nāḍiyāchiddaṃ ||12||
ahavā duvassajāyāe gayakumārīe pucchavālehiṃ |
bihiṃ bihiṃ guṇehiṃ tehi u kāyavvaṃ nāḍiyācchiddaṃ ||13||
ahavā suvaṇṇamāsehiṃ caühiṃ caturaṃgulā kayā sūī |
nāliyatalaṃmi tīe u kāyavvaṃ nāliyāchiddaṃ ||14||

Now I shall state its (i.e. of the instrument to measure one *nālikā*) constitution (i.e. shape), [the size of its] hole (*chiḍḍaṃ*)[118] and the [volume and quality of] water.
11. [The vessel called] *nālikā* should be made of metal in the shape of a pomegranate flower, with an aperture at its bottom. Now listen from me about the size of the hole.
12. Take ninety-six hairs from the tail of a three-year-old female elephant calf (*gayakumārī*); straighten and bundle them together, and with this make the hole (i.e. make such a hole in which this bundle of hairs just fits) in the *nālikā* vessel.
13. Or take twice [the previous number] of hairs (i.e. 192) from the tail of a two-years-old female elephant calf, and with them make the hole.

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[115] Cf. Kapadia 1937: xxxix-xl.

[116] Thus 7 x 7 x 38.5 = 1886.5 *prāṇa*s or respirations make 1 *nālikā* whereas in Siddhāntic astronomy it is 60 x 6 = 360 *prāṇa*s which constitute 1 *nāḍikā.* Thus *prāṇa* here is of 4 seconds duration.

[117] JKP 18a reads *gokumārīya,* 'female calf of a cow'.

[118] Malayagiri (p. 6): '*chidraṃ' vivaram adhobhāge yenodakaṃ nālikāmadhye praviśati udakaṃ ca yādṛgbhūtaṃ chidreṇa praviśat nālikāyāṃ bhūtvā yathoktanālikā-rūpa-kālaviśeṣa-parimāṇa-hetur bhavati.*

14. Or with four *māṣa*s of gold, make a needle four *aṅgula*s long. With it make the hole at the bottom of the [vessel called] *nālikā*.

Units of Weight

evaṃ chiddapamāṇaṃ dharimaṃ mejjaṃ ca me nisāmeha |
etto udagapamāṇaṃ vocchaṃ udagaṃ ca jaṃ bhaṇiyaṃ ||15||
cattāri madhuragattaṇaphalāṇi so seyasāsavo ekko |
solasa ya sāsavā puṇa havaṃti masapphalaṃ ekkaṃ ||16||
do ceva dhannamāsaphalāṇi guṃjāphalaṃ havaï ekkaṃ |
guṃjāphalāṇi donni u ruppiyamāso havaï ekko ||17||
solasa ruppiyamāsā ekko dharaṇo havejja saṃkhitto |
aḍḍhāijjā dharaṇā ya suvaṇṇo so ya puṇa kariso ||18||
karisā cattāri palaṃ palāṇi puṇa addhaterasa pattho |
bhāro ya tulā vīsaṃ esa vihī hoi dharimassa ||19||

15. Thus the size of the hole. Now listen from me the [units of] weight (*dharima*) and volume (*mejja*), with the help of which I shall state the volume and weight of the water (*udaka-pamāṇa*) and also [the quality of the] water.
16. Four seeds of the sweet grass are [equal in weight to] one white mustard seed (*seyasāsavo* = *śveta-sarṣapa*); again, sixteen of these [white] mustard seeds are [equal in weight to] one been seed (*māsa* = *māṣa*);
17. two of these been seeds are equal to one *guñjā* (arbus precatorius) seed; two *guñjā* seeds equal one *rūpya-māṣa (karma-māṣa)*;
18. sixteen *ruppiyamāsā*s equal one *dharaṇa*; two and a half *dharaṇa*s equal one *suvarṇa,* which is the same as one *karṣa*:
19. four *karṣa*s are one *pala*; twelve and a half *pala*s are equal to one *prasthā*; twenty *tulā*s equal one *bhāra.*[119] This is the rule (*vidhī*) of the weights (*dharima*).

[119] The text does not define *tulā.* Apparently, a line stating that 8 *prastha*s make 1 *tulā,* or 100 *pala*s make 1 *tulā* is missing in both JKM and JKP. Malayagiri (p. 9) says *palaśatikā tulā;* the Prakrit gloss (p. 5) says *palasatigā tula.*

TABLE 2: UNITS OF WEIGHT[120]

4 *madhura-tṛṇa-phalāni*	=	1 *śveta-sarṣapa*
16 *śveta-sarṣapa*	=	1 *māṣa* (*dhānya-māṣa-phala*)
2 *dhānya-māṣa-phala*	=	1 *guñjā-phala*
2 *guñjā-phala*	=	1 *rūpya-māṣa (karma-māṣa)*
16 *rūpya-māṣaka*	=	1 *dharaṇa*
2 ½ *dharaṇas*	=	1 *suvarṇa* = *karṣa*
4 *karṣa*	=	1 *pala*
12 ½ *pala*	=	1 *prastha*
[8 *prasthas*	=	1 *tulā*]
20 *tulā*	=	1 *bhāra*

Steelyard

paṇatīsa lohapaliyā vaṭṭā bāvattaraṃgulā dīhā |
paṃcapaladharaṇagassa ya samāyakaraṇe tulā hoï ||20||
savvaggeṇa tulāe lehāo paṇṇavīsaī hoṃti |
cattari ya lehāo jāo naṃdīpiṇaddhāo ||21||
samakaraṇi addhakariso tattoo karisuttarā ya cattāri |
tatto paluttarāo jāva ya dasagotti lehāo ||22||
bārasa pannarasa vīsage ya etto dasuttarā aṭṭha |
evaṃ savvasamāso lehāṇaṃ pannavīsaṃ tu ||23||
paṃcasu pannārasage tīsagapannārasage ya lehāo |
naṃdīpiṇaddhakāo sesāo ujjulehāo ||24|| [121]

20-24. The [beam of the] balance (*tulā*) is [made of] thirty-five *pala*s of metal/copper/iron (*loha*), seventy-two *aṅgula*s in length, round/smooth (*vaṭṭā*). When it is in equilibrium (*samāyakaraṇa*) with a weight (*dharaṇa*) of five *pala*s at one end, [a line is drawn on the beam perpendicular to its length]. [Besides this line of zero weight], there will be in total (*savvaggeṇa*= *sarvāgreṇa*) twenty-five lines [to indicate different weights]. [Of these] four lines will be covered (*pinaddha*) with a *ṇandī.* [There will be lines at] the place of equilibrium (*samakaraṇa*), at ½ *karṣa,* thereafter four [lines] at each *karṣa,* then [lines] at each *pala* up to

[120] Cf. Kapadia 1937: xxxviii, *unmāna-pramāṇa* (*unmāna* = measure by weight).

[121] Cf. AS 1.19.12-16 (footnote 48 above).

ten [*pala*s], at 12, 15 and 20 [*pala*s], thereafter eight [lines] at each ten *pala*s. Thus, in short, [there will be] twenty-five lines. The lines [indicating] five, fifteen, thirty and fifty [*pala*s] should be covered (*pinaddha*) with a *ṇaṃdī.*[122] The rest will be straight lines (*ujjalehāo*).

Units of Volume (*meya-pramāṇa*)

tinni u palāṇi kulavo karisa'ddhaṃ ceva hoï boddhavvo |
cattāri ceva kulavā pattho puṇa māgaho hoï ||25||
caüpattham āḍhagaṃ puṇa cattāri ya āḍhagāṇi doṇo u |
solasa doṇā khārī khārīo vīsaī bāho ||26||

25. Three *pala*s make one *kuḍava* (*kulava*) and four *kuḍava*s one *prastha* (*pattha*) of Magadha. 26. Four *prastha*s make one *āḍhaka* (*ādhaga*) and four *ādhaka*s one *droṇa* (*dona*). Sixteen *droṇas* make one *khārī* and twenty *khārīs* one *vāha* (*bāha*).

TABLE 3: UNITS OF VOLUME

3 *pala*s	=	1 *kuḍava*	
4 *kuḍava*s	=	1 *prastha*	= 12 *pala*s
4 *prastha*s	=	1 *āḍhaka*	= 48 *pala*s
4 *āḍhaka*s	=	1 *droṇa*	= 192 *pala*s
16 *droṇa*s	=	1 *khārī*	= 3072 *pala*s
20 *khārī*s	=	1 *vāha*	= 61440 *pala*s

Quantity and Quality of Water

dharimassa ya meyassa ya esa vihī nāligāe udagassa |
uddese uvaïṭṭhaṃ udagapamāṇaṃ ao vocchaṃ ||27||
udagassa nāliyāe havaṃti do āḍhagā u parimāṇaṃ |
udagaṃ ca icchiyavvaṃ jārisagaṃ taṃ ca vocchāmi || 28 ||
eyassa u parikammaṃ kāyavvaṃ dūsapaṭṭaparipūtaṃ |
mehodayaṃ pasannaṃ sāraïyaṃ vā girinaīṇaṃ ||29||

[122] On the beam should be engraved/drawn twenty-five lines to represent different weights from ½ *karṣa* to 100 *palas*. Of these twenty-five lines, twenty-one should be straight (*ṛju*). The text says that the remaining four which indicate 5 *pala*s (= 9th line), 15 *pala*s (=16th line), 30 *pala*s (= 18th line), and 50 *pala*s (= 20th line) should be *ṇaṃdī-pinaddhakāo,* which the commentary explains as *phullaḍikā-yuktāḥ.*

27. This is the rule (*vihī*) of the weight (*dharima=tolya*) and the volume (*meya*) of the water in the *nālikā* vessel. Now I shall mention the quantum (*pamāṇa*) which was mentioned/ promised at the outset (*uddeśa,* i.e. verse 10)
28. The volume of water in the *nālikā* [vessel] is two *āḍhakas*.[123] Now I shall tell what type of water is desirable.
29. This [water] must be purified with a filtering cloth (*dūsapaṭṭa,* Skt. *dūṣyapaṭṭa*); or collect clear rain water, or clear water from the mountain streams in autumn.

Subdivisions of the Year

> *be nāliyā muhutto saṭṭhiṃ puṇa nāliyā ahoratto* |
> *pannarasa ahorattā pakkho tīsaṃ diṇā māso* ||30||
> *saṃvaccharo u bārasa māso pakkhā ya te caüvvīsaṃ* |
> *tinneva sayā saṭṭhā havaṃti rāiṃdiyāṇaṃ tu* ||31||

30. Two *nāḍikā*s (*nāliya*) make one *muhūrta* (*muhutta*) and sixty *nāḍikā*s one nychthemeron (*ahoratta* = *ahorātra*). Fifteen nychthemerons make one fortnight (*pakkha* = *pakṣa*) and thirty nychthemerons (*diṇa* = *dina* = *days*) one month (*māsa*).
31. Twelve months make one year (*saṃvacchara* = *saṃvatsara*), which consists of twenty-four fortnights or three hundred and sixty nychthemerons or days (*rāiṃdina* = *rātriṃdina*).

TABLE 4: SUBDIVISIONS OF THE YEAR

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2 *nāḍikā*s	=	1 *muhūrta*
60 *nāḍikā*s	=	1 *ahorātra*
15 *ahorātra*s	=	1 *pakṣha*
30 *dina*s	=	1 *māsa*
12 *māsa*s	=	1 *saṃvatsara* = 24 *pakṣaha* = 360 *ratriṃdina*

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[123] The text does not state the weight of the water with which the vessel is filled; but the commentary (p. 12) mentions that it is 100 *pala*s: *yāvatpramāṇacchidreṇa praviṣṭena nālikā paripūrṇā bhavati tāvatpramāṇasya nālikodakasya meyapramāṇacintāyāṃ dvāv āḍhakau parimāṇāṃ bhavati, dharimapramāṇacintāyāṃ punaḥ palaśataṃ*.

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JK = *Jyotiṣkaraṇḍaka*

JKM = *Vallabhīyācāryīyaṃ Śrījyotiṣkaraṇḍakaṃ Prakīrṇakaṃ, Śrīman-Malayagiry-ācārya-kṛta-vṛttiyuktaṃ.* Ratlam: Rishabhdevji Kesharimal Shvetambar Samstha, 1928.

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