Nepal Sambat Algorithm: *A scientific dissection*

*Algorithm based on astronomy, physics and mathematics surrounding Nepal Sambat.

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***Abstract*—Nepal Sambat is a lunisolar calendar in use in Nepal since 879AD. This document is a detailed analysis of the inner workings of this calendar from a scientific perspective. Utilizing these understandings, this document formulates an algorithm to generate the Nepal Sambat calendar and its conversion to and from other calendars.**

Keywords— Nepal Sambat, Nepal Samvat, Astronomical Algorithms, Calendrical Calculations

INTRODUCTION

A calendar reflects the richness and growth of human civilization. Several calendars have been used throughout history. Each one carries historical and cultural significance and provides a peek into the mathematical and astronomical genius behind it.

Fig 1 Calendrical Significance

Nepal Sambat (henceforth abbreviated as NS) calendar is a lunisolar calendar that has been in use in Nepal since AD 879. Almost all festivals and culturally significant events in the country are celebrated using this calendar.

The details of how the NS calendar is computed are still hidden in old manuscripts and are not widely available to the public. Proper documentation is important not only to preserve its cultural and historical value but also to standardize the technological parameters for eventual official and general use of the NS calendar.

This paper presents an algorithm that can be utilized to compute every element of the NS calendar, which can be used to generate NS calendars for any given year, month, or day. In-depth research on the NS calendar was performed to analyze it from mathematical and scientific perspectives. This included, but was not limited to, consultations with various linguistic, historical, and astrological experts.

This paper is divided into six major chapters. The first chapter provides the historical background of the NS calendar. The second, third, and fourth chapters provide analyses and details of important astronomical phenomena used in the NS calendar. The fifth chapter provides a way to represent the NS calendar. And the sixth chapter presents the algorithm, which is the main outcome of this paper and research.

I. HISTORICAL BACKGROUND

Nepal, a country sandwiched between India and China, is rich in its heritage and history with strong ethnic, cultural, and linguistic diversity. A country with 123 different spoken languages (CBS, 2014) that uses three prominent calendars. NS serves as an integral part of Nepali society.

NS was founded during the reign of Thakuri King, Raghava Deva, in AD 879. It is also believed that NS was established to commemorate the day when Sankhadhar Sakhwa, a merchant from Kathmandu, relieved the country of all its debts. The inception of NS defied the normal tradition to name a calendar or an era after a king, a popular individual, or a religion. NS was named after the country itself. During the early Medieval Period (AD 879-1199) and the Malla reign (AD 1200-1769), NS was promoted as the official calendar in Nepal (Shrestha, 2015).3 Several historical inscriptions, documents, chronicles, and scriptures support that NS was used primarily in Nepal and even in India and China. NS is, undoubtedly, the longest-running prevalent calendar of Nepal.

Fig I.1 Artist's depiction of Shankhadhar Sakhwa

After the conquest of Nepal by Prithvi Narayan Shah in AD 1769, Saka Era was implemented. However, the use of NS was continued together with Bikram and Saka Eras.[3] In AD 1903, Rana Prime Minister Chandra Shumsher introduced Bikram Sambat (henceforth abbreviated as BS). BS is a solar calendar, which is believed to be initiated by a king named "Vikramaditya" from Ujjain, India. Even though BS was neither internationally accepted nor originated in Nepal, it became the de facto calendar of Nepal.

During the Panchayat period (AD 1960-1990), King Mahendra and his government adopted the one nation-one language ideology. A single language was imposed upon a population speaking 123 different languages. This ideology made NS even more inferior to the imposed BS. NS went to the brink of extinction as the younger generation were no longer being taught or even informed about it.

In the 1980s and 1990s, the people of Nepal, especially the Newah community from Kathmandu valley, started initiating campaigns demanding recognition of NS as a national calendar. The New Year's Day of NS became synonymous with celebration combined with protest. Even though the government punished and humiliated the people involved, the movement gained momentum. However, as the Newah group started being more vocal, NS began being labeled as a 'Newar' or 'Newari' calendar amongst the general population.[3]

In 2008, NS was declared to be the National Era of Nepal. In 2011, Prime Minister Dr. Baburam Bhattarai announced that NS would be applied to daily matters of government and formed a task force to do so. In a speech, he made it clear that the NS did not only belong to the Newah but to all Nepali. However, this remained limited to the speech and hasn't come to fruition yet.

NS remains to be comparatively less known in Nepal despite being more scientifically accurate than BS and being originated in and named after Nepal. This paper intends to establish an algorithm so that NS can be preserved and be utilized in daily lives through technology and digitization of the NS calendar.

II. Correlation of Movements of Celestial bodies

From early ages, human civilizations have depended on the movements of celestial bodies for keeping track of time and defining months, seasons, and years. The word 'month' itself is related to the moon. It originally measured how long the moon took to cycle around the earth. The correlation of movements of the celestial bodies like the earth, moon, sun, planets, and stars play a significant role in many calendars, including NS.

NS is a lunisolar calendar system. It depends on computed positions of the sun, moon, and stars, taking into account that the solar and lunar motions vary in speed across the celestial sphere. Each new moon indicates the start of a new month, which is also taken reference with the solar year. Even being heavily dependent on the lunation, NS keeps the solar seasons in check with the use of intercalary months.

This article focuses on analyzing NS from astronomical and mathematical standpoints and utilizing these concepts to formulate an algorithm. Some of the key astronomical phenomena that play vital roles in formulating the NS calendar algorithm are described below.

A. Sidereal Year

The sidereal year is the time taken by the earth to revolve around the sun to return to its initial point of reference. If we take a distant star as a reference for the earth, sun, and the star to align in a straight line, it takes on average 365 days, 6 hours, 9 minutes, and 10 seconds (equivalent to 365.25636 solar days) for the earth to revolve around the sun and align back in position with the sun and the star. This is called a sidereal year. Since the seasonal year is rounded to 365 days, the solar calendars have a concept of leap day to keep itself synchronized with the seasonal year.

B. New Moon

The new moon plays a significant role in the lunar calendar as it indicates the start of the new month. It occurs when the moon comes between the earth and the sun, and all are on the same plane. Per astronomical convention, a new moon is defined as the instant when the geocentric ecliptic longitudes of the sun and moon are equal.

The moon's orbit around the earth is tilted by 5.1° in comparison to the earth's orbit around the sun. Therefore, the solar eclipse does not occur with every new moon. The intersection of these two orbits forms an imaginary point called lunar nodes. A solar eclipse occurs when the lunar nodes line up with the earth, moon, and sun.

C. Sidereal Month

The sidereal month is the period taken by the moon to make a 360° revolution around the earth. The sidereal month is 27.321661 days long, i.e., 27 days, 4 hours, 43 minutes, and 12 seconds.

D. Synodic Month / Lunation

Synodic month or lunation is the period between two consecutive new moons. This period is different from sidereal month because the moon requires additional time to position itself into the same line as the earth and sun. A synodic month is nearly 2.21 days longer than the sidereal month. As the moon revolves around the earth, both objects also progress in orbit around the sun. After completing one revolution with respect to the stars, the moon must continue a little farther along its orbit to catch up to the same position it started from relative to the sun and earth. This explains why the mean synodic month is longer than the sidereal month.

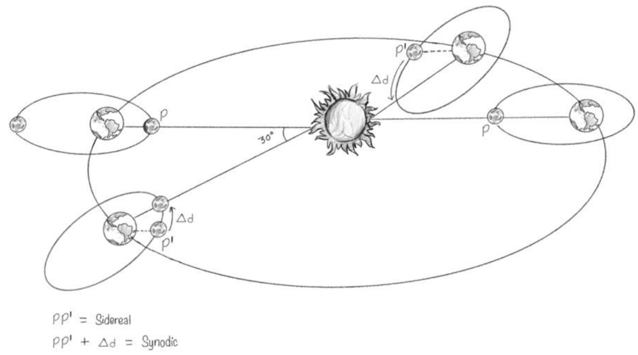


Fig II-1 Illustration of sidereal and synodic months.

E. Orbit of the Moon, Apogee and Perigee

The moon's orbit around the earth is not perfectly round; it is elliptical. Therefore, its distance from the earth varies. The closest distance, called perigee, is about 363104 kilometers away, whereas the farthest point, called apogee, is about 405696 kilometers away from the earth. The moon is travelling at its fastest when it is at its closest to the earth.

F. Tithi / NS Lunar Day

A lunar day of NS or tithi in NS is the duration taken by the moon to traverse 12° on its orbit respective from the new moon. For example, 0°-12° is day one, 12+°-24° is day two, 24+°-36 ° is day three, and so on. All *tithis* are not the same length due to the variation of the speed of the moon and earth. The moon travels fastest at perigee, which is about 1.06km/s to 1.09km/s, whereas it travels at apogee at about 0.97km/s. Also, the moon requires less distance to cover 12° in perigee than in apogee. Due to the varying speed of the moon during its revolution around the earth and the variant distance it needs to cover the 12° of the moon's orbit, the length of each day (*tithi*) varies as well. This results in the average number of days in a month between 29.18 to 29.93 days, which averages about 29.53 days a month.

G. Julian Day / Dynamic Time

The simplest way to identify a given day is to use a continuous count, starting at some arbitrary origin in the past, totally ignoring the idea of the year, month, and week.

Julian Day: We take an origin point to use it as a reference for all other days. This point is known as epoch date. Any other day after that is the number of days past the epoch. The date to be calculated is the count of days after the epoch regardless of the year, month, and date. This concept of Julian day and epoch is used in all calculations to make it easier and consistent.

H. Kepler's Law of Planetary Motion

Kepler gave three laws on planetary motion, which describes the motion of the planetary bodies around the sun:

Planets revolve around the sun in an elliptical orbit with the sun at one of the foci of the ellipse.

A planet covers an equal amount of area in an equal length of time regardless of its position in its orbit.

A planet's orbital period is proportional to the size of its semi-major axis, the square of its revolution time is proportional to the cube of its semi-major axis.

$T^2 \propto a^3$ (T is time taken, a is semi-major axis)

III. Sunrise

NS lunar day (*tithi*) is computed at the time when the moon traverses to an angle multiple of 12° relative to the position of the moon at the new moon. Thus, the crossover of *tithi* can happen at any time during the 24-hour day clock. Thus, a single 24-hour cycle can have two *tithis* overlapped. To avoid this confusion of having two days interlaced into the same solar day, NS injects an idea of using sunrise as a point of reference for the entire day. Whichever *tithi* the moon is at the time of sunrise, the entire day is named after it. This makes the time of sunrise one of the most critical components of the NS calendar algorithm.

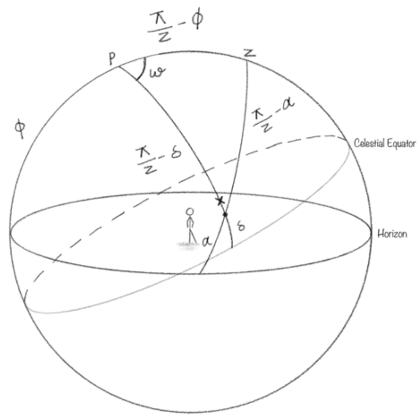
The time of sunrise depends on various factors, including the location (latitude and longitude), elevation, and refraction. A specific location is thus important for the computation of the time of sunrise. NS uses the location of Kaal Bhairab located at Hanuman Dhoka in Kathmandu, Nepal. The term *kaal* means time, and the deity Kaal Bhairab represents keeper of time per ancient mythology.

Fig III-1 Artist's depiction of Kaal Bhairab

A. Computation of hour angle

The earth rotates at an angular velocity of 15° per hour. This angular displacement represents time for an observer on the earth's surface. The meridian directly under the sun from the observer's perspective is called the solar noon. The angle through which the earth would turn to bring the observer closer to or away from the solar noon is defined as the hour angle. The hour angle is zero at solar noon.

To compute the hour angle, we can utilize a unit sphere from the location with the sun as the point of celestial reference. A unit sphere is a sphere of radius one around a given center. This concept is used widely to calculate angles at a distance. The unit sphere to compute the time of sunrise is described below:



where,

Celestial Equator = projection of earth's equator into space

Horizon = imaginary horizontal plane at 90° from observer's zenith.

X = point of interest (in this case, position of the sun)

Z = zenith (a point in the celestial sphere directly above the observer)

P = north celestial pole

α = angle of ascension of the sun eastward of horizon

δ = angle of declination of the sun measured north/south of the celestial equator

φ = latitude of observer with respect to the earth's equator

ω = hour angle

The hour angle of a point is the angle between two planes: one containing the earth's axis and the meridian plane, and the other containing the earth's axis and the given point. The hour angle may be measured in degrees or in time, with 24 hours equaling to exactly 360°, i.e., 1 hour = 15°. Computation of the hour angle makes computation of the time of sunrise and sunset easier.

Using spherical law of cosines on above unit sphere, we get:

$$cos\left(\frac{\pi}{2} - \alpha\right) = cos\left(\frac{\pi}{2} - \delta\right).cos\left(\frac{\pi}{2} - \phi\right) + \sin\left(\frac{\pi}{2} - \delta\right).\sin\left(\frac{\pi}{2} - \phi\right) cos\omega$$

Or,

$$sin\alpha = sin\delta.sin\phi + cos\delta.cos\phi.cos\omega \qquad (3.1)$$

Since, at sunrise, α =0, the hour angle at sunrise ω_o is given by,

$$0 = sin\delta.sin\phi + cos\delta.cos\phi.cos\omega_o$$

Thus,

$$cos\omega_o = -tan\delta.tan\phi \qquad (3.2)$$

B. Algorithm to compute time of Sunrise

Reference [1], *Astronomical Algorithms* by Jean Meeus, is used to derive the algorithm to compute the time of sunrise for a given day as below:

$$\boldsymbol{jd} = \ julian\ day\ of\ a\ given\ day\ (input\ parameter)$$

To use the pre-known constants, the epoch date is set at noon of Jan 1, 2000. The number of days since this date (n) can be computed as

$$n = \lceil \mathrm{jd} - 2451545.0 + 0.0008 \rceil$$

Mean solar time then be computed as:

$$\text{mean-solar-time} = n - \frac{\lambda}{360^o}$$

where, λ is the longitude of observer

Solar mean anomaly (M) can then be defined as:

$$M = (357.5291 + 0.98560028 \times \text{mean-solar-time}) \bmod 360$$

Equation of the center is then defined as,

$$C = 1.9148 \sin(M) + 0.0200 \sin(2M) + 0.0003 \sin(3M)$$

Ecliptic longitude can then be computed as,

$$\lambda_e = (M + C + 180 + 102.9372)\ mod\ 360$$

Declination of the sun can thus be computed as,

$$\sin\delta = \sin\lambda_e \times \sin 23.44° \qquad (3.3)$$

Substituting the value of declination of the sun from equation (3.3) to equation (3.2) and adjusting for atmospherical refraction, the hour angle be computed as:

$$\cos\boldsymbol{\omega}_{\circ} = \frac{\sin(-0.83°) - \sin\varphi \times \sin\delta}{\cos\varphi \times \cos\delta} \qquad (3.4)$$

Local true solar transit (or solar noon) at the location for given day can then be computed as:

$$\textbf{solar-transit} = 2451545.0 + \text{mean-solar-time} + 0.0053 \sin(\mathrm{M}) - 0.0069 \sin(2\lambda) \qquad (3.5)$$

Using the values computed from equation (3.3) and (3.4), we can now define the sunrise equation for a given day (jd) at location (with longitude λ and latitude ϕ) as:

$$\textbf{sunrise-equation}(jd, location) \stackrel{def}{=} \text{solar-transit} + \frac{\omega_o}{360°} \qquad (3.6)$$

Equation (3.5) is used to compute the time of sunrise for the NS calendar algorithm.

IV. Moon Movements Calculations

The computation of movement of the moon is more complicated since it comprises a three-body system, including the sun, moon, and earth. Moreover, the size of the moon is one-fourth the size of the earth, which makes the effect of gravity between these three bodies much more illustrative.

The NS calendar depends heavily on the movement of the moon in the celestial sphere. The month begins on the new moon, and each day is defined as the duration of time taken by the moon to traverse 12°. Thus, the computation of the movements of the moon plays a very significant role in formulating an algorithm for the NS calendar.

A. Solar Longitude

Solar longitude defines the position of the sun in the celestial space relative to the observer on Earth. This angular value plays a very significant role in the formulation of the NS calendar algorithm.

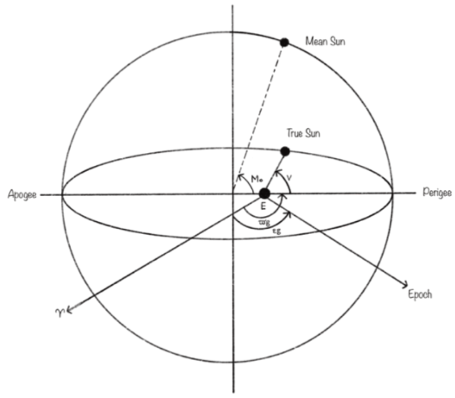


Fig IV-1 Geometry to compute solar longitude

When viewed from Earth (denoted by E in above Fig IV-1), the sun seems to move in orbit around the earth. To calculate the sun's position, let us assume that the sun is in an elliptical orbit around the earth. From Kepler's law, we know that a planet covers the same area of space in the same amount of time irrespective of its position in orbit. The speed may vary depending on the proximity of the sun to the earth. Imagine that there is Kepler's orbit around the ecliptic path, and the sun moves in a circle around the earth at a constant speed rather than along the ellipse that it traces.

Mean anomaly, M_{o}, which is the angle between perigee and the sun with respect to epoch can be computed as:

$$M_{\mathrm{o}} = \frac{360}{365.2422} \times d + \varepsilon_{\mathrm{g}} - \omega_g$$

where,

d = number of Julian days since epoch,

ε_{g}= ecliptic longitude at epoch,

ω_g= ecliptic longitude of perigee at epoch

For the epoch of Jan 1, 1980, values of ε_{g} and ω_g are 278.833540 and 282.596403, respectively.

Once we have calculated the mean anomaly, we calculate the true anomaly, denoted by v, which helps us to know the position of the sun in the ecliptic orbit, and which can be calculated more precisely using Kepler's equation. To get the true anomaly, we also need to calculate the eccentric anomaly, denoted by E. Eccentric anomaly is the angle between the periapsis of an orbit and a given point on a circle around the orbit, as seen from the center of the orbit.

Eccentric anomaly, E is calculated as:

$$E - e \times \sin E = M_{\mathrm{o}}\ radians$$

where,

e is eccentricity of orbit at epoch (at epoch 1980 it's taken as 0.016718)

The following steps can further be run to get more accurate values:

Step 1: Set initial condition as, E = E_{o} = M_{o}

Step 2: Find the value of $\delta = E - e \times \sin E - M_o$

Step 3: If $|\delta| \leq \varepsilon$ go to step 6.

Step 4: Find $\Delta E = \frac{\delta}{1 - e \times \cos E}$

Step 5: Take new value $E = E - \Delta E$. Go to step 2.

Step 6: Current value of E is the solution, correct to within ε of the true value.

Once we get the true value, we can now get the true anomaly (v) by following equation:

$$v = 2 \times \tan^{-1}\left(\sqrt{\frac{1+e}{1-e}} \times \tan\left(\frac{E}{2}\right)\right)$$

Conversion from radians to degrees is required for v as the solar longitude computed below is in degrees.

Thus, the sun's ecliptic longitude can now be defined as:

$$\lambda = v + \omega_g \ degrees$$

For usage of this value in our NS calendar algorithm, we will define solar longitude as:

$$\textbf{solar-longitude}(jd) = \lambda \qquad (4.1)$$

B. Lunar Longitude

To an observer on the earth, the moon appears to be in orbit around the earth, making one complete revolution with respect to the background of stars in 27.3217 days. This period is called the sidereal month. During this time, the earth moves along its own orbit, so that the sun's position changes with respect to the stars. Hence, the moon has some extra distance to make up to regain its position relative to the sun. The interval defined by the time taken for the moon to return to the same position relative to the sun is called the synodic month and is equal to 29.5306 days. The figure below shows the movement of the moon in sidereal and synodic months.

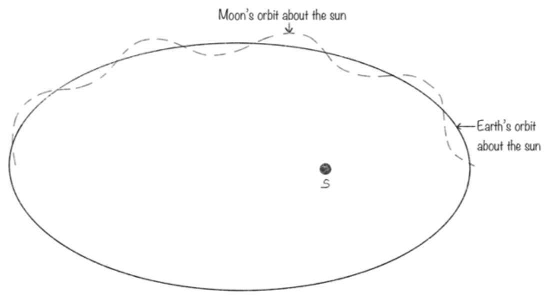


Fig IV-2 Orbits of Moon and Earth relative to each other

There are three main effects of perturbations caused by the sun on the moon's apparent orbit around the earth.

The first is due to the evection in which the apparent value of the eccentricity of the moon's orbit varies slightly.

The second is due to the variation of the earth-sun distance as the earth travels in its own ellipse around the sun. This correction is called the annual equation.

The third inequality takes account of the motion of the moon in the sun's gravitational field. When the moon is on one side of the earth, it is nearer to the sun so that the sun's gravitational attraction is slightly more than when the moon is on the other side of the earth. This correction is called the variation.

These corrections, together with the usual correction, is called the equation of the center.

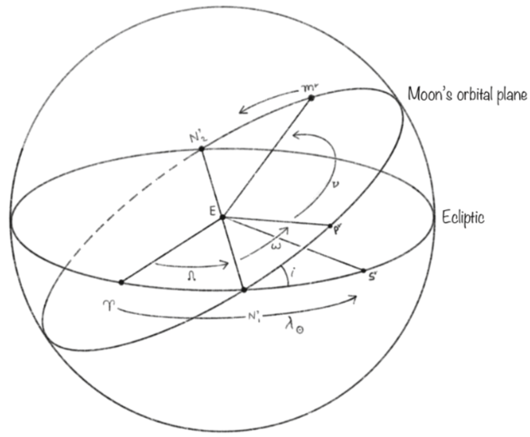


Fig IV-3 Defining Moon's orbit

We calculate factors for the moon as below:

Moon's mean longitude, l_m, given by

$$l_m = 13.1763966 \times D + L_\circ$$

where,

D is the number of days since the epoch to the required date and time,

and $L_\circ$ is the mean longitude of the moon at the epoch. For the epoch of 1980.0, the value is 278.833540

Moon's mean anomaly, Mm, given by

$$M_m = l_m - 0.1114041 \times D - P_\circ$$

where,

$P_\circ$ is the moon's mean longitude of the perigee at the epoch. For the epoch of 1980.0, the value is 64.975464.

Next, we calculate the corrections for evection (Ev); the annual equation, (Ae); and a third correction, (A_3):

$$Ev = 1.2739 \times \sin(2(l_m - \lambda) - M_m)$$

$$Ae = 0.1858 \times \sin(M_m)$$

$$A_3 = 0.37 \times \sin(M_m)$$

where,

λ = solar coordinate for given jd computed from equation (4.1)

With these corrections, we can find the moon's corrected anomaly, Mm':

$$M'_m = M_m + Mv - Ae - A_3$$

Correction for the equation of the center can be computed:

$$Ec = 6.2886 \times \sin(2M'_m)$$

Then, another correction term A4 is computed as:

$$A_4 = 0.214 \times \sin(2M'_m)$$

Now, we can find the value of the moon's corrected longitude, l' from

$$l' = l_m + Ev + Ec - Ae + A_4$$

The final correction to apply to the moon's longitude is the variation, V, given by:

$$V = 0.6583 \times \sin\left(2(l' - \lambda)\right)$$

Then, the moon's true orbital longitude is defined as:

$$\textbf{lunar-longitude}(jd) \overset{def}{=} l' + V \qquad (4.2)$$

C. New Moon

A new moon is by far the most important astronomical event for the NS calendar. The key to the success of the algorithm for NS depends on the computation of the day and time of the new moon.

The relative positions of the sun and moon (as viewed from earth) change constantly during a month. An observer from Earth sees only the part of the moon which is facing the earth. And the part of the moon facing towards the sun is illuminated. This causes the moon to be illuminated in different phases, as seen from Earth. The phase of the moon when only the dark side of the moon is illuminated when observed from Earth is called a new moon. The moon lies between the earth and the sun in a straight celestial plane in this phase.

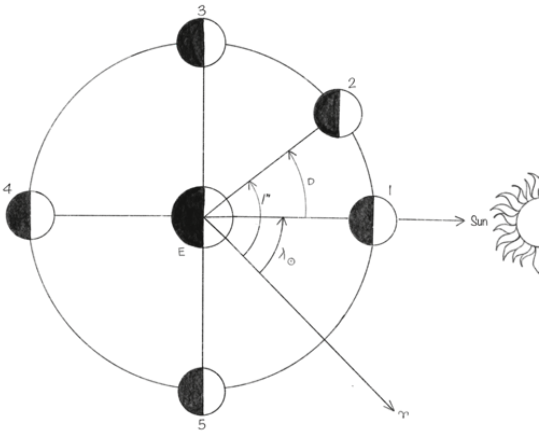


Fig IV-4 Illustration of phases of moon

The following algorithm can be used to find the day and time of new moons closest to a given day (converted to Julian day, jd). We will call the new moon that occurs before jd as "last new moon" and the one after as "next new moon."

The epoch used for this algorithm is noon of Jan 1, 1900. All epoch-specific constants are used based on this date.

Traverse 45 days earlier to given date as:

$$jd = jd - 45$$

Number of lunar cycles passed since 1900 is given by:

$$k = \lfloor \left(\frac{j}{jd_{year}} + \frac{jd_{month} - 1}{12} - 1900 \right) \times 12.985$$

Where, 12.985 is the number of lunar cycles per year

Number of days since 1900 can be computed as:

$$jd = jd - 45$$

Number of centuries passed can be defined as:

$$\text{number-of-centuries}(n) = \frac{n}{36525} \qquad (4.3)$$

Number of centuries since 1900 to given day given by:

$$t = \text{number-of-centuries}(jd - 2415021)$$

Approximate day of a new moon can be derived from following equation:

$$\begin{aligned} \text{mean-new-moon}(jd, k, t) &= (\,2415020.75933 + 29.5306 \times \mathrm{k} \\ &+ 0.0001178 \times \mathrm{t}^2 \\ &- 0.000000155 \times \mathrm{t}^3 \\ &+ 0.00033 \\ &\times \sin(166.56 + 132.87 \times \mathrm{t} \\ &- 0.009173 \times \mathrm{t}^2)\,) \qquad (4.4) \end{aligned}$$

where, k = number of lunar cycles and t = number of centuries since 1900 for a given day (jd)

The value of the approximate new moon date can now be:

$$nt = d = \text{mean-new-moon}(jd, k, t)$$

We can now adjust this approximate value further by using the following steps:

Step 1: Calculate parameters for next new moon:

$$d = d + 29.5306$$

$$k' = k + 1$$

$$t = \text{number-of-centuries}(\,d - 2415021)$$

Step 2: Get the approximate new moon day

$$nt' = d' = \text{new-moon-calc}(d, k1, t)$$

Step 3: If $nt \leq d \; and \; d < nt'$, go to step 5.

Step 4: Go to Step 1 with reassigned values:

$$nt = nt' \,; and \; k = k'$$

Step 5: The final value for the lunar cycle is k'

True Phase Algorithm:

Now that we have the final value for the lunar cycle, the following steps can further be utilized to get the true value for the new moon:

true-phase-nm(k') is defined as:

Get the value of centuries from the number of lunar cycles:

$$t = \frac{k'}{1236.85}$$

Where, 1236.85 is the number of lunar cycles in a century

Calculate the mean new moon phase for this lunar cycle:

$$nt1 = \text{mean-new-moon}(jd, k', t) \qquad (4.5)$$

Other factors for corrections to get the true phase are:

Solar mean anomaly:

$$\begin{aligned} M = {} & 359.2242 + 29.10535608 \times \mathrm{k}' \\ & - 0.0000333 \times \mathrm{t}^2 - 0.00000347 \times \mathrm{t}^3 \end{aligned}$$

Lunar mean anomaly:

$$\begin{aligned} \mathrm{M_m} = {} & 306.0253 + 385.81691806 \times \mathrm{k}' \\ & + 0.0107306 \times \mathrm{t}^2 + 0.00001236 \times \mathrm{t}^3 \end{aligned}$$

Moon's argument of latitude:

$$\begin{aligned} \mathrm{L_m} = {} & 21.2964 + 390.67050646 \times \mathrm{k}' \\ & - 0.0016528 \times \mathrm{t}^2 - 0.00000239 \times \mathrm{t}^3 \end{aligned}$$

Applying these corrections to the value from equation 4.5, we get the final true time of the new moon for the given date.

$$
\begin{aligned}
nm' = nt1 + (0.1734\ &-\ 0.000393\ \times t) \times\ sin(M) \\
&+\ 0.0021\ \times\ sin(2M) \\
&-\ 0.4068\ \times\ sin(M_m) \\
&+\ 0.0161\ \times\ sin(2M_m) \\
&-\ 0.0004\ \times\ sin(3M_m) \\
&+\ 0.0104\ \times\ sin(2L_m) \\
&-\ 0.0051\ \times\ sin(M\ +\ M_m) \\
&-\ 0.0074\ \times\ sin(M\ -\ M_m) \\
&+\ 0.0004\ \times\ sin(2L_m\ +\ M) \\
&-\ 0.0004\ \times\ sin(2L_m\ -\ M) \\
&-\ 0.0006\ \times\ sin(2L_m\ +\ M_m) \\
&+\ 0.0010\ \times\ sin(2L_m\ -\ M_m) \\
&+\ 0.0005\ \times\ sin(M\ +\ 2M_m))
\end{aligned}
$$

True phase of the new moon for lunar cycle k' can be defined as:

$$\textbf{true-phase-nm}(k')\ \stackrel{def}{=}\ nm' \tag{4.6}$$

Thus, the equation to compute the day and time of the new moon for a given day (jd) can be defined as:

$$\textbf{get-last-new-moon}(jd)\ \stackrel{def}{=}\ \text{true-phase-nm}(k') \tag{4.7}$$

Similarly, to get the next new moon (new moon occurring after the given date), we can utilize the same method with the next lunar cycle. The equation to compute the day and time of the next new moon for a given day (jd) can be defined as:

$$\textbf{get-next-new-moon}(jd)\ \stackrel{def}{=}\ \text{true-phase-nm}(k'+1) \tag{4.8}$$

V. REPRESENTATION OF NS CALENDAR

The NS calendar is structured differently than other solar or lunar calendars. Each month of NS is divided into two parts, called *Tho* and *Ga Paksha*. A month number can be reused when a leap or extra month (*analā*) occurs. A month number can be skipped when a skipped month (*nhalā*) occurs. A day can be repeated, and sometimes a day can be skipped. Because of these abnormal behaviors of the NS calendar, a new structure is required to represent a day of the NS calendar. Reference [1], *Coding and Decoding of NS Tithis* by Dr. Bhagwandas Manandhar, is used for the representation of a day in the NS calendar as below:

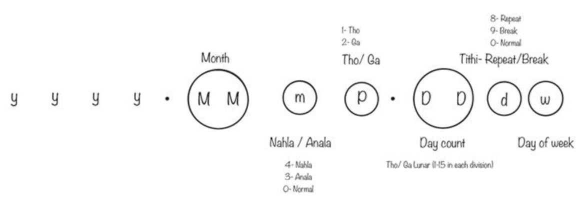


Fig V-1 Day format of NS calendar

Representation format is defined as:

$$\textbf{NS-Day-Format}\ \stackrel{def}{=}\ yyyy.MMmP.DDdw \tag{5.1}$$

where,

- $yyyy$ = NS year is represented with 4 digits
- MM = Month of the year (from 1 to 12)
- m = 3 if Analā, 4 if Nhalā, 0 otherwise
- P = 1 if Tho, 2 if Ga
- DD = Day of the month (from 1 to 15)
- d = 8 if the day is repeated, 9 if the day is after a skipped day, 0 otherwise
- w = day of the week

A. Paksha

One fortnight is represented as a "Paksha" in the NS calendar. A month in the NS Calendar has two Pakshas each consisting of a maximum of 15 days. The first 'Paksha' from the new moon to the full moon is called "Tho" or "Shukla Paksha". It represents the luminosity of the moon's crescent getting brighter by the day. The second 'Paksha' from the full moon to the new moon is called "Ga" or "Krishna Paksha". It represents the luminosity of the moon's crescent getting lower by the day. Thus, a month in the NS calendar needs to be defined with the month number together with Paksha (1 for Tho and 2 for Ga).

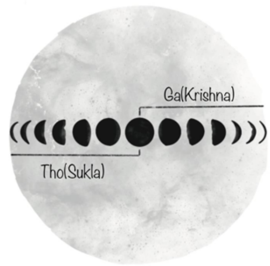


Fig V-2 Pakshas in NS calendar

B. Month

Months are denoted by numbers from 1 to 12 followed by month type, then by a Paksha number. An introduction of a leap month can make a year consist of 13 months. It takes the same month number when it occurs followed by a number 3 denoting Analā. For example: if a leap month falls on second month of the year, it will consist of two months denoted by 2,0 and 2,3. Similarly, when Nhalā occurs, the same month number can be repeated. For example – if third month is skipped in a given year, the months be sequenced as 2,0 then 2,4 followed by 4,0.

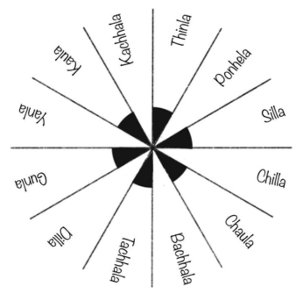


Fig V-3 Months in NS Calendar

C. Tithi

Tithis are the days of NS calendar. They are denoted by numbers from 1 to 15. Day 15 represents a full moon for Tho Paksha and new moon for Ga Paksha. Tithis can repeat over two consecutive days or skipped completely. When a tithi is repeated, the second one in the list is added with a suffix of 8 to denote repeat and 9 if a day is skipped. For example: 1,0 | 1,8 | 2,0 | 4,9 is a valid tithi sequence.

Fig V-4 Tithis in NS calendar

VI. NEPAL SAMBAT CALENDAR ALGORITHM

A. Epoch and Julian Day

Every calendar has an epoch or starting date. The NS era began on Oct. 24, AD 879. Epoch play important roles in every calendrical algorithm because it makes it convenient to mark the date as the number of days from the epoch. To avoid confusing situations of date references on different calendars, astronomical algorithms usually represent the date and time in Julian days (JD) or Julian astronomical days (JAD).

The Julian day number represents a given date as the number of days that have passed since the creation of the world, which was then considered to be on Jan. 1, 712 BCE at noon. Therefore, the days which begin at midnight have a JD with a fraction of 0.5. There are several epochs with pre-calculated Julian days which can be used to compute the JD of any given date. All computation in this algorithm is done based on JD.

Below are a few epochs and corresponding Julian days that were utilized to test this algorithm. Any other epoch date can be used in place of these.

$$\text{ns-epoch} \stackrel{def}{=} 2042404.5 \quad | \text{ Oct 24, 879}$$

$$\text{ad-epoch} \stackrel{def}{=} \mathit{2451545.5} \quad | \text{ Jan 1, 2000}$$

Using these values, a Julian day of any given date can be computed as below. This value is utilized to compute other components of the calendar in this algorithm.

$$\boldsymbol{jd} \stackrel{def}{=} \text{epoch-jd} + \text{ number of days from epoch} \quad (6.1)$$

B. Sunrise

The time at sunrise plays a very significant role in the computation of the NS calendar. The position of the moon at sunrise defines the name of the day for the entire day. The computation of time at sunrise depends on the location. Thus, a standard location needs to be pre-defined. NS uses the location of Kaal Bhairab located at Hanuman Dhoka in Kathmandu, Nepal.We use the following constants for computing time of sunrise:

$$\boldsymbol{location} \stackrel{def}{=} \begin{cases} city = kathmandu \\ longitude\ (\lambda) \ = 27.7172 \\ latitude\ (\phi) \ = 85.3240 \end{cases} \quad (6.2)$$

The time of sunrise is computed by passing these constants to the sunrise equation described in equation (3.6):

$$\textbf{sunrise-time } (jd) = \text{sunrise-equation}(jd, location) \quad (6.3)$$

C. Lunar Angle at Sunrise

The lunar angle or lunar phase is the difference between the solar longitude and lunar longitude (see Section 4.A and 4.B for details). Since the earth, moon, and sun are in the same line, with the moon between the sun and earth during the new moon, the solar longitude and lunar longitude are the same. Thus, the lunar angle in a new moon is effectively 0 degrees. Similarly, during a full moon, the lunar angle is 180 degrees. Lunar angles are relied upon heavily for calculations in lunar calendars and lunisolar calendars.

The lunar angle or lunar phase at any given time (t) can be computed as:

$$\textbf{lunar-angle(t)} \stackrel{def}{=} \text{lunar-longitude}(t) - \text{solar-longitude}(t) \quad (6.4)$$

The lunar angle at sunrise is used to identify the name of the day in the NS calendar. The lunar phase that the moon is located at the time of sunrise is taken for the entire day. Applying the time of sunrise from equation 6.3 to equation 6.4, the lunar angle at sunrise can be computed as:

$$\textbf{lunar-angle-at-sunrise} \stackrel{def}{=} \text{lunar-angle(sunrise-time)} \quad (6.5)$$

D. Tithi (Lunar Day)

Tithi is defined by the lunar phase at sunrise (see 6.5). The difference in longitudes between the positions of the sun and moon at sunrise defines the lunar phase at sunrise. Dividing this difference in degrees by 12 gives an integer in the range of 0 and 29. Therefore, ceiling this integer gives the *tithi*, or lunar day, for the NS calendar.

Thus, the lunar day (*tithi*) in NS is defined as:

$$\textbf{tithi (jd)} \stackrel{def}{=} \lceil \frac{\text{lunar-angle-at-sunrise}}{12} \quad (6.6)$$

Lunar days are not necessarily sequential because of the varying motion of the moon. A lunar day is computed in 6.6 ranges from 21.5 to 26.2 hours and can cause two sunrises to fall within one lunar day. Also, a lunar day can begin and end between two sunrises. Thus, the same number can be computed from the equation in 6.6 for two consecutive days, or a number might be skipped between two days. In order to differentiate these in the NS calendar, the current day's number is compared with that of the previous day's number. If they are the same, then it is called a leap (aka *adhika*) day and is represented by "8" in our representation scheme (see section 5.1). If they differ by 2, then it is a skipped (aka *xhaya*) day and is represented by "9" in our representation scheme.

Thus, leap and skip days can be computed as:

today = tithi (jd)

yesterday = tithi (jd - 1)

$$\textbf{tithi-type} \stackrel{def}{=} \begin{cases} 8\ \boldsymbol{if}\ (yesterday = today) \\ 9\ \boldsymbol{if}\ (yesterday - today = 2) \\ 0\ \boldsymbol{otherwise} \end{cases} \quad (6.7)$$

E. Paksha (Half Lunar Cycle)

A lunar cycle (from a new moon to the next new moon) is divided into two parts. The first from the new moon to the full moon is called *Tho* (or *Sukla*) *paksha*. And the second from the full moon to the next new moon is called *Ga* (*Krishna*) *paksha*. They represent the moon increasing its luminosity in *Tho paksha* and decreasing in *Ga paksha*.

Paksha in NS is defined as:

$$\textbf{paksha} \stackrel{def}{=} \begin{cases} 1\ (Tho), & tithi \le 15 \\ 2\ (Ga), & otherwise \end{cases} \quad (6.8)$$

F. Tithi Names (Representation)

Tithis are named and numbered from 1 till 15 for each *paksha*. However, the 15th day of *Tho paksha* (also a full moon) is called *Punhi*, and the 15th day of *Ga paksha* (a new moon) is called *Ammai*.

Tithi names in NS are defined as:

$$\textbf{tithi-name} \overset{def}{=} \begin{cases} tithi \quad , & paksha = 1 \\ tithi - 15, & paksha = 2 \end{cases} \quad (6.9)$$

Numerical representation in Section 6.9 is used as the day number in the calendrical representation scheme (Section 5.1).

Traditional names each day represented by numbers from 6.9 can be mapped as:

in BLE 6.1 NS CALENDAR TITHI NAMES

tithi-name	Traditional names of a Tithi	
	In English	***In Nepal Bhasa***
1	Paru	पारु
2	Dwitiya	द्वितीया
3	Tritiya	तृतीया
4	Chaturthi	चतुर्थी
5	Panchami	पञ्चमी
6	Sashthi	षष्ठी
7	Saptami	सप्तमी
8	Astami	अष्टमी
9	Nawami	नवमी
10	Dashami	दशमी
11	Ekadashi	एकादशी
12	Dwadashi	द्वादशी
13	Trayodashi	त्रयोदशी
14	Chaturdashi	चतुर्दशी
15	Punhi (at Tho), Ammai (at Ga)	पुन्हि (थ्व), आमै (गा)

[a] Data collected from traditional printed calendars and experts in Nepal Bhasa

G. Duration of Tithi

Tithi, or a lunar day, is the time taken for the longitudinal angle between the moon and sun to increase by 12 degrees (see Section 5.C). By this definition, the duration of *tithi* varies in duration. Also, the elliptical orbit of the moon around the earth makes the duration of a *tithi* shorter when the moon is close to perigee and longer when the moon is close to apogee.

A *tithi* ends and the next *tithi* begins at every 12 degrees interval starting from the new moon at which the lunar angle is at 0 degrees. Therefore, the first lunar day (*Tho, Paru*) starts when the lunar angle is at 0 degrees and ends when it reaches 12 degrees. The second day ranges from 12 to 24 degrees and so on.

The lunar angle at a given time can be computed from equation 6.5. But time at which the lunar angle will be at a certain angle cannot be derived from the equation because it depends on lunar longitude and solar longitude, both of which can vary independently at any given time. In order to solve this problem, we utilize Lagrange Inversion theorem, as below:

Calculate lunar angle degrees left to reach a multiple of 12:

$$\textbf{degrees-left} = \left(\lfloor \frac{\text{lunar-angle-at-sunrise}}{12} \right) \times 12 \\ - \text{lunar-angle-at-sunrise}$$

Define offsets for one day (number of offsets can vary):

$$\mathbf{x} = [\ 0.25, 0.50, 0.75, 1.0\ ]$$

$$y = [\ \text{lunar-angle}(\text{sunrise-time} + t) \\ - \text{lunar-angle-at-sunrise}\ ]$$

$$where\ t\ in\ x$$

$$y_a = \text{degrees-left}$$

$$\textbf{tithi-duration} \overset{def}{=} InverseLagrange(x, y, y_a)$$

$$where\ InverseLagrange\ is\ given\ by:$$

$$L(y_a) = \sum_{i=0}^{n} x_i \left(\prod_{\substack{0 \le j \le n \\ j \ne i}} \frac{y_a - y_j}{y_i - y_j} \right)$$

H. Month

A month in the NS calendar is defined as the duration between two new moons. The name of the month is established according to the constellation sign at the new moon on which the month starts. The solar or lunar longitudes that we used in the equations above can be utilized to compute the month name. Since the earth, moon, and sun is in a straight plane at the new moon, the solar longitude and lunar longitude are the same at the new moon.

Month name can be computed as:

Using the equation described in Section 4.8, find the day of the new moon (last new moon from current day) as:

$$\text{new-moon-day} = \text{get-last-new-moon(jd)}$$

Then, utilizing the equation described in Section 4.1, find the solar longitude at the new moon as:

$$\text{solar-longitude-at-new-moon} \\ = \text{solar-longitude(new-moon-day)}$$

NS months are divided into 12 equal months. Therefore, dividing above longitude (in degrees) by 30 should give the numerical representation of the month-name as:

$$\textbf{ns-month-name (jd)} \overset{def}{=} \lceil \frac{\text{solar-longitude-at-new-moon}}{30} \quad (6.9)$$

The first month of the NS calendar begins on the new moon when the solar longitude points towards the Scorpious constellation, which is a large constellation located in the southern hemisphere near the center of the Milky Way. It also corresponds to the *nakshatras Anuradha*, *Jyeshtha*, and *Mula*.

If the epoch date is picked at the new moon of the first month of the NS calendar, equation 6.9 should give the correct numerical representation of the month.

Traditional names for the computed NS months can be mapped from the table below.

TABLE 6.1 NS CALENDAR MONTH NAMES

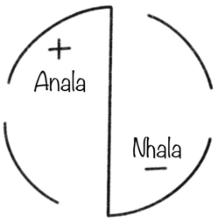
month-name	Traditional names of a Month	
	In English	***In Nepal Bhasa***
1	Kachhalā	कछला
2	Thinlā	थिंला
3	Ponhelā	प्वँहेला
4	Sillā	सिल्ला

month-name	Traditional names of a Month	
	In English	***In Nepal Bhasa***
5	Chillā	चिल्ला
6	Chaulā	चौला
7	Bachhalā	बछला
8	Tachhalā	तछला
9	Dillā	दिल्ला
10	Gunlā	गुंला
11	Yanlā	ञला
12	Kaulā	कौला

[a] Data collected from traditional printed calendars and experts in Nepal Bhasa

I. Leap Month (*Analā*)

An average synodic month (number of days between two new moons) is about 29.530588 days (29 days, 12 hours, 44 minutes). NS months are synonymous with the synodic month. Therefore, an NS year lasts around 354.4 days, which is more than ten days shorter than the tropical year. This causes the NS months not to sync with the seasons (which are based on the solar phase) over time. To solve this problem, a leap month is introduced every three years, making a leap year with 13 months. This month is called *Analā* in the NS calendar.



Analā occurs when two new moons fall over the same solar month (*Shukla paksha*). In other words, both the solar longitude of the new moon at the start of the month and the solar longitude of the new moon at the start of the next month produce the same month value.

An *Analā* month can be identified for given jd as:

$$\text{new-moon} = \text{get-last-new-moon}(jd)$$

$$\text{this-month} = \lfloor \frac{\text{solar-longitude(new-moon)}}{30}$$

$$\text{next-new-moon} = \text{get-last-new-moon}(jd)$$

$$\text{next-month} = \lfloor \frac{\text{solar-longitude(next-new-moon)}}{30}$$

$$\textbf{anala} \overset{def}{=} \begin{cases} 1\ (Yes), & \textit{this-month} = \textit{next-month} \\ 0\ (No), & otherwise \end{cases} \quad (6.11)$$

J. Skipped Month (*Nhalā*)

If *Analā* is the golden crown of the NS calendar, *Nhalā* is the diamond jewel of that crown. The ability to get these two correct defines the success or failure of the algorithm and any computer program implementing the algorithm. Just like *Analā*, *Nhalā* plays a significant role in keeping the NS calendar in sync with the seasons, which depend on the solar year. However, *Nhalā* is much rarer.

Nhalā, or skipped month, occurs when a solar month elapses without a new moon. In other words, between two new moons that define a lunar month, an entire solar month is included. For this to happen, the relative position of the sun must move by more than 12 degrees between two new moons. This is the reason why *Nhalās* occur usually in the winter, near the perihelion, when the apparent motion of the sun is the fastest. And they occur very rarely, with a gap of 19 to 141 years between the occurrences of two consecutive skipped months.

A similar approach used for computing *Analā* can be used to compute *Nhalā*. By definition, Nhalā occurs when an extra solar month is skipped between two new moons. So, the difference between the months at the new moon and the next new moon should be 2.

$$\textbf{nhala} \overset{def}{=} \begin{cases} 1\ (Yes), & (\textit{next-month} - \textit{this-month}) = 2 \\ 0\ (No), & otherwise \end{cases} \quad (6.12)$$

Anala and *Nhala* take the month name of the next month. Therefore, in the NS calendar, there can be two and sometimes even three months with the same month name (month sequence number). In order to represent it properly, the NS calendar requires one more parameter to define a month which is defined as:

$$\textbf{month-type} \overset{def}{=} \begin{cases} 3\ \boldsymbol{if}\ (anala = 1) \\ 4\ \boldsymbol{if}\ (nhala = 1) \\ 0\ \boldsymbol{otherwise} \end{cases} \quad (6.13)$$

K. Year

A year in the NS calendar can consist of 11, 12, or 13 months depending on whether a year has a leap month, a skipped month, both, or none. There are several methods of calculating an NS year. The Nepal Sambat era began on AD 879, Oct 24th, considered as NS year 0 or NS epoch. The number of years from this epoch can be used to compute the NS year.

For higher accuracy, the Kaliyuga epoch can also be utilized for computing the NS year. *Aryabhatiya* of *Aryabhata* mentions the conjunction of all planets, moon, and node at the start of Kaliyuga. The Kaliyuga epoch is well defined as 17/18 Feb, 3102 BC, which puts the Julian day number of the Kaliyuga epoch to be 588465.5. After adjusting it for the current month, the following offset table can be utilized to convert it to the respective year in each era.

TABLE 6.3 SAKA OFFSETS FOR VARIOUS ERAS

Era	*Current year*	*Elapsed year*
Kali Yuga	+3180	+3179
Saka	+1	0
Nepal Sambat	+801	+800
Vikrama	+136	+135
Bengal		-515

[a] Data collected from Calendrical calculations by Reingold and Dershowitz

NS year is computed as:

$$\text{days-since-ky} = jd - 588465.5$$

$$\text{ky-year} = \lfloor \frac{\text{days-since-ky} + (10 - \text{ns-month}) \times 30}{365.25636}$$

$$\text{saka-year} = \text{ky-year} - 3179$$

$$\textbf{ns-year} \overset{def}{=} \text{saka-year} - 800 \quad (6.14)$$

L. NS Date

NS date can be represented utilizing components derived from previous sections as:

$$\textbf{ns-date} \overset{def}{=} YYYY.MMmP.DDdw \tag{6.15}$$

$where$

$YYYY = \text{ns-year} \quad from\ eq. 6.14$

$MM = \text{ns-month} \quad from\ eq. 6.12$

$m = \text{ns-month-type} \quad from\ eq. 6.10$

$P = paksha \quad from\ eq. 6.12$

$DD = \text{tithi-name} \quad from\ eq. 6.7$

$d = \text{tithi-type}\ from\ eq. 6.6$

$w = day\ of\ week$

M. Case Study

Let's consider the unusual NS calendar for NS years 1102 and 1103. NS year 1103 is particularly a very interesting year. This year consists of a leap month (*Analā*) and a skipped month (*Nhalā*), making the total number of months in the year to be still 12 even when it is a leap year. The leap month in 1103 is more fascinating given the fact that it occurred only after four months of last *Analā*. This unusual behavior indicates that the leap month does not necessarily occur only every three years in the NS calendar. Hence, the method used in the algorithm described in this paper produces more accurate data than counting the leap month from three years after the last leap month.

Table 6.4, listed below, analyzes these two years and illustrates how the algorithm produces an accurate calculation necessary for the NS calendar, including *Analā* and *Nhalā*. The table consists of four major pieces of information: the date in AD when the event occurs, the time of the new moon, which determines the start of the lunar month, the solar longitudes at the multiples of 30 showing the sections of solar months, and the corresponding NS month. These data points illustrate how NS months are determined and how the solar longitudes and new moon times are utilized to name NS months, including a leap month (*Analā*) and a skipped month (*Nhalā*).

The date and time of the new moon in this table indicates the time when the lunar and solar longitudes are the same. Technically, the lunar month starts at this date and time. However, since the NS calendar takes the day name at the time of sunrise, the NS month usually starts on the next day of the date indicated in this table.

The new moon on Sep 17 lies between 330° and 0° solar latitudes. Technically, this should have qualified for month 12. However, we can notice that the next new moon also is within the same solar longitudes. Thus, this month is an extra lunar month and is marked as 11.3 *Analā*.

On the contrary, there is no new moon that lies between the solar longitude 90° (Jan 15, 1983) and 120° (Feb 13, 1983). Thus, an entire month is skipped. And this is marked as 2.4 *Nhalā*. To make things more interesting, two new moons occur in the next cycle (120° and 150°). This makes a leap month marked as 2.3 *Analā* right after a skipped month, *Nhalā*. And this leap month occurs only four months after the last leap month. Thus, this unusual year, NS 1103, has a *Nhalā* with an *Analā* followed right after, skipping two lunar months 3 and 4 and still making the number of months in the year to be 12.

TABLE 6.4 ANALYSIS OF NS 1103

Date	***New Moon at***	***Solar longitude***	***NS Month***
May 15,1982		210°	
May 23, 1982	10:25		8 | Tachhalā
Jun 16,1982		240°	
Jun 21, 1982	05:36		9 | Dillā
Jul 17,1982		270°	
Jul 21,1982	13:51		10 | Gunlā
Aug 17,1982		300°	
Aug 19, 1982	08:29		11 | Yanlā
Sep 17,1982		330°	
Sep 17,1982	17:54		**11.3 | Analā**
Oct 17, 1982	04:35		12 | Kaulā
Oct 18,1982		0°	
NS 1102 ends, and **NS 1103** starts			
Nov 15, 1982	20:54		1 | Kachhalā
Nov 17,1982		30°	
Dec 15, 1982	15:03		2 | Thinlā
Dec 16,1982		60°	
Jan 14, 1983	10:52		**2.4 | Nhalā**
Jan 15,1983		90°	
Feb 13,1983		120°	
Feb 13,1983	06:16		**2.3 | Analā**
Mar 14, 1983	23:28		5 | Chillā
Mar 15,1983		150°	
Apr 13, 1983	13:43		6 | Chaulā
Apr 15,1983		180°	
May 12, 1983	01:10		7 | Bachhalā
May 16,1983		210°	
Jun 11, 1983	10:22		8 | Tachhalā
Jun 16,1983		240°	
Jul 10, 1983	18:03		9 | Dillā
Jul 17,1983		270°	
Aug 8, 1983	01:02		10 | Gunlā
Aug 18,1983		300°	
Sep 7, 1983	08:19		11 | Yanlā
Sep 18,1983		330°	
Oct 6, 1983	17:00		12 | Kaulā
Oct 18,1983		0°	
Nov 4, 1983	4:06		NS 1104 starts

[a.] Data collected from computer model developed utilizing algorithm from this paper

CONCLUSION

A new algorithm for solving the computation problem for the NS calendar is presented. The algorithm is based on astronomical calculations and converting traditional understandings into mathematical formulas. The author believes that this will not only help preserve the heritage and mathematical genius of NS but will also help for the eventual implementation of NS into various technology platforms. The proposed algorithm is computationally tested and checked for accuracy comparing with the historical calendar. The algorithm is capable of producing calendars for the past as well as the future.

DISCUSSION / OPINION

NS originated, remained as the most prevalent calendar in its history, and is still used widely for cultural events in Nepal. However, it does not have official recognition to a point that most people (even in Nepal) are not aware of this masterpiece left behind by their ancestors. Nepal uses BS as its official calendar when it was neither originated in Nepal nor is internationally used. NS has a more scientific and mathematical background than BS and is more accurate, making it riper for the digital era. Therefore, the usage of BS instead of NS or AD as an official language of Nepal does not make sense from cultural, patriotic, and technological points of view.

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