CALCULATING THE UPOSATHA MOONDAYS

v1.0 · 20th November 2015 · link

TL,DR

Too Long, Didn't Read

- The method is based on a set of formulas called *suriyayatra* (สุริยยาตร์), originating from India and including additional rules observed in Southeast Asia.
- These formulas are now implemented in suriya-go for generating the uposatha moondays for any arbitrary year.
- The lunar year starts with Magasira month in November. The Seasons end on the Full Moon day. The lunar months end on the New Moon day, the Full Moon is in the middle. Visākha 15, Āsāḷha 15, etc. is always Full Moon.
- To keep the lunar year in sync with the solar, add an extra month 7 times in 19 years (the adhikamāsa, อธิกมาส), and add an extra day 11 times in 57 years (the adhikavāra, อธิกวาร).
- Conditions on the values produced by formulas determine if a year should be assigned an adhikamāsa or adhikavāra.
- The 3-3-2 - 3-3-3-2 shorthand to determine adhikamāsa years is not sufficient.
- Conventions on how to practise this can be differ by countries and monastic groups.
- Common and adhikamāsa years have been regular in past calendars and thus reliable to predict. Some adhikavāra years have been irregular, approx. 1 in 20. However, everything since 1997 have been according to the regular pattern.

"One must acquire the habit of saying 'different' rather than 'wrong.'"
JC Eade, *Calendrical Systems*, p. 4.

How long?

The first section (3 pages) is already quite informative if you just wish to have a better understanding of the uposathas. The sections get progressively more involved, drop it when you don't need more.

3 pages To understand the sequence of uposathas in a given year, see page 3-5.

+4 pages The formulas and conditions which determine the adhikamāsa and adhikavāra are described on page 14-17 in sec. 4.

+3 pages The formulas continue with calculating the angular position of the Sun and Moon on a given day at sec. 4.5, page 18-20.

+2 pages A day is visualized with the zodiac wheel diagrams (a.k.a *duang chata*). Making sense of these is in sec. 5, page 21-22.

Them formulas

Dive in at page 16, or see how we can ask the machine to do it in Golang at page 23.

Related:

- Forest Sangha Calendar
  forestsangha.org/community/calendars
- suriya-go Golang package
  github.com/splendidmoons/suriya-go
- Splendid Moons online uposatha calendar
  splendidmoons.github.io
- Uposatha .ical link for Google Calendar
  splendidmoons.github.io
  (top-right corner, calendar icon)

Download this PDF or a ZIP archive with the PDFs referenced in this document.

CONTENTS

Section 1 · Mahānikāya Uposatha Calendar Tutorial 3

1.1 Collecting information about the year 3
1.2 Common year 4
1.2.1 Alternate 30 and 29 day months 4
1.2.2 Marking the Vassa and Major Moondays 4
1.3 Adhikamāsa year 5
1.3.1 Marking the Vassa and Major Moondays 5
1.4 Adhikavāra year 5

Section 2 · The Mahānikāya Uposatha Calendar Method 6

2.1 Adding the extra month 6
2.2 Adding the extra day 6
2.3 Marking the Vassa and Major Moondays 6

Section 3 · The Thai luni-solar calendar 9

3.1 Date of New Year in Thailand 11
3.2 Time periods in the Calendar 11
3.2.1 Years 11
3.2.2 Months 11
3.2.3 Seasons 12
3.2.4 Days 12
3.3 Names of the months 12

Section 4 · Suriyayatra formulas 14

4.1 Overview 14
4.2 Calculating the properties of the year 15
4.3 Adhikamāsa conditions 17
4.4 Adhikavāra conditions 17
4.5 Calculating the Position of the Sun and the Moon 18

Section 5 · The Duang Chata 21

5.1 Rasi 22
5.2 Nakshatra, lunar mansions 22

Section 6 · In Golang 23

6.1 Year 1288 23
6.2 Date of Casting of the Mangrai Buddha 24

Colophon 25

Bibliography 26

Full page includes 26

1 Mahānikāya Uposatha Calendar Tutorial

This section is a step-by-step guide on how to calculate the uposathas for the period of a **solar** year.

The boundaries of lunar months and season overlap. The months end on the day of the New Moon, the seasons end on the day of the Full Moon. More on this at sec. 3.2.

1.1 Collecting information about the year

We need to know the following:

- the last uposatha of the previous Rainy Season, Kattika Full Moon
- whether there is an extra lunar month (adhikamāsa),
- or an extra day (adhikavāra),
- or neither, and so this is a common year.

Find the Full Moon in last year November, this is Kattika Full Moon, the last uposatha of the previous Rainy Season.

In Thai practice a lunar year can't have both an adhikamāsa and an adhikavāra.

Check Table 1.1 whether the given year will have an adhikamāsa or adhikavāra. For more data, see Table 2.1.

Keep in mind that the data on future adhikavāra years is provisional. Even when a year would be due for an adhikavāra, the calendar authorities may choose to add it in a different year.

Now we know that the year is either:

- a common year,
- an adhikamāsa year, or
- an adhikavāra year.

Gregorian leap years don't affect the lunar calendar, but it may be useful to check when planning ahead. Table 1.2 shows a few leap years.

Table 1.2: Gregorian leap years

2004	2016	2028	2040
2008	2020	2032	2044
2012	2024	2036	2048

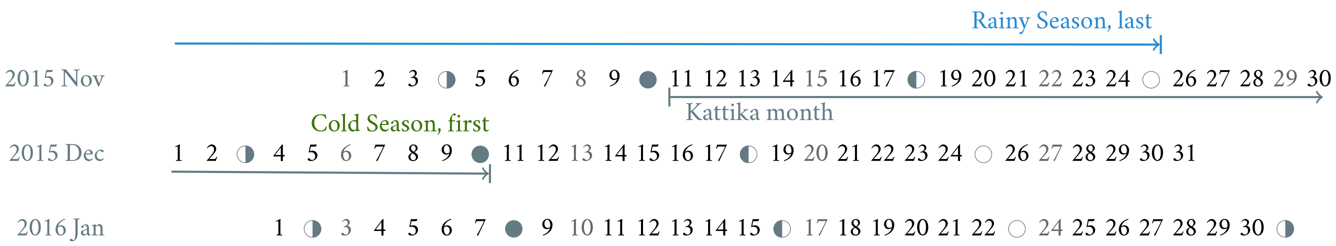
Year	Δ M	Δ V
2000		6
2001		
2002	3	
2003		
2004	2	
2005		5
2006		
2007	3	
2008		
2009		4
2010	3	
2011		
2012	2	
2013		
2014		
2015	3	
2016		7
2017		
2018	3	
2019		
2020		4
2021	3	
2022		
2023	2	
2024		
2025		5
2026	3	
2027		
2028		
2029	3	
2030		5

Table 1.1: 2000-2030.

ΔM, ΔV: years since the last adhikamāsa (M) or adhikavāra (V).

1.2 Common year

1.2.1 *Alternate 30 and 29 day months*



Kattika is the 12th lunar month, 30 days long. Complete the month by adding a 15-day New Moon after the Full Moon.

The 1st month is Magasira, 29 days long. Add a 15-day Full Moon and a 14-day New Moon.

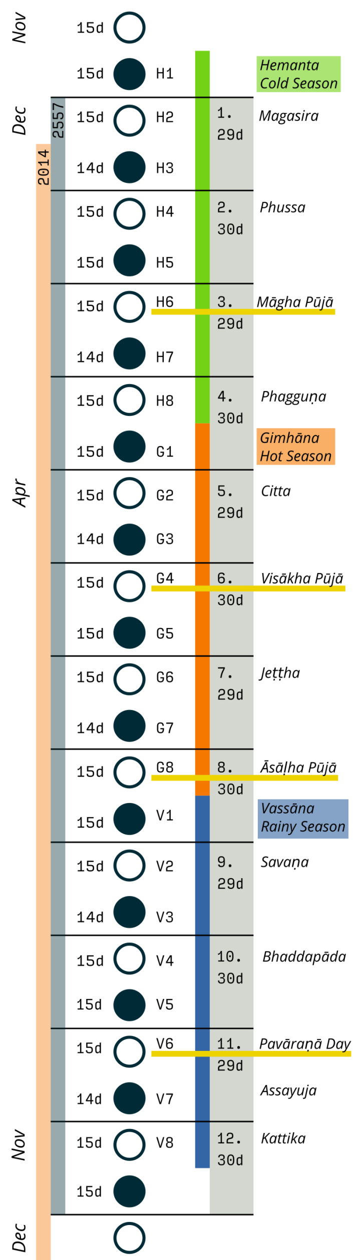
15 days	○ Full Moon	Kattika	Last uposatha of the Rainy Season
15 days	● New Moon	Kattika	End of the 12th month, 30 days
15 days	○ Full Moon	Magasira	
14 days	● New Moon	Magasira	End of the 1st month, 29 days

The Full Moon is always on the 15th day. Every second New Moon is on the 14th day.

The ◐ Waxing- and ◑ Waning Moons are on the 8th day.

Keep alternating 30 and 29 day months. One season is four months, one year is three seasons: Cold-, Hot- and Rainy Season. See Figure 1.1 or Table 3.1 for the Pāli names of months and seasons.

Figure 1.1: Common Year.



1.2.2 *Marking the Vassa and Major Moondays*

Mark the months and seasons according to Figure 1.1.

The key annual events are on the Full Moon of the given lunar months.

Table 1.3: Major Events in a Common Year

Event	Time
Māgha Pūjā	3rd Full Moon
Visākha Pūjā	6th Full Moon
Āsāḷha Pūjā	8th Full Moon
First Day of Vassa	the day after Āsāḷha
Pavāraṇā Day	11th Full Moon
Last Day of Vassa	Pavāraṇā Day

Mark the Vassa (Rainy Season Retreat):

- The first day of the Vassa is the day after Āsāḷha Pūjā
- The last day of the Vassa is Pavāraṇā Day

The Vassa Retreat therefore is 6 uposathas long (5 + Pavāraṇā), and the Vassāna season is 8 uposathas.

In a common year, the calendar is finished.

1.3 Adhikamāsa year

1.3.1 *Marking the Vassa and Major Moondays*

Adding the extra month has three consequences:

- the Major Moondays shift to the next Full Moon
- Gimhāna (Hot Season) has 10 uposathas instead of 8
- the Vassa starts 30 days later

The extra month is a 30 day month. In Thai practice, it is added after the 8th month (Āsāḷha). The convention is to call this the 'second 8th' or 'second Āsāḷha', marked as 8/8. The Hot Season will end on the Full Moon day of the 2nd Āsāḷha.

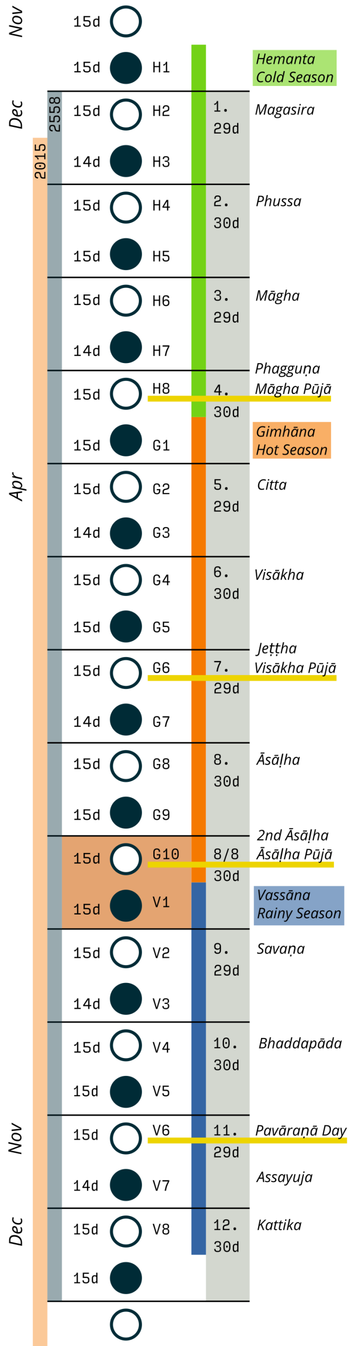
Āsāḷha Pūjā will be held in the 8/8 2nd Āsāḷha month, the first day of the Vassa being on the following day. The Vassa remains the same length, 8 uposathas.

Āsāḷha Pūjā and Pavāraṇā Day therefore shifted 30 days later in the year.

Māgha Pūjā and Visākha Pūjā are moved to the next month, and are marked in the 4th and 7th month instead of the 3rd and 6th. The origin of this practice is not clear, but it has the advantage that there will not be a large gap between Visākha and Āsāḷha Pūjā (now in the 2nd Āsāḷha).

Figure 1.2 shows how the sequence of the uposathas and the major moondays fall in an adhikamāsa year.

Figure 1.2: Adhikamāsa Year.



1.4 Adhikavāra year

The extra day is inserted at the 7th uposatha of the Hot Season (the New Moon uposatha before Āsāḷha Full Moon), making it a 15-day uposatha instead of the expected 14-day, and making Jeṭṭha a 30-day month that year.[1]

In adhikavāra years the Vassa starts one day later.

order	name	days
6	Visākha	30
7	Jeṭṭha	**30**
8	Āsāḷha	30
9	Savaṇa	29

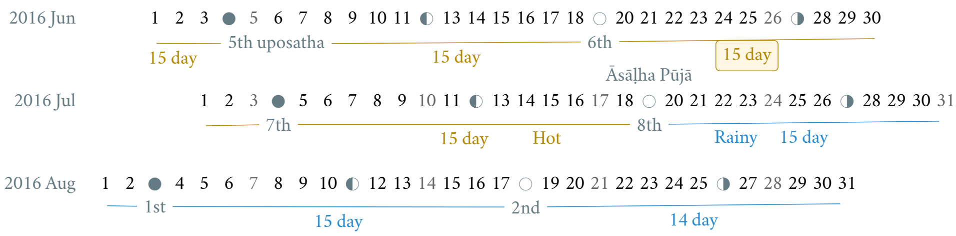
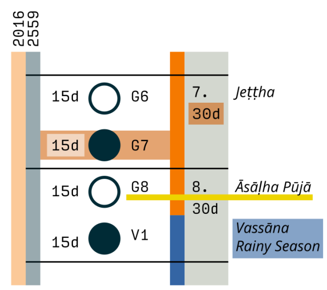


Figure 1.3: Adhikavāra Year.



[1] Hāsapañño, *The Lunar and Solar Zodiac*.

2 THE MAHĀNIKĀYA UPOSATHA CALENDAR METHOD

2.1 Adding the extra month

The extra month (adhikamāsa) is added 7 times in a 19 year period. This is determined by the formulas at sec. 4, which generate a pattern such that an adhikamāsa year is due in every 2 or 3 years.

It is not sufficient to rely on a shorthand pattern to determine the variation of 2 or 3 years – the pattern of 3-3-2 - 3-3-3-2 has been mentioned by Ajahn Khemanando,[1] but this doesn't always match the cycles produced by the formulas.

Table 2.1 shows adhikamāsa years for 1975-2030.

order	name	days
8	Āsāḷha	30
8/8	2nd Āsāḷha	30
9	Savaṇa	29

The extra month is a 30 day month. In Thai practice, it is added after the 8th month (Āsāḷha). The convention is to call this the 'second 8th' or 'second Āsāḷha', marked as 8/8. The Hot Season will end on the Full Moon day of the 2nd Āsāḷha.

In adhikamāsa years the Vassa starts 30 days later, on the day after the Full Moon uposatha of the 2nd Āsāḷha.

2.2 Adding the extra day

The extra day (adhikavāra) is added 11 times in every 57 year.

Whether a year should have an extra day is determined by the conditions at sec. 4.4.

In Thai practice a year with an extra month is not allowed to also have an extra day. If the year should have an extra day, but it already has an extra month, the extra day is assigned to one of the flanking years (next or previous, in the case of planning several years in advance).

In adhikavāra years the Vassa starts one day later.

The extra day is inserted at the 7th uposatha of the Hot Season (the New Moon uposatha before Āsāḷha Full Moon), making it a 15-day uposatha instead of the expected 14-day, and making Jeṭṭha a 30-day month that year.[2]

The announcement of the adhikavāra years by the calendar authorities is not entirely predictable. In some of cases the calendar committees add the adhikavāra in a different year than the regular pattern. However, the years since 1997 have all been regular.

See Table 2.2 for examples of irregular years in the past.

Nonetheless it would be observed that:

- the count for 11 times in 57 years is maintained to keep the calendar at pace
- the extra day will not be in years that also have an extra month.

2.3 Marking the Vassa and Major Moondays

Common year: sec. 1.2.2

Adhikamāsa year: sec. 1.3.1

Adhikavāra year: the logic is the same as in common years.

[1] Khemanando, *The Cycle of the Adhikamāsa*.
[2] Hāsapañño, *The Lunar and Solar Zodiac*.

Table 2.1: Adhikamāsa and adhikavāra years

ΔM, ΔV: years since the last adhikamāsa (M) or adhikavāra (V). nM, nV: n-th place in the adhikamāsa 19-year cycle (M) or the adhikavāra 57 year cycle. 'x' marks years which would qualify for adhikavāra, but there is already an adhikamāsa, and so the adhikavāra is carried on to the following year.

CE year	BE year	nM	Δ M	nV	Δ V
1975	2518	11	3	49	
1976	2519	12		50	
1977	2520	13	2	51	
1978	2521	14		52	5
1979	2522	15		53	
1980	2523	16	3	54	
1981	2524	17		55	
1982	2525	18		56	
1983	2526	19	3	57	
1984	2527	1		1	6
1985	2528	2	2	2	
1986	2529	3		3	
1987	2530	4		4	
1988	2531	5	3	5	
1989	2532	6		6	5
1990	2533	7		7	
1991	2534	8	3	8	
1992	2535	9		9	
1993	2536	10	2	10	
1994	2537	11		11	5
1995	2538	12		12	
1996	2539	13	3	13	
1997	2540	14		14	
1998	2541	15		15	
1999	2542	16	3	16	x
2000	2543	17		17	6
2001	2544	18		18	
2002	2545	19	3	19	
2003	2546	1		20	
2004	2547	2	2	21	x
2005	2548	3		22	5
2006	2549	4		23	
2007	2550	5	3	24	
2008	2551	6		25	
2009	2552	7		26	4
2010	2553	8	3	27	
2011	2554	9		28	
2012	2555	10	2	29	
2013	2556	11		30	
2014	2557	12		31	
2015	2558	13	3	32	x
2016	2559	14		33	7
2017	2560	15		34	
2018	2561	16	3	35	
2019	2562	17		36	
2020	2563	18		37	4
2021	2564	19	3	38	
2022	2565	1		39	
2023	2566	2	2	40	
2024	2567	3		41	
2025	2568	4		42	5
2026	2569	5	3	43	
2027	2570	6		44	
2028	2571	7		45	
2029	2572	8	3	46	
2030	2573	9		47	5

Table 2.2: Irregular Adhikavāra years. Past calendar sources: myhora.com, thaiorc.com.

CE year	BE year	K	A	T	nM	Δ M	nV	Δ V	Āsāḷha by Calc.	Āsāḷha in Calendar	test	comments
1977	2520	54	252	27	13	2	51		1977-07-30	1977-07-30		
1978	2521	647	126	9	14		52	5	1978-07-20	1978-07-19	X	adhikavāra is missing from the calendar
1979	2522	440	681	19	15		53		1979-07-09	1979-07-09		
…												
1983	2526	412	144	4	19	3	57		1983-07-24	1983-07-24		
1984	2527	205	7	15	1		1	6	1984-07-13	1984-07-12	X	adhikavāra is missing
1985	2528	798	573	26	2	2	2		1985-08-01	1985-07-31	X	off by -1 day
1986	2529	591	436	7	3		3		1986-07-21	1986-07-20	X	off by -1 day
1987	2530	384	299	18	4		4		1987-07-10	1987-07-10		
…												
1993	2536	742	191	25	10	2	10		1993-08-02	1993-08-02		
1994	2537	535	54	6	11		11	5	1994-07-23	1994-07-22	X	adhikavāra is missing
1995	2538	328	609	16	12		12		1995-07-12	1995-07-11	X	off by -1 day
1996	2539	121	472	27	13	3	13		1996-07-30	1996-07-29	X	off by -1 day
1997	2540	714	346	9	14		14		1997-07-19	1997-07-19		

3 THE THAI LUNI-SOLAR CALENDAR

Luni-solar calendars are constructed so as to count **years** according to the *solar* cycle, but to count **months** according to the *lunar* cycle.

tropical year[1] of the Earth	365.24219 days
synodic month[2] of the Moon	~29.53 days, can vary up to 7 hours

The epoch of the Thai lunar calendar is 25 March 638 CE, this is the beginning of the *Chulasakkarat Era*.[3]

The epoch of the *Buddhist Era* is the date when the Buddha attained Parinibbāna. According to Thai tradition it is 11 March 545 BCE, but the difference between CE and BE in Thailand is now fixed at 543 years.[4]

Thus the conversion between the eras:

CE 1963	Common Era	
BE 2506	Buddhist Era	CE + 543
CS 1325	Chulasakkarat Era	CE - 638

The Thai luni-solar calendar is *procedural*. It uses a few constant, key numbers derived from astronomical observations, and applies a series of mechanical calculations (i.e. the "rules") again and again to generate the dates of lunar phases and new years.

> This working is deliberately concise, since it thereby reflects how the calculation would have been made by a South East Asian calendrist. Each stage is subjected to an operation learnt by rote, and the underlying theory disappears from view. The rote operations, however, will provide a valid answer for any date in any year. It seemed greatly preferable to set out the procedure thus starkly, rather than to give a detailed exposition of what is involved.[5]

Southeast Asian astronomers refined a fraction to obtain the length of the year. Taking 800 years as one Era and 292207 days in the Era, they expressesed the length of one year in days as:[6]

$$\frac{292207}{800} = 365.25875 \text{ days} \tag{3.1}$$

This is 0.01656 days longer than the modern measurement (accumulating 1 day in ~60 years). Remarkably, the *suriyayatra* accounts for this and generates accurate results:

> For instance, a Pagan inscription of 14 April 1288 AD maintains that at midnight the Sun's position was 0 signs, 19 degrees and 59 minutes: the computer program returns 0 19 59.[7]

The program prints:

```
Horakhun: 1
Date: 0638 March 25
True Sun: 0:2°38'
True Moon: 0:20°30'
Tithi: 1
```

Which can be represented on a zodiac wheel:

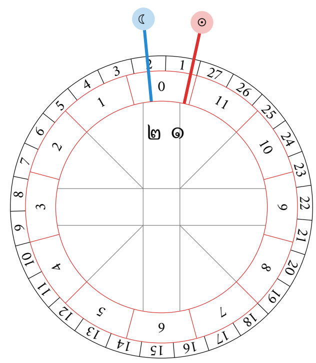


Figure 3.1: Horakhun 1, first day of the CS Era

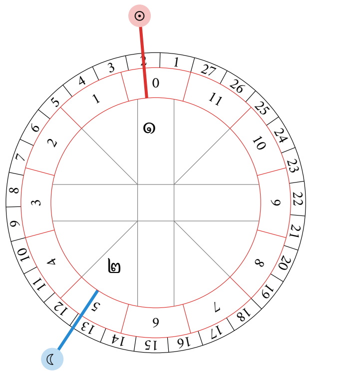
[1] tropical year: the time it takes the Earth to complete an orbit around the Sun
[2] synodic month: the time it takes the Moon to reach the same visual phase
[3] Eade, *Calendrical Systems*.
[4] Ibid.
[5] Eade, "Interpolation in the Thai Calendar".
[6] Ibid.
[7] Eade, *Calendrical Systems*, p. 2.

Let's see if we can get the same results. 14 April 1288 was 41 days into the lunar year, counting from Citta 1. While checking that, we might as well see day 103, i.e. 15 June 1288, which should turn out to be Āsāḷha Pūjā.

The code example is at 6.1. It prints:

```
Year: 1288
Adhikamāsa: false
Adhikavāra: false
---
Year, Day: 1288, 41
True Sun: 0:19°58'
True Moon: 5:11°27'
Tithi: 12
---
Year, Day: 1288, 103
True Sun: 2:19°9'
True Moon: 8:19°1'
Tithi: 15
```

Figure 3.2: 1288 April 14



Sun:	0:19°58′
Moon:	5:11°27′
Tithi:	12

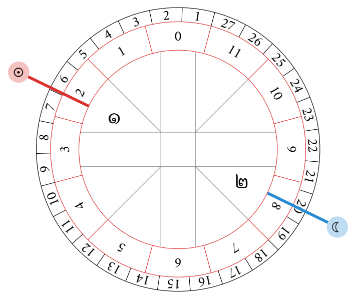
The Moon is in the 13. nakshatra, Hasta.

On day 103, tithi 15 means 15 lunar days since last New Moon, i.e. it is Full Moon. The Sun and Moon are angularly opposite, which also means Full Moon, and it appears in the 20. nakshatra, so the month is Āsāḷha.

As a reality check, we can look up the historical phases and see if the day is listed under the Full Moons:[8]

Year	New Moon	First Quarter	Full Moon	Last Quarter
1288	Jan 5 04:22	Jan 12 02:53	Jan 20 07:58	Jan 27 23:48
	Feb 3 14:57	Feb 10 21:41	Feb 19 00:59	Feb 26 08:21
	Mar 4 01:58	Mar 11 17:25	Mar 19 15:17	Mar 26 14:37
	Apr 2 13:53 A	Apr 10 12:25	Apr 18 02:44 p	Apr 24 19:57
	May 2 02:54	May 10 05:36	May 17 11:40	May 24 01:51
	May 31 16:54	Jun 8 20:25	Jun 15 18:54	Jun 22 09:39
	Jun 30 07:40	Jul 8 08:40	Jul 15 01:30	Jul 21 20:20
	Jul 29 22:55	Aug 6 18:29	Aug 13 08:43	Aug 20 10:25
	Aug 28 14:20	Sep 5 02:22	Sep 11 17:43	Sep 19 03:48
	Sep 27 05:25 A	Oct 4 09:13	Oct 11 05:18 t	Oct 18 23:46
	Oct 26 19:36	Nov 2 16:13	Nov 9 19:44	Nov 17 21:00
	Nov 25 08:28	Dec 2 00:37	Dec 9 12:39	Dec 17 17:31
	Dec 24 19:59	Dec 31 11:17		

Figure 3.3: 1288 June 15



Sun:	2:19°9′
Moon:	8:19°1′
Tithi:	15

The Moon is in the 20. nakshatra, Pūrva Ashādhā.

Nonetheless, the calendar dates published in Thailand (historical or recent) in a given year reflect not only these principles, but also adjustments and omissions which cannot be foreseen or retraced.

> The historical record however, frequently defies prediction, forcing the conclusion that the pressure upon the *horas* (astronomers / astrologers) was not to follow the "rules" but merely, within some more leisurely constraints, to ensure that the calendar did not get out of control.[9]

Eade discusses a calendar error in CS 855 (CE 1493) when the formulas have determined a *twelfth* adhikavāra year in a 57 year period, which was not noticed by several astronomers at the time, who were using the "11 times in 57 years" rule of thumb for

[8] AstroPixels - Moon Phases: 1201 to 1300

[9] Eade, *Calendrical Systems*.

adhikavāra years. This resulted in wrong dates being used on any inscriptions (carved into stone) until the error was corrected in the civil calendar.[10]

3.1 Date of New Year in Thailand

The officially used new year date in Thailand is January 1st, after a government ruling in 1940:

"…it is now appropriate for Thailand to observe New Year's Day on the first day of January."[11]

The Songkran festival, commonly called the Thai New Year, is held on April 13-14-15, at the time of the spring equinox.

3.2 Time periods in the Calendar

3.2.1 Years

The reckoning of the lunar year has an everyday convention which is aligned with the solar year. Here, the first month of the lunar year is Magasira in November.

By this reckoning Āsāḷha is the 8th month, and hence the 2nd Āsāḷha is marked 8/8, เดือน ๘/๘.

A different reckoning is assumed in the formulas which is based on the zodiac wheel. Here, the first month is Citta in April. This is at the spring equinox, which is at 0° on the wheel, corresponding to Aries.

3.2.2 Months

In Thai practice, a lunar month is a wave: it has a waxing phase, its crest is in the middle at Full Moon, and has a waning phase ending with the New Moon on the last day.

The lunar months (duean เดือน) are alternatingly 29 or 30 days long. The waxing phase (khang khuen ข้างขึ้น) to the Full Moon is always 15 days, every second waning phase (khang raem ข้างแรม) is 14 days.[12]

This convention gives a consistent way to refer to the day of the Full Moon, which are always on the 15th day of the month: Visākha 15, Āsāḷha 15, etc.

The waxing and waning moons are marked on the 8th day from the Full- or New Moon day.

[10] Eade, "Irregular dating in Lan Na: an anomaly resolved".
[11] Wikipedia, "Proclamation on Observance of New Year's Day on 1 January".
[12] Wikipedia, "Thai lunar calendar".

3.2.3 *Seasons*

The first season of the lunar year is the Cold Season, which begins after Kattika Full Moon.

Cold Season ends on:	Hemanta Phagguṇa 15
Hot Season ends on:	Gimhāna Āsāḷha 15
Rainy Season ends on:	Vassāna Kattika 15

Marking the seasons is a monastic tradition. Periods in the monastic calendar are observed between certain Full Moon days of the year, and so the seasons end on Full Moon days.

The lunar months end on the New Moon day, the month and season boundaries therefore overlap.

The months and seasons are two separate way of referencing lunar phases, they are never used together in the same expression.

They are used in different contexts too, so the overlap doesn't seem to bother anyone. The civil calendar marks periods by *months* in the year, but the monastic calendar is concerned instead with the number of *uposathas* in the season.

The monastic tradition references Full- and New Moons as the "Nth uposatha of the X Season."

3.2.4 *Days*

A 'day' marks the time at midnight on that day, unless the time is specified. Positions of the Sun, the Moon and other calculated properties of the day are understood to reach that value at midnight.

3.3 Names of the months

The zodiac wheel is divided in 27 segments called *nakshatra*, associated with and area of the sky around certain stars.

The name of a given month is determined by the nakshatra which the Full Moon enters at midnight. See Table 3.1.

Table 3.1: Lunar and Solar Months and Zodiacs[13]

Season		days	Lunar Month	Solar Month	Solar Zodiac (Western / Sanskrit)
Hemanta	1	29	Magasira	December	Sagittarius / Dhanus
Cold Season	2	30	Phussa	January	Capricorn / Makara
	3	29	Māgha	February	Aquarius / Kumbha
	4	30	Phagguṇa	March	Pisces / Mīna
Gimhāna	5	29	Citta	April	Aries / Meṣa
Hot Season	6	30	Visākha	May	Taurus / Vṛṣabha
	7	29	Jeṭṭha	June	Gemini / Mithuna
	8	30	Āsāḷha	July	Cancer / Karkaṭa
Vassāna	9	29	Savaṇa	August	Leo / Siṃha
Rainy Season	10	30	Bhaddapāda	September	Virgo / Kanyā
	11	29	Assayuja	October	Libra / Tulā
	12	30	Kattika	November	Scorpio / Vṛścika

[13] Hāsapañño, *The Lunar and Solar Zodiac*.

Table 3.2: Adhikamāsa and adhikavāra in the period 1958 to 1978 (CS 1320-1340).[14]

m for adhikamāsa, d for adhikavāra years, Δm and Δd for years since last adhikamāsa and adhikavāra.

Δ d		Δ m		year	type	Asalha	2nd Asalha
		0		1320	m	19:42	22:24
0		1		1321	d	21:05	
1		2		1322		20:40	
2		3	3	1323	m	19:12	22:00
3		4		1324		20:38	
4	4	5		1325	d	19:34	
5		6	3	1326	m	19:38	22:05
6		7		1327		21:15	
7		8	2	1328	m	19:20	22:55
8		9		1329		21:48	
9	5	10		1330	d	20:26	
10		11	3	1331	m	19:59	22:50
11		12		1332		21:20	
12		13		1333		20:02	
13		14	3	1334	m	19:03	21:33
14	5	15		1335	d	20:40	
15		16		1336		20:44	
16		17	3	1337	m	19:44	22:19
17		18		1338		21:11	
18		19	2	1339	m	19:45	22:35
19	5			1340	d	21:05	

[14] Eade, "Interpolation in the Thai Calendar".

4 SURIYAYATRA FORMULAS

4.1 Overview

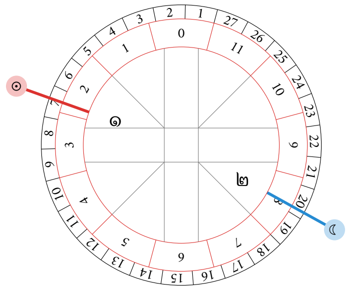
The formulas take two inputs: the year, and the n^{th} day in the lunar year. They go through a series of operations step by step to produce certain values which describe properties of the lunar year and the given day.

In this context, the lunar year starts at the spring equinox: this is 0° on the zodiac wheel, Aries, Citta 1, April.

The results are used to determine whether the year is common, adhikamāsa or adhikavāra. They can also give us the angular position of the Sun and the Moon on a particular day.

For example in a common year, when we calculate the Moon's position for $\mathbf{day} = 103$, it should tell us that it is Full Moon, and it is found in the region of the sky associated with Āsāḷha month.

Figure 4.1: 2014 July 11, Āsāḷha Full Moon



True Sun:	$2{:}25^\circ 22'$
True Moon:	$8{:}16^\circ 6'$
Raek:	$20{:}12'$
Masaken:	17022
Avoman:	391
Horakhun:	502683
Kammacubala:	69195
Uccabala:	1102
Tithi:	14

At midnight the Moon would be seen in the 20. Nakshatra, Pūrva Ashādhā, around the stars δ and ε Sagittarii.

Significant values are assigned names.[1] The following three will determine the adhikamāsa and adhikavāra:

Kammacubala กัมมัชพล used as a remainder value for 800ths of a day,
1 day = 800 kammacubala

Avoman อวมาน used for the Moon's mean motion,
1 day = 11 avoman

Tithi[2] **ดิถี** age of the Moon in *lunar* days, from 0-29,
692 solar days = 692 + 11 lunar days

As we follow the steps, we will also obtain:

Horakhun[3] **อหรคุณ** day index, or elapsed days of the era

Uccabala อุจจพล age of the Moon's apogee

Masaken มาสเกณฑ์ elapsed months of the era

MeanSun, TrueSun, MeanMoon, TrueMoon Mean- and True longitude of the Sun and the Moon

Raek The position of the Moon in terms of the 27 lunar mansions, which will determine the month

While mean longitude measures a mean position and assumes constant speed, true longitude meausures the actual longitude and assumes the body has moved with its actual speed, which varies around its elliptical orbit.[4]

The zodiac wheel (a.k.a *duang chata*, sec. 5) is divided into 12 segments called *rasi* (ราศี), 30° each, and into 27 lunar mansions called *nakshatra* (นักษัตร), $13^\circ 20'$ each.

Angular positions are given in a notation that expresses the rasi number plus the degrees and arcminutes. These values are also called the *rasi*, *angsa* and *lipda*.

$2 : 25^\circ 22'$ notation represents *rasi*, *angsa* (degrees), *lipda* (minutes).
$r : a^\circ l' = r * 30 + a + l/60$,
thus $85^\circ 22'$ is $2 : 25^\circ 22'$.

[1] Eade, *Southeast Asian Ephemeris*.
[2] a.k.a. Thaloengsok or New Year's Day
[3] a.k.a. Ahargana
[4] Wikipedia, "Mean longitude".

Only basic operations in a series of simple steps are necessary to produce these results. It can be carried out entirely on paper, although the aim here is to get the machine to do it for us eventually.

This is a simplistic clockwork model of the solar system. It is not a framework to model orbital mechanics, and doesn't account for such things as the varying speed of the Moon in its elliptical orbit.

Therefore there can be inaccuracies for a given day between its results and observations made with telescopes (or indeed by plain sight) about what is actually going on "out there", but nonetheless it keeps the long-term calendar in sync with the periodic cycles of the celestial bodies.

Consider the ancient *hora* โหรา (astronomer / astrologer) in a rural village who is practising these steps. He doesn't have the equipment to make precise astronomical observations. He is not educated in the underlying theory of the complex interaction of the Sun, Earth and the Moon. He is only trained in following the steps, and still this allows him to obtain the necessary information to describe the progression of these events in any year.

4.2 Calculating the properties of the year

First we will see if we should add an extra month or extra day to keep the lunar year in sync with the solar year.

Then we will calculate the position of the Moon for the day that should be Āsāḷha Pūjā, see if the Moon is Full, and if we are in fact in Āsāḷha month, and not at some other Full Moon.

We can also use other sources to check us, looking up historical phases of the Moon can show us if the Āsāḷha Pūjā date had in fact been a Full Moon.

Let's take the year CE 1963 (CS 1325) as an example and calculate its properties. We should find that it is an adhikavāra year. If you calculate the following year CE 1964 (CS 1326) as an excercise, you should find that it is adhikamāsa.

Era Constants. The offsets are required because their value was not 0 at the beginning of the Era. For readability, where the meaning is not ambiguous, we will use their values directly.

CS_{diff}	638	CE - CS Era difference	U_{base}	3232	Uccabala base for 360°
$Days_{Era}$	292207	Days in the Era	$Days_M$	30	Days in a month
$Years_{Era}$	800	Years in the Era	$Days_{Cycle}$	692	Days in a cycle
H_{Era}	373	Horakhun Era offset	$Tithi_{Cycle}$	703	Tithi in a cycle
U_{Era}	2611	Uccabala Era offset	$Tithi_{inc}$	11	Tithi daily increase
A_{Era}	650	Avoman Era offset	Kc_{inc}	800	Kammacubala daily increase

The relationship between cycles of **solar days** and **tithi** (lunar days): ”For every 692 solar days that elapse there are also 703 tithi. Since 703 / 692 can be expressed as 692 + 11 / 692, the ratio is simplified to these terms ... 11 is the daily increase (excess tithi over days).”[5]

$$\frac{703}{692} = \frac{692 + 11}{692} \tag{4.1}$$

Let’s begin then:

$$\begin{aligned}
\textbf{CS_year} &= \textbf{CE_year} - 638 \\
&= 1325 && (4.2)\\
a &= (\textbf{CS_year} * 292207) + 373 \\
&= 387174648 && (4.3)\\
\textbf{Horakhun} &= \lfloor a/800 + 1 \rfloor \\
&= 483969 && (4.4)\\
\textbf{Kammacubala} &= 800 - (a \bmod 800) \\
&= 552 && (4.5)\\
\textbf{Uccabala} &= (\textbf{Horakhun} + 2611) \bmod 3232 \\
&= 1780 && (4.6)\\
a &= (\textbf{Horakhun} * 11) + 650 \\
&= 5324309 && (4.7)\\
\textbf{Avoman} &= a \bmod 692 \\
&= 61 && (4.8)\\
b &= \lfloor a/692 \rfloor \\
&= 7694 && (4.9)\\
\textbf{Masaken} &= \lfloor (b + \textbf{Horakhun})/30 \rfloor \\
&= 16388 && (4.10)\\
\textbf{Tithi} &= (b + \textbf{Horakhun}) \bmod 30 \\
&= 23 && (4.11)
\end{aligned}$$

Now we can determine if the year qualifies for adhikamāsa or adhikavāra.

Notation recap:

$a \bmod b$ produces the *remainder part* of a/b.

$14 \bmod 5 = 4$, because $14/5 = 2 * 5 + 4$.

$\lfloor a \rfloor$ *floors* (or truncates) a fraction value, meaning we discard the fraction part and only keep the integer part.

$\lfloor 12.8 \rfloor = 12$.

$|a|$ is the *absolute value* of a.

$|-4.21| = 4.21$ and $|4.21| = |4.21|$.

CS_{diff}	638
$Days_{Era}$	292207
$Years_{Era}$	800
H_{Era}	373
U_{Era}	2611
A_{Era}	650
U_{base}	3232
$Days_M$	30
$Days_{Cycle}$	692
$Tithi_{Cycle}$	703
$Tithi_{inc}$	11
Kc_{inc}	800

[5] Eade, *Calendrical Systems*, p. 48.

4.3 Adhikamāsa conditions

Thai: atikamat อธิกมาส

The year could be adhikamāsa:

- **IF** the **Tithi** is between 24 and 29 inclusive,
- **OR** between 0 and 5 inclusive,
- **THEN** it could be adhikamāsa.

However:

- **IF** the next year also satisfies the above,
- **THEN** this year will not be adhikamāsa, and the next year will be.

Adhikamāsa years are not allowed to be contiguous, and max. 2 years are allowed between them. If next year also qualifies for adhikamāsa, then it will be assigned there and not to the current year.

In the above example for year CS 1325, the **Tithi** is 23, which doesn't satisfy the first condition, and so it can't be adhikamāsa.

4.4 Adhikavāra conditions

Thai: atikawan อธิกวาร

Determine if it is a leap year:

- **IF** the **Kammacubala** is less than or equal to 207,
- **THEN** it is a leap year.

The year could be adhikavāra:

- **IF** it is a leap year **AND** the **Avoman** is less than or equal to 126,
- **THEN** it could be adhikavāra.
- **ELSE IF** it is **NOT** a leap year **AND** the **Avoman** is less than 137,
- **THEN** it could be adhikavāra.

However:

- **IF** the year is adhikamāsa,
- **THEN** it can't be adhikavāra.
- **ELSE IF** there is a carried adhikavāra from last year,
- **THEN** this year will be adhikavāra.

"Carried adhikavāra" meaning that last year qualified both for adhikamāsa and adhikavāra, so it was not allowed to be assigned the adhikavāra, which was "carried on" and will now be assigned to this year.
In Thailand, years with an extra month are not allowed to also have an extra day, and the adhikavāra may be assigned to one of the flanking years. So in theory it could be assigned to the following or preceding year, but the general practice is to "carry on" the adhikavāra and assign it to the following year.

In the above example for year CS 1325: The year is not adhikamāsa, so we can examine it further. The **Kammacubala** is 552 so it is not a leap year. The **Avoman** is 61, so the year qualifies to be assigned an adhikavāra.

Now we know if the year is adhikamāsa, adhikamāsa or common, and we can plan the uposathas as shown in the diagram on p.27.

Checking the past calendars for year CS 1325 (see Table 3.2), we see that indeed it was adhikavāra, conforming to the formulas.

Nonetheless, the future remains uncertain and the past inscrutable at times. When the calendar comittees plan several years ahead, they may assign the adhikavāra to a different year for reasons that remain obscured, causing at least two irregular years. This can be observed in past calendars (Table 2.2), but recently this hasn't been happening, and the years follow the prediction of the formulas.

4.5 Calculating the Position of the Sun and the Moon

Eade describes the formulas at the end of his paper *Rules for interpolation in the Thai calendar*.[6] This allows us to continue examining the year CE 1963 (CS 1325).

We know now that the year needed an adhikavāra extra day, so Āsāḷha Pūjā is one day later, on day 104, which is 1963 July 6. Let's find the position of the Sun and the Moon on that day, to see if the Moon reached its Full phase, and if it is in the region of the sky associated with the correct month (i.e. the nakshatra).

The **Horakhun**, etc. values now relate to the **day**, unless marked otherwise. First we establish the properties of the day:

His notation however, is a puzzle in itself, with its implied conversions and obscure progression from one step to the next.
The folks at Astronomy Stack Exchange helped to decipher it:

- How to interpret this old degree notation?
- From Mean Moon to True Moon in an old procedural calendar

$$\begin{aligned}\textbf{elapsedDays} &= \textbf{Day} - \textbf{Year\_Tithi} \\ &= 81\end{aligned} \tag{4.12}$$

$$\begin{aligned}\textbf{Horakhun} &= \textbf{Year\_Horakhun} + \textbf{elapsedDays} \\ &= 484050\end{aligned} \tag{4.13}$$

$$\begin{aligned}\textbf{Kammacubala} &= Kc_{inc} - (\textbf{CS\_Year} * 292207 + 373) \bmod Years_{Era} \\ &\quad + \textbf{elapsedDays} * Kc_{inc} \\ &= 65352\end{aligned} \tag{4.14}$$

$$\begin{aligned}\textbf{Uccabala} &= (\textbf{Horakhun} + 2611) \bmod 3232 \\ &= 1861\end{aligned} \tag{4.15}$$

$$\begin{aligned}a &= (\textbf{Horakhun} * 11) + 650 \\ \textbf{Avoman} &= a \bmod 692 \\ &= 260\end{aligned} \tag{4.16}$$

$$\begin{aligned}b &= \lfloor a/692 \rfloor + 2611 + \textbf{Horakhun} \\ \textbf{Masaken} &= \lfloor b/30 \rfloor \\ &= 16391\end{aligned} \tag{4.17}$$

$$\begin{aligned}\textbf{Tithi} &= b \bmod 30 \\ &= 15\end{aligned} \tag{4.18}$$

CS_{diff}	638
$Days_{Era}$	292207
$Years_{Era}$	800
H_{Era}	373
U_{Era}	2611
A_{Era}	650
U_{base}	3232
$Days_{M}$	30
$Days_{Cycle}$	692
$Tithi_{Cycle}$	703
$Tithi_{inc}$	11
Kc_{inc}	800

Find the position of the **Mean** and **True Sun**:

Degree to radian conversion noted as $a_{rad} = a * \frac{\pi}{180}$.

Note that 60 converts values between degrees and arcminutes:

$$a^\circ * 60 = b' \quad \text{and} \quad b'/60 = a^\circ$$

[6] Eade, "Rules for interpolation in the Thai calendar".

$$
\begin{aligned}
a &= \textbf{elapsedDays} * Years_{Era} + \textbf{Year\_Kammacubala} \\
\textbf{MeanSun} &= (a/Days_{Era}) * 360° - 3' \\
&= 80.45° = 2 : 20°27'
\end{aligned} \tag{4.19}
$$

$$
\begin{aligned}
a &= |\textbf{MeanSun} - 80°| \\
\textbf{TrueSun} &= \textbf{MeanSun} + \frac{\lfloor 134 * sin(a_{rad}) \rfloor}{60} \\
&= 80.4666° = 2 : 20°27'
\end{aligned} \tag{4.20}
$$

CS_{diff}	638
$Days_{Era}$	292207
$Years_{Era}$	800
H_{Era}	373
U_{Era}	2611
A_{Era}	650
U_{base}	3232
$Days_M$	30
$Days_{Cycle}$	692
$Tithi_{Cycle}$	703
$Tithi_{inc}$	11
Kc_{inc}	800

$-3'$ and $-40'$ are geographical correction for the Sun and the Moon.[7]

$-80°$ is the Sun's apogee value for Mean- to True longitude conversion.[8]

Find the position of the **Mean** and **True Moon**:

$$
\begin{aligned}
a &= \frac{\textbf{Avoman} + \lfloor \textbf{Avoman}/25 \rfloor}{60} \\
\textbf{MeanMoon} &= \textbf{TrueSun} + a° + \textbf{Tithi} * 12° - 40' \\
&= 264.2999° = 8 : 24°17'
\end{aligned} \tag{4.21}
$$

One **Tithi** is 12°, from $360°/30 = 12°$.

The **meanUccabala** in one step:

$$
\begin{aligned}
\textbf{meanUccabala} &= \left(\frac{(\textbf{Year\_Uccabala} + \textbf{elapsedDays}) * 3}{808} * 30 * 60 + 2 \right) /60 \\
&= 207.4343° = 6 : 27°26'
\end{aligned} \tag{4.22}
$$

Breaking it down:

- Multiply by 30 to conform with the notation $r : a°l' = 30 * r + a + l/60$.
- Division by 808 probably helps to express the length of the lunar month, since $808/30 = 26.9333$.
- Multiply by 60 to convert to arcmin
- Add 2, correction for geographical position
- Divide by 60 to convert back to degree

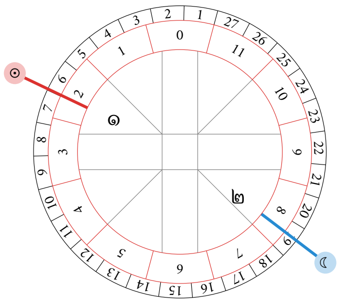
$13°20'$ is one nakshatra or lunar mansion, $360°/27$.

$$
\begin{aligned}
a &= \textbf{MeanMoon} - \textbf{meanUccabala} \\
\textbf{TrueMoon} &= \textbf{MeanMoon} - \frac{296 * sin(a_{rad})}{60} \\
&= 260.1636° = 8 : 20°9'
\end{aligned} \tag{4.23}
$$

$$
\begin{aligned}
\textbf{Raek} &= \textbf{TrueMoon}/13°20' + 1 \\
&= 20.5123° = 20°30'
\end{aligned} \tag{4.24}
$$

[7] Eade, "Rules for interpolation in the Thai calendar", p. 6, fn. 13.
[8] Eade, *Calendrical Systems*, p. 134.

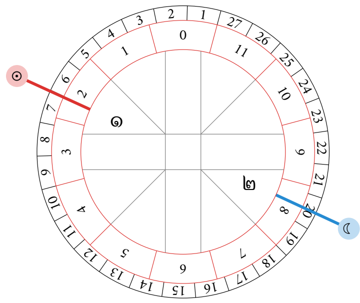
Day 103, 1963 July 5



Sun:	2:19°28′
Moon:	8:7°41′
Tithi:	14

19. nakshatra, Mūla.

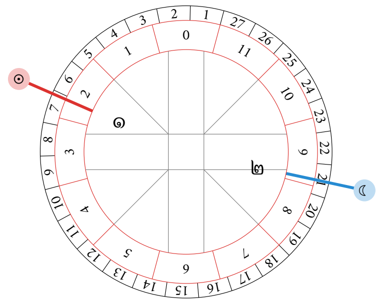
Day 104, 1963 July 6



Sun:	2:20°27′
Moon:	8:20°9′
Tithi:	15

20. nakshatra, Pūrva Ashādhā.

Day 105, 1963 July 7



Sun:	2:21°28′
Moon:	9:2°51′
Tithi:	16

21. nakshatra, Uttara Ashādhā.

Let's look up if 1963 July 6 is listed under Full Moons:[9]

Year	New Moon	First Quarter	Full Moon	Last Quarter
1963		Jan 3 01:02	Jan 9 23:08 n	Jan 17 20:34
	Jan 25 13:42 A	Feb 1 08:50	Feb 8 14:52	Feb 16 17:38
	Feb 24 02:06	Mar 2 17:17	Mar 10 07:48	Mar 18 12:08
	Mar 25 12:10	Apr 1 03:15	Apr 9 00:56	Apr 17 02:52
	Apr 23 20:29	Apr 30 15:07	May 8 17:23	May 16 13:36
	May 23 04:00	May 30 04:55	Jun 7 08:30	Jun 14 20:53
	Jun 21 11:46	Jun 28 20:23	Jul 6 21:55 p	Jul 14 01:57
	Jul 20 20:43 T	Jul 28 13:13	Aug 5 09:31	Aug 12 06:21
	Aug 19 07:34	Aug 27 06:54	Sep 3 19:34	Sep 10 11:42
	Sep 17 20:51	Sep 26 00:38	Oct 3 04:44	Oct 9 19:27
	Oct 17 12:43	Oct 25 17:20	Nov 1 13:55	Nov 8 06:37
	Nov 16 06:50	Nov 24 07:56	Nov 30 23:54	Dec 7 21:34
	Dec 16 02:06	Dec 23 19:54	Dec 30 11:04 t	

[9] AstroPixels - Moon Phases: 1901 to 2000

5 THE DUANG CHATA

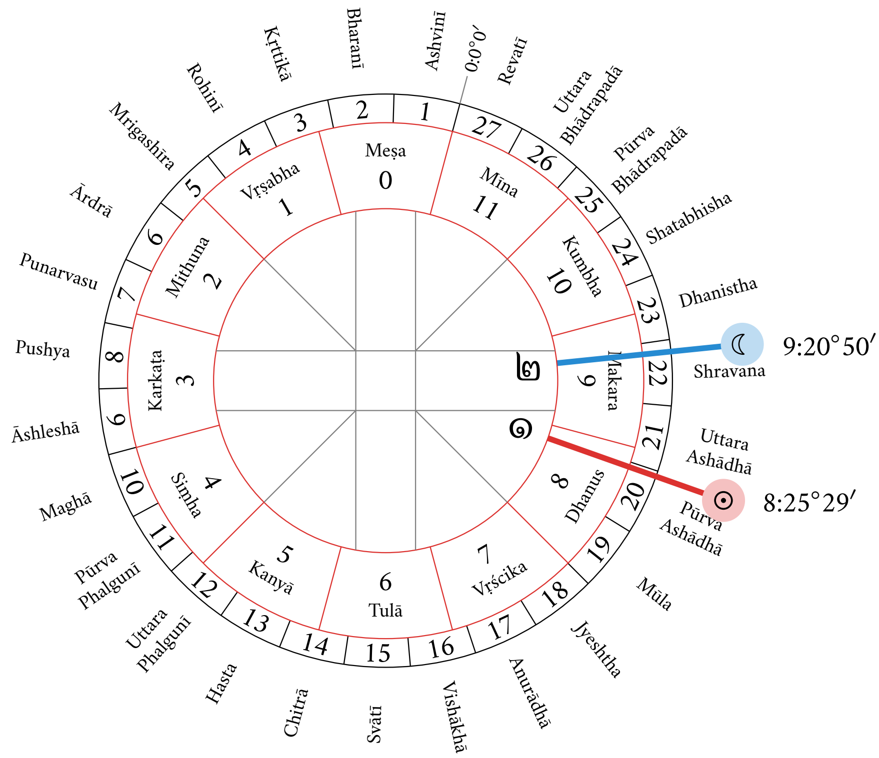
The *duang chata* ดวงชะตา, or *horasat* โหราศาสตร์ represents date and time by the positions of the celestial bodies. When it represents a day, the positions are at the time of midnight.

0° (Aries) is the spring equinox, the segments 0-11 are the *rasi*, the segments 1-27 are the *nakshatra* or lunar mansions.

On the Thai historical inscriptions, the planets are labelled by a number.[1] The stone inscription below is found on the base of the Buddha image at Wat Chai Phra Kiat, Chiang Mai, and records the date of casting the image.[2] The photo was republished by JC Eade in his paper.[3]

Wat Chai Phra Kiat:
Google Maps
renown-travel.com

We can look at the inscription and find the date for which the formulas reproduce the given positions.



Here we only calculate the Sun ⊙ (1, ๑) and the Moon ☾ (2, ๒), this already allows us to identify day 298 in the lunar year, and gives us the date as **1566 January 3**.

The code at sec. 6.2 prints:

```
Day: 298
Date: 1566 Jan 3
Horakhun: 338865
Tithi: 2
True Sun: 8:25°29'
True Moon: 9:20°50'
```

$9:19°13'$ notation represents *rasi*, *angsa* (degrees), *lipda* (minutes). $r:a°l' = r*30+a+l/60$, thus $289°13'$ is $9:19°13'$.

[1] Eade, *Calendrical Systems*, p. 79.
[3] Eade, "The Mangrai Buddha Image".
[3] The image caption in the paper places the inscription at Wat Chang Kham, which is probably an editorial mistake. Wat Chang Kham is in the Nan province, and the paper only discusses Wat Chai Phra Kiat in Chiang Mai.

5.1 Rasi

Thai: rasi ราศี

The circle is divided into 12 segments called *rasi*, each marking 30 degrees. Their numbering starts from 0, to express $x * 30°$. See Table 5.1.

Table 5.1: Names of the 12 Rasi.

	Western	Sanskrit	Thai
0	Aries	Meṣa	เมษ
1	Taurus	Vṛṣabha	พฤษภ
2	Gemini	Mithuna	เมถุน
3	Cancer	Karkaṭa	กรกฎ
4	Leo	Siṃha	สิงห์
5	Virgo	Kanyā	กันย์
6	Libra	Tulā	ตุลย์
7	Scorpio	Vṛścika	พิจิก
8	Sagittarius	Dhanus	ธนู
9	Capricorn	Makara	มังกร
10	Aquarius	Kumbha	กุมภ์
11	Pisces	Mīna	มีน

5.2 Nakshatra, lunar mansions

Thai: naksat นักษัตร

JC Eade in *Calendrical Systems*:

The Thai term for nakshatra is "raek", and the Burmese term is "nekkhat". The reference is to the 27 segments into which the moon's orbit is divided.[4] Each segment is therefore 13°20′ in extent, and the inclination of the Moon's orbit relative to the Sun's orbit is not taken into account, so that the lunar mansions can be considered as lying in the same plane as the Sun's rasi. In very general terms, and since the Moon's average motion is 13° a day, the Moon can be considered to traverse one lunar mansion per day.[5]

The names of the lunar month are derived from the name of the nakshatra that the Moon will normally be occupying at Full Moon. But caution is required: since the Moon's speed varies sharply, it may be that the mansion at Full Moon is one (even two) short of, or past, where it "ought" to be.[6]

Table 5.2: Names of the 27 Nakshatra.

	Sanskrit	Thai
1	Ashvinī	อัศวินี
2	Bharanī	ภรณี
3	Kṛttikā	กฤติกา
4	Rohinī	โรหิณี
5	Mrigashīra	มฤคศีรษะ
6	Ārdrā	อาทรา
7	Punarvasu	ปุนวสุ
8	Pushya	ปุษยะ
9	Āshleshā	อาศเลศา
10	Maghā	มฆา
11	Pūrva Phalgunī	บูรพผลคุณี
12	Uttara Phalgunī	อุตรผลคุณี
13	Hasta	หัสตะ
14	Chitrā	จิตรา
15	Svātī	สวาตี
16	Vishākhā	วิศาขา
17	Anurādhā	อนุราธา
18	Jyeshtha	เชษฐะ
19	Mūla	มูละ
20	Pūrva Ashādhā	บูรพาษาฒ
21	Uttara Ashādhā	อุตราษาฒ
22	Shravana	ศรวณะ
23	Dhanistha	ศรวิษฐะ
24	Shatabhisha	ศตภิษัช
25	Pūrva Bhādrapadā	บูรพภัทรบท
26	Uttara Bhādrapadā	อุตรภัทรบท
27	Revatī	เรวตี

[4] The Southeast Asian system makes no use of a 28th raek.
[5] Eade, *Calendrical Systems*, p. 31.
[6] Ibid., p. 34.

6 IN GOLANG

Going through all this may be intriguing to calculate once, but mention repeating it every year, then checking and proofing it, and one is reminded of a phrase in Eade's *Calendrical Systems*: "Few would undertake cheerfully the task."[1]

Better tell the machine how to do it and let us get on with living. Let's import suriya-go and ask the machine in Golang.

6.1 Year 1288

We will investigate 14 April 1288, and while doing that, also 15 June 1288, which should turn out to be the date of Āsāḷha Pūjā.

```
package main

import "fmt"
import "github.com/splendidmoons/suriya-go"

func main() {
        var suDays []suriya.SuriyaDay
        var day suriya.SuriyaDay
        var year suriya.SuriyaYear

        // 1288 April 14 is 41 days into the lunar year,
        // counting from Citta 1
        day.Init(1288, 41)
        suDays = append(suDays, day)

        // Let's also see Asalha Puja day. This is day 103,
        // which would have been 1288 Jun 15.
        day.Init(1288, 103)
        suDays = append(suDays, day)

        // Print the results:

        year.Init(1288)
        fmt.Printf("Year: %v\nAdhikamāsa: %v\nAdhikavāra: %v\n",
                year.Year, year.Is_Adhikamasa(), year.Is_Adhikavara())

        fmtStr := `---
Year, Day: %v, %v
True Sun: %v
True Moon: %v
Tithi: %v
`
        for _, day = range suDays {
                fmt.Printf(fmtStr,
                        day.Year, day.Day,
                        suriya.DegreeToRalString(day.TrueSun),
                        suriya.DegreeToRalString(day.TrueMoon),
                        day.Tithi)
        }
}
```

[1] Eade, *Calendrical Systems*.

Which prints:

```
Year: 1288
Adhikamāsa: false
Adhikavāra: false
---
Year, Day: 1288, 41
True Sun: 0:19°58'
True Moon: 5:11°27'
Tithi: 12
---
Year, Day: 1288, 103
True Sun: 2:19°9'
True Moon: 8:19°1'
Tithi: 15
```

6.2 Date of Casting of the Mangrai Buddha

```go
package main

import (
	"fmt"

	"github.com/splendidmoons/suriya-go"
)

func main() {
	suDay := suriya.SuriyaDay{}
	suDay.Init(1565, 298)
	fmt.Printf(`Day: %v
Date: %v
Horakhun: %v
Tithi: %v
True Sun: %v
True Moon: %v
`,
		suDay.Day,
		suriya.HorakhunToDate(int64(suDay.Horakhun)).Format("2006 Jan 2"),
		suDay.Horakhun,
		suDay.Tithi,
		suriya.DegreeToRalString(suDay.TrueSun),
		suriya.DegreeToRalString(suDay.TrueMoon),
	)
}
```

Which prints:

```
Day: 298
Date: 1566 Jan 3
Horakhun: 338865
Tithi: 2
True Sun: 8:25°29'
True Moon: 9:20°50'
```

COLOPHON

Much appreciation for the answers from the Venerable Ajahns who endured my questions. In particular Ajahn Amaro and Ajahn Hāsapañño, and many others who helped to correct and improve this document. Comprehension and consistency was only possible with their experience and understanding.

Made with Org-mode and LaTeX. Sources at Github.

Please send comments, corrections and further information to:

`Gambhiro Bhikkhu <gambhiro.bhikkhu.85@gmail.com>`

Last updated on 2015-11-20.

BIBLIOGRAPHY

Eade, J.C. "Irregular dating in Lan Na: an anomaly resolved". *Journal of the Siam Society* 95 (2007).

———. "Rules for interpolation in the Thai calendar". *Journal of the Siam Society* 88 (2000): 195.

———. "Rules for interpolation in the Thai Calendar: *Suriyayatra* versus the *Sasana*". Accessed 2014-10-02, *Journal of the Siam Society* 88, no. 1 and 2 (2000).

———. *Southeast Asian Ephemeris: Solar and Planetary Positions, A.D. 638-2000* (*preview on Google Books*). Southeast Asia Program, Cornell University, 1989. https://books.google.com/books?id=g%5C_JEgc5C-OYC.

———. *The calendrical systems of mainland south-east Asia* (*preview on Google Books*). E.J. Brill, 1995. https://books.google.com/books?id=d5C8adRzSEQC.

———. "The Mangrai Buddha Image of Chiang Mai: A Computer-Assisted Rereading". Accessed 2015-11-18, *Journal of the Siam Society* 81, no. 1 (1993).

Hāsapañño, Bhikkhu. *The Lunar and Solar Zodiac*. https://sites.google.com/site/wideanglewilderness/miscellany, 2014.

Khemanando, Bhikkhu. *The Cycle of the Adhikamāsa*.

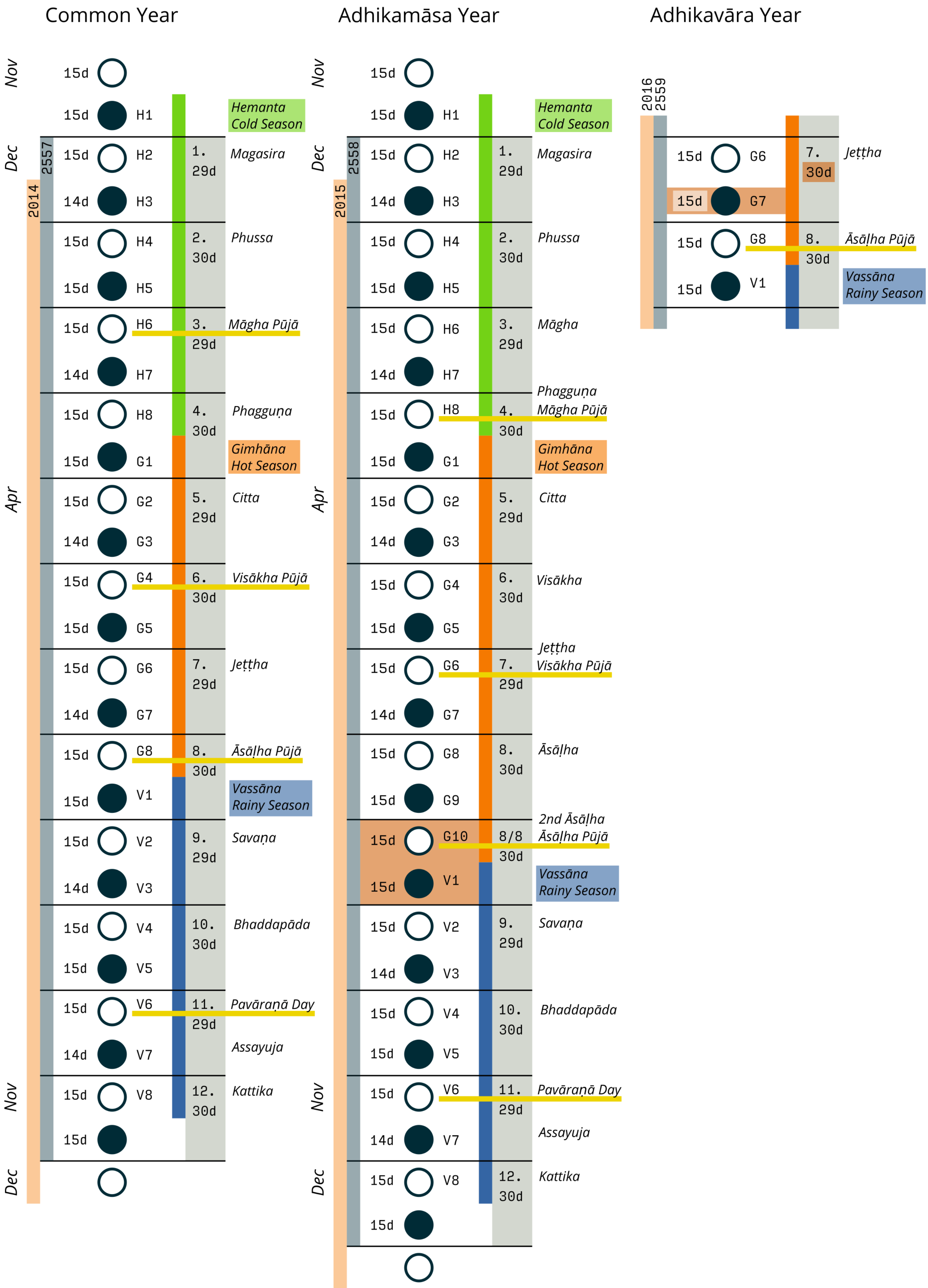
Wikipedia. "Mean longitude". https://en.wikipedia.org/wiki/Mean_longitude.

———. "Proclamation on Observance of New Year's Day on 1 January". https://en.wikisource.org/wiki/Proclamation_on_Observance_of_New_Year's_Day_on_1_January,_dated_24_December_1940.

———. "Thai lunar calendar". https://en.wikipedia.org/wiki/Thai_lunar_calendar.

FULL PAGE INCLUDES

Full page includes follow.


Common Year
Adhikamāsa Year
Adhikavāra Year
Nov
Dec
Apr
2014
2557
2015
2558
2016
2559
Hemanta
Cold Season
Gimhāna
Hot Season
Vassāna
Rainy Season
1. 29d Magasira
2. 30d Phussa
3. 29d Māgha Pūjā
4. 30d Phagguṇa
5. 29d Citta
6. 30d Visākha Pūjā
7. 29d Jeṭṭha
8. 30d Āsāḷha Pūjā
9. 29d Savaṇa
10. 30d Bhaddapāda
11. 29d Pavāraṇā Day
Assayuja
12. 30d Kattika
3. 29d Māgha
4. 30d Phagguṇa
Māgha Pūjā
6. 30d Visākha
7. 29d Jeṭṭha
Visākha Pūjā
8. 30d Āsāḷha
8/8 30d 2nd Āsāḷha
Āsāḷha Pūjā
7. 30d Jeṭṭha
8. 30d Āsāḷha Pūjā
H1 H2 H3 H4 H5 H6 H7 H8
G1 G2 G3 G4 G5 G6 G7 G8 G9 G10
V1 V2 V3 V4 V5 V6 V7 V8
15d
14d

Forest Sangha Calendar 2014 - 2557

			W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F			
January			1	2	3	4	5	6	7	◐	9	10	11	12	13	14	○	16[1]	17	18	19	20	21	22	◑	24	25	26	27	28	29	●	31			
February						1	2	3	4	5	6	◐	8	9	10	11	12	13	○[2]	15	16	17	18	19	20	21	◑	23	24	25	26	27	●			
March						1	2	3	4	5	6	7	◐	9	10	11	12	13	14	○	16	17	18	19	20	21	22	◑	24	25	26	27	28	29	●	31
April		1	2	3	4	5	6	◐	8	9	10	11	12	13	○	15	16	17	18	19	20	21	◑	23	24	25	26	27	●	29	30					
May				1	2	3	4	5	◐	7	8	9	10	11	12	○[3]	14	15	16	17	18	19	20	◑	22	23	24	25	26	27	●	29	30	31		
June							1	2	3	4	◐	6	7	8	9	10	11	○	13	14	15	16	17[4]	18	19	◑	21	22	23	24	25	●	27	28	29	30
July		1	2	3	◐	5	6	7	8	9	10	○[5]	12[6]	13	14	15	16	17	18	◑	20	21	22	23	24	25	●	27	28	29	30	31				
August					1	2	◐	4	5	6	7	8	9	○	11	12	13	14	15	16	17	◑	19	20	21	22	23	●	25	26	27	28	29	30	31	
September	◐	2	3	4	5	6	7	○	9	10	11	12	13	14	15	◑	17	18	19	20	21	22	●	24	25	26	27	28	29	30						
October			◐	2	3	4	5	6	7	○[7]	9	10	11	12[8,9,10]	13	14	15	◑	17	18	19[11]	20	21	●	23	24	25	26[12]	27	28	29	◐	31			
November						1	2[13]	3	4	5	○	7	8	9	10	11	12	13	◑	15	16	17	18	19	20	●	22	23	24	25	26	27	28	◐	30	
	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W					
December	1	2	3	4	5	○	7	8	9	10	11	12	13	◑	15	16	17	18	19	●	21	22	23	24	25	26	27	◐	29	30	31					

1 Jan 16: *Ajahn Chah Memorial Day*
2 Feb 14: *Māgha Pūjā*
3 May 13: *Vesākha Pūjā*
4 Jun 17: *Ajahn Chah's Birthday*

5 July 11: *Āsāḷhā Pūjā*
6 July 12: *Vassa begins*
7 Oct 8: *Pavāraṇā*

Robe offering ceremonies:
8 Oct 12: *Dhammapala*
9 Oct 12: *Hartridge*
10 Oct 12: *Santacittarama*

11 Oct 19: *Aruna Ratanagiri*
12 Oct 26: *Cittaviveka*
13 Nov 2: *Amaravati*

event note
moon day, traditional
moon phase, astronomical

Download from www.forestsangha.org/calendar

Forest Sangha Calendar 2015 - 2558

	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T
January				1	2	3	○	5	6	7	8	9	10	11	◐	13	14	15	16[1]	17	18	●	20	21	22	23	24	25	26	◐	28	29	30	31			
February							1	2	○	4	5	6	7	8	9	10	◐	12	13	14	15	16	●	18	19	20	21	22	23	24	◐	26	27	28			
March							1	2	3	○[2]	5	6	7	8	9	10	11	◐	13	14	15	16	17	18	●	20	21	22	23	24	25	26	◐	28	29	30	31
April			1	2	○	4	5	6	7	8	9	10	◐	12	13	14	15	16	●	18	19	20	21	22	23	24	◐	26	27	28	29	30					
May					1	○	3	4	5	6	7	8	9	◐	11	12	13	14	15	16	●	18	19	20	21	22	23	24	◐	26	27	28	29	30	31		
June	○[3]	2	3	4	5	6	7	8	◐	10	11	12	13	14	●	16	17[4]	18	19	20	21	22	◐	24	25	26	27	28	29	○							
July			1	2	3	4	5	6	7	◐	9	10	11	12	13	14	●	16	17	18	19	20	21	22	◐	24	25	26	27	28	29	○[5]	31[6]				
August						1	2	3	4	5	6	◐	8	9	10	11	12	13	●	15	16	17	18	19	20	21	◐	23	24	25	26	27	28	○	30	31	
September		1	2	3	4	5	◐	7	8	9	10	11	●	13	14	15	16	17	18	19	◐	21	22	23	24	25	26	○	28	29	30						
October				1	2	3	4	◐	6	7	8	9	10	11	●	13	14	15	16	17	18	19	◐	21	22	23	24	25	26	○[7]	28	29	30	31			
November							1[8]	2	3	◐	5	6	7	8[9,10]	9	●	11	12	13	14	15[11]	16	17	◐	19	20	21	22[12,13]	23	24	○	26	27	28	29	30	
		T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T					
December		1	2	◐	4	5	6	7	8	9	●	11	12	13	14	15	16	17	◐	19	20	21	22	23	24	○	26	27	28	29	30	31					

[1] Jan 16: *Ajahn Chah Memorial Day*
[2] Mar 4: *Māgha Pūjā*
[3] Jun 1: *Vesākha Pūjā*
[4] Jun 17: *Ajahn Chah's Birthday*

[5] July 30: *Āsāḷhā Pūjā*
[6] July 31: *Vassa begins*
[7] Oct 27: *Pavāraṇā*

Robe offering ceremonies:
[8] Nov 1: *Aruna Ratanagiri*
[9] Nov 8: *Santacittarama*
[10] Nov 8: *Hartridge*

[11] Nov 15: *Amaravati*
[12] Nov 22: *Cittaviveka*
[13] Nov 22: *Dhammapala*

event note
moon day, traditional
moon phase, astronomical

Forest Sangha Calendar 2016 - 2559

					F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S		
January					1	◐	3	4	5	6	7	●	9	10	11	12	13	14	15	◐[1]	17	18	19	20	21	22	○	24	25	26	27	28	29	30	◐		
February	1	2	3	4	5	6	●	8	9	10	11	12	13	14	◐	16	17	18	19	20	21	○[2]	23	24	25	26	27	28	29								
March		◐	2	3	4	5	6	●	8	9	10	11	12	13	14	◐	16	17	18	19	20	21	○	23	24	25	26	27	28	29	◐	31					
April					1	2	3	4	5	●	7	8	9	10	11	12	13	◐	15	16	17	18	19	20	○	22	23	24	25	26	27	28	◐	30			
May							1	2	3	4	●	6	7	8	9	10	11	12	◐	14	15	16	17	18	19	○[3]	21	22	23	24	25	26	27	◐	29	30	31
June			1	2	3	●	5	6	7	8	9	10	11	◐	13	14	15	16	17[4]	18	○	20	21	22	23	24	25	26	◐	28	29	30					
July					1	2	3	●	5	6	7	8	9	10	11	◐	13	14	15	16	17	18	○[5]	20[6]	21	22	23	24	25	26	◐	28	29	30	31		
August	1	2	●	4	5	6	7	8	9	10	◐	12	13	14	15	16	17	○	19	20	21	22	23	24	25	◐	27	28	29	30	31						
September				●	2	3	4	5	6	7	8	◐	10	11	12	13	14	15	○	17	18	19	20	21	22	23	◐	25	26	27	28	29	30				
October						●	2	3	4	5	6	7	8	◐	10	11	12	13	14	15	○[7]	17	18	19	20	21	22	23	◐	25	26	27	28	29	●	31	
November		1	2	3	4	5	6	◐	8	9	10	11	12	13	○	15	16	17	18	19	20	21	◐	23	24	25	26	27	28	●	30						
				T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S			
December				1	2	3	4	5	6	◐	8	9	10	11	12	13	○	15	16	17	18	19	20	21	◐	23	24	25	26	27	●	29	30	31			

[1] Jan 16: *Ajahn Chah Memorial Day*
[2] Feb 22: *Māgha Pūjā*
[3] May 20: *Vesākha Pūjā*
[4] Jun 17: *Ajahn Chah's Birthday*
[5] July 19: *Āsāḷha Pūjā*
[6] July 20: *Vassa begins*
[7] Oct 16: *Pavāraṇā*

event note
moon day, traditional
moon phase, astronomical