MEASUREMENT
OF
TIME

Deepak Joshi
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Astronomy is the oldest science known to humans. Birth of stars, planets, galaxies or even life on the Earth can be traced back through such astronomical studies. Ancient Indian sages and ‘Jyotirvids’ have done pioneering work in astronomy with precision and accuracy which is well documented in so many Sanskrit texts available today. It is a well-known fact that the human brain is an amazing organ that could think, react, and process information. These abilities enabled humans to develop the techniques of measurement, comparison, referencing, data processing and time keeping. The practice of measuring time based on the Earth’s rotation and celestial events has a long tradition in India. This tradition is kept alive with continuous research in the field of astronomy, making and refining almanacs, and present day calendars.

This book takes an extensive account of evolution of science of measurement of time or Chronometry, not only in India but also in other civilisations of the world. We are sure that every Indian would feel proud to know the expertise of ancient Indians in chronometry.

We are happy to present this book to our readers, especially the students, as part of study material of Vidyarthi Vigyan Manthan (VVM 2020-21) - a national science talent search exam organised by Vigyan Bharati, Vigyan Prasar and NCERT. This book is a sequel of a book on life and work of an Indian Jyotirvid, born in 1854, titled as “Eminent Indian Scientist - Shri Venkatesh Bapuji Ketkar”. He devoted his life for almanac research and purification continuing the tradition of Ganesh Daivajna (Born in 1507).

We are fortunate to have Shri. Deepak Joshi, a passionate astronomer and life member of ‘Jyotirvidya Parisanstha’ (founded in 1944) to author the original book in Marathi titled ‘Kalamaapana’. Coincidently, he is also the member of the core team of VVM which triggered him to prepare study material for students. He readily accepted the task that demanded compiling the work on Measurement of Time and presenting it in a manner that appeals to the young generation. We are grateful to him and take joy in announcing that he has done it successfully.
The original Marathi book authored by Deepak Joshi is translated in English by Ms. Siddhi Mahajan, an active karyakarta from Goa Vidnyan Parishad. She was the obvious choice, as she was the author of the book ‘Eminent Indian Scientist - Shri Venkatesh Bapuji Ketkar’ which has direct relevance to the topic under consideration. We appreciate her talent and the hard work which reflects in this book.

We both, as editors, enjoyed the process of writing original Marathi book by Deepak ji and consequent English translation by Siddhi. Our suggestions and modifications were accepted by both wherever it was worth to be considered. The brainstorming sessions were mutually enriching!

We also put on record our sincere thanks and gratitude to Shri Jayant Sahasrabudhe, national organizing secretary of Vijnana Bharati for his idea and continuous support for bringing this topic and subject to the forefront.

The contents of this book make it worth adding to the home library of every Indian!

Ms. Sangeeta Abhyankar  
Content Coordinator, VVM

Dr. Arvind C. Ranade  
National Convenor, VVM
Preface

Chronometry or measurement of time is an incessant process. When and where this process originated is an unsolved mystery. This book reviews the Indian chronometry. While doing so, special attention has been paid to introduce concepts of the Indian chronometry to the school students. In Vidyarthi Vigyan Manthan 2020, Vijnana Bharati has decided to introduce the concepts of Indian Chronometry to school children along with the contribution of Venkatesh Bapuji Ketkar, a world class astronomer, to Astronomy. Bearing this in mind, this book has been penned.

I am especially grateful to Hon'ble Jayant Sahasrabuddhe, National Organizing Secretary of Vijnana Bharati and National Convener of Vidyarthi Vigyan Manthan, Dr. Arvind C. Ranade for giving me this opportunity. The bibliotheca of the Jyotirvidya Parisansth in Pune was extremely useful for compiling and editing the information from various sources. I am truly indebted to the organization for this. The concepts of Chronometry are in complex language and consist of intricate details. The book could not have been completed or made easy for students to understand, without the help of Ms. Sangeeta Abhyankar from Goa. I am extremely obliged to her for this.

Astronomy is the basis of Chronometry. The purpose behind this book is to make the students curious about this subject by reading this book.

Deepak Joshi
Pune

September 17, 2020
Śālivāhana Saka 1942, Bhādrapada Amavasya
Vikram Samvat 2077, 26 Īsh
According to the Indian National Calendar, Saka 1942, 26 Bhādrapada
Julian Day Number 2459109.5
Measurement of Time

Measurement is an integral part of science. Historical evidence, such as archeological excavations, stone and copper inscriptions, suggest that length, area, and volume have been measured using various methods since time immemorial. Eventually a need was established to standardise the units of measurements; especially for communication of comparison of quantities. In modern times, we use the MKS (meters, kilograms, seconds) or FPS (feet, pounds, seconds) systems of standards. Surprisingly, the units of time measurement are the same i.e. seconds/minutes/hours in both these systems.

Have the same units been used to measure time, since ancient times? Today, we use seconds-minutes-hours-days-months-years very casually for measurement of time. We use units of measurement of time to describe any event. The units that are in use today have evolved over a long period of time. This book is an effort to introduce different methods of measurement of time. The contribution of the ancient Indians is very significant and indisputable in this field.

We still come across some people using various traditional standards based on human body parts. E.g. one angul (digit), one hasta (elbow length), one purush (Height of a person) as units of distance. In the olden times, it was customary to measure the distance between two villages by 'a day'. One village is seven days away from the other; which means that, if we travel for seven days, we will reach the other village. Even today, we say that a place is ten minutes away from home. This attempt to tell distance and time together is not scientifically...
accurate; however, we use it constantly in practice. Accuracy in measurement is required in scientific studies. Man has been working in that direction since ancient times.

Natural phenomena proved to be an important factor in these efforts. The rotation of the earth is the supportive pillar of the measurement of the day. The concept of a month is based on the time period required for the Moon to revolve around the earth. The concept of a year is based on the time taken by the earth to complete one rotation around the Sun. These natural events are periodic in nature. The process of observing the frequency of these events and expressing it in the form of equations is called the measurement of time. The science of accurate time measurement is called chronometry.
The earth is constantly rotating around its own axis. This rotation occurs from west to east. Due to this, the Sun appears to rise in the east and set in the west. Numerous stars begin to shine in the sky after the sunset. These twinkling stars appear to be traveling westwards. The time period in which the Sun is seen in the sky is called the Divasa or a day; whereas the time period in which it is not visible in the sky is called the Rātri or the night. In Indian chronometry, day and night together are called Ahorātrā, and it is considered as a full day. The day begins at Sunrise.

In ancient India, a very simple and easy method was used for the measurement of time. Ghaṭikā Pātra and Chāyā Shankū were the main instruments used.

**Ghaṭikā Pātra**

Ghaṭikā Pātra is an instrument which was derived from a tool in daily use. It consists of a large container filled with water. A copper vessel of specific weight and size is suspended within it. This copper vessel has a small hole at its bottom. Water slowly starts accumulating from the bigger container, in the copper vessel. As the water level increases, the copper vessel starts sinking gradually. After some time, it sinks to the bottom of the larger container. The time taken by the copper vessel to sink fully is called a ghaṭikā. The structure of the Ghaṭikā pātra has been described by the ancient Indian scholar Vārahamihir as follows. Take a semicircular copper vessel.
(Tāmrapātra) with a radius of six angulas and containing sixty Paḷe (240 Toḷās / ounces) of water. Pierce a hole at its bottom such that a golden needle of length of 4 angulas, weighing 31/3 Māse, (12 Māse = 1 Toḷā) can effortlessly pass through it. Thus a Ghaṭikā Pātra is designed.

The time measured by the Ghaṭikā Pātra as per the measurement of modern clock is as follows:

1 Vipāḷa = 4/45 seconds
1 Prāṇa = 4 seconds
1 Vināḍī / Paḷa = 24 seconds
1 Nāḍī or Ghaṭikā = 24 minutes
1 Muhūrta = 48 minutes

It takes a Nāḍī i.e. 24 minutes, to empty a pot full of water.

Chāyā Shankū (Solar Gnomon)

Chāyā means a shadow and Shankū means a cone. It is a stick (Gnomon) casting a shadow against the Sun. The use of Chāyā Shankū is mentioned in the book Atharva jyōtiṣa to measure the time when the Sun is in the sky. The standards they have set are as follows:

12 Nimesha = 1 Lava,
30 Lava = 1 Kalā
30 Kalā = 1 Truṭī
30 Truṭī = 1 Muhūrta
30 Muhūrta = 1 Ahorātra (full day)

Figure No. 3: Chāyā Shankū

Thirty Muhūrtas occur in a full day, of which fifteen Muhūrtas occur when the Sun is seen in the sky, and fifteen Muhūrtas occur when it is not seen. While measuring the Muhūrta, a twelve ‘angulas’ long stick is used which is tapering upward. The Chāyā Shankū is an instrument used to measure the Sun's shadow
casted by the gnomon. The length of the shadow is measured by the unit 'angula'.

**What is an ‘Angula’?**

From ancient times, human body parts have been used as units in various measurements. The smallest unit is the finger/digit. An ‘Angula’ is the distance equal to the breadth or thickness of a finger.

**Muhūrtas in a day**

The shadow of a gnomon falls to its west after Sunrise and the length of the shadow is the longest at Sunrise. As the Sun moves upwards in the sky, the length of the shadow begins to decrease. The unit 'angula' is used to measure the length of shadow. The eight *Muhūrtas* from sunrise to the noon are calculated as depicted in Table No 1.

<table>
<thead>
<tr>
<th>Muhūrta number</th>
<th>Name of the <em>Muhūrta</em></th>
<th>Length of shadow in <em>Angulas</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Raudra</td>
<td>96 Angulas</td>
</tr>
<tr>
<td>Second</td>
<td>Śveta</td>
<td>60 Angulas</td>
</tr>
<tr>
<td>Third</td>
<td>Maitra</td>
<td>12 Angulas</td>
</tr>
<tr>
<td>Fourth</td>
<td>Sārbhata</td>
<td>6 Angulas</td>
</tr>
<tr>
<td>Fifth</td>
<td>Sāvitra</td>
<td>5 Angulas</td>
</tr>
<tr>
<td>Sixth</td>
<td>Vairaj</td>
<td>4 Angulas</td>
</tr>
<tr>
<td>Seventh</td>
<td>Viśvāsū</td>
<td>3 Angulas</td>
</tr>
<tr>
<td>Eighth</td>
<td>Abhijāta</td>
<td>Less than 3 Angulas</td>
</tr>
</tbody>
</table>
Abhijāta

‘Yasmin chāyāpratiṣṭhitā’ - (Meaning: The muhurta in which the shadow is fixed). The Abhijāta muhurta occurs at noon. The shadow is very small (less than 3 angulas) as the Sun is over the head at this time. In the region from the Tropic of Cancer to the Tropic of Capricorn, though the Sun appears overhead, it is not necessarily at zenith. There are only two days in a year; when the Sun is exactly at the zenith and the shadow is not cast at local noon. These days are called 'zero shadow days' (ZSD). This phenomenon can be experienced in India towards the south of the tropic of Cancer. The first ‘Zero Shadow Day’ falls between April 9 and June 21; The second falls between June 21 and August 30.

Figure No. 4: Image showing ‘Zero Shadow Day’ taking place in different locations and on different days in India.
As the Sun tilts westward, the shadow of Chāyā Shankū falls eastward and gradually grows larger. Thus, the 9th Muhūrta is again Viśvāsū muhurta. Similarly, in reverse order, the Raudra Muhūrta appears again at the time of Sunset.

Modern chronometry divides the time into seconds, minutes, hours, days, months, and years. Astronomy has been used in the construction of these chronometric components. Generally, we count 24 hours as a day in practical life. The Earth takes 23 hours, 56 minutes and 4.09053 seconds to complete a revolution around the Sun. We know that latitudes and longitudes are used to represent any place on the earth. The zero degree longitude passes through the city of Greenwitch in England. An observatory has been set up in the city of Greenwich. The telescope in this observatory is permanently pointed towards the zenith. The period of 23 hours, 56 minutes and 4.09053 seconds has been fixed for the rotation of the Earth upon observation of the star Beta cassiopeiae (Indian name Śarmiṣṭhā).

In modern chronometry, the time of rotation of the earth is calculated on the basis of the frequency of the vibrations of the atom of Cesium 133. The atomic clock is the most accurate tool used in modern chronometry. A second is officially defined as a duration of 9,192,631,770 oscillations of the atom of Cesium 133. Also, a year is officially defined as a duration of 290,09,200,500,000,000 oscillations of the atom of Cesium 133.

The nucleus of the element Cesium 133 consists of 55 protons and 78 neutrons. 55 electrons revolve around the nucleus in different stable orbits. The last orbit contains only one electron. The energy state of this electron can be changed by applying external energy; so that the electron changes its orbit for a very short interval of time and returns to its original state by emitting a wave of frequency 9,192,631,770. It is used in the atomic clock for measurement of time.
Vāra (Weekday)

In Indian time keeping system, Vāra is one of the important attributes. It is difficult to tell exactly when and where the Vāra originated. Vāras are not mentioned in ancient Indian texts. However, since the time of Vārahamihira, mention of Vāra has appeared in Indian texts. According to Vārahamihira, the seven greatest celestial bodies, viz. Sun, Moon, Mars, Jupiter, Saturn, Venus and Mercury were invoked in the yajna karma. The ancient Indian texts 'Āryabhatiya' and 'Sūrya Siddhānta' give the rules to define the weekdays or Vāras, as follows:

‘मंदात अध: क्रमेण स्यु: चतुथादिनाधिपाः’

‘Mandāta adhaḥ Krameṇa syuḥ Caturthā dinādhipāḥ’

According to this verse, if planets are arranged from slower to faster; then the fourth planet is considered as Dinādhipatī (the one who rules the day). The Moon, the Sun, and the visible planets viz. Mars, Jupiter, Saturn, Venus, and Mercury appear to move in the sky against the background of the stars. Observations from the Earth show that Saturn is the slowest orbiting planet. Based on the time taken by the planets to move on the stellar background, an ascending order of their pace can be formed as Saturn, Jupiter, Mars, Sun, Venus, Mercury and Moon.

The word ‘Hōrā’ is used in Vārahamihira's literature. Vārahamihira writes that the word 'Horā' was formed by omitting the two letters ‘A’ and ‘Tra’ from the word ‘Ahōrātra’. There are 24 Hōrās in the Ahōrātra. One planet was considered the lord of each Hōrā and was called ‘Hōrādhipatī’. The Hōrādhipatī at Sunrise is called ‘Dinādhipatī’ which decides the name of the Vāra. In the following table, the planets from Saturn to the Moon have been arranged according to their pace.
Table No. 2: Determining the names of the Vāras

<table>
<thead>
<tr>
<th>Śani (Saturn)</th>
<th>Guru (Jupiter)</th>
<th>Maṅgaḷa (Mars)</th>
<th>Ravi (Sun)</th>
<th>Śukra (Venus)</th>
<th>Budha (Mercury)</th>
<th>Candra (Moon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hōrā 1 Śanivāra</strong></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>22</td>
<td>23</td>
<td>24</td>
<td><strong>Hōrā 1 Ravivāra</strong></td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td><strong>Hōrā 1 Somavāra</strong></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>23</td>
<td>24</td>
<td><strong>Hōrā 1 Maṅgalavāra</strong></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td><strong>Hōrā 1 Budhavāra</strong></td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>24</td>
<td><strong>Hōrā 1 Guruvāra</strong></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td><strong>Hōrā 1 Śukravāra</strong></td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

The first day in the Table No. 2 is Saturday as Saturn is the lord of the first Hōrā of the day. The lord of the twenty-fourth Hōrā is Mars. After this, the second day begins. Ravi (Sun) is the lord of the first Hōrā; So Ravi is the ‘Dinādhipati’. Hence the day is Sunday. In the same way Monday (lunar day), Tuesday, Wednesday, Thursday, Friday come in an order.
How to find the weekday/Vāra from a specific date of the Gregorian calendar?

(The Gregorian calendar is a calendar started by Pope Gregory XIII in 1582 and used worldwide)

This is made possible by a very simple mathematical equation. The following formula can be used for this:

$$\text{Day} = \text{Remainder} \left( \text{D} + \text{Y} + \text{integer} \left( \frac{\text{Y}}{4} \right) - \text{integer} \left( \frac{\text{Y}}{100} \right) + \text{integer} \left( \frac{\text{Y}}{400} \right) + \text{integer} \left( \frac{31 \times \text{M}}{12} \right) \right) / 7$$

Day = Weekday/Vāra
D = date
Y = Year - A     [A = 0 (if month> 2), and A = 1 (if month <3)]
M = Month - B     [B = 2 (if month> 2), and B = 1 (if month <3)]

<table>
<thead>
<tr>
<th>Day = 0 = Sunday</th>
<th>Day = 1 = Monday</th>
<th>Day = 2 = Tuesday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day = 3 = Wednesday</td>
<td>Day = 4 = Thursday</td>
<td>Day = 5 = Friday</td>
</tr>
<tr>
<td>Day = 6 = Saturday</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example: To find out the weekday of August 5, 2020:
August 5, 2020 = 5/8/2020
D = 5
Y = 2020 - 0 = 2020
M = 8 - 2 = 6

$$\text{Day} = \text{Remainder} \left( 5 + 2020 + \text{integer} \left( \frac{2020}{4} \right) - \text{integer} \left( \frac{2020}{100} \right) + \text{integer} \left( \frac{2020}{400} \right) + \text{integer} \left( \frac{31 \times 6}{12} \right) \right) / 7$$

$$\text{Day} = \text{Remainder} \left( 5 + 2020 + 505 - 20 + 5 + 15 \right) / 7$$

$$\text{Day} = \text{Remainder} \left( 2530 \right) / 7$$

$$\text{Day} = 3$$
August 5, 2020 was Wednesday.

***************
Pakṣa (Fortnight)

The day/Vāra consists of 24 hours. Seven days make a week. We have seen the details about the names assigned for seven days of the week. The next unit consists of two weeks that make a fortnight. This group of fifteen days is called "Pakṣa". Two Pakṣas make a month. Śukla Pakṣa and Krishna Pakṣa, have been the terms used in the Indian chronometry. They are also called Śuddha Pakṣa and Vadya Pakṣa respectively. The day and night are caused by the rotational motion of the earth. During the day, the Sun appears to travel through the sky. The Sunlight is scattered by the dust particles from the earth's atmosphere. Thus the stars are not visible during the daytime. These stars are visible after the Sunset.

Through continuous observations, we can trace the apparent motion of the Moon in the stellar background. In the evening sky, a very feeble crescent moon can be seen near the horizon after the Sunset. Day by day, the crescent moon appears to move away from the western horizon, and becomes larger gradually (waxing moon). A half Moon can be observed within a week and appears at the zenith. The Moon gradually waxes and can be seen rising as a full Moon on the eastern horizon at the time of Sunset. This period of fortnight in which the western front of the Moon gets illuminated gradually is called Śukla Pakṣa.

Over the next fortnight, the Moon can be seen rising 52 minutes belated after the Sunset. Also, the Moon wanes gradually. Over a period of seven to eight days, the Moon rises in the east around midnight and sets in the west around noon next day. Over the next seven or eight days, the crescent moon wanes, becomes feeble and becomes invisible on the fifteenth day. On this day the Moon and the Sun have the same ecliptic longitude. This second fortnight in which the eastward front of the Moon is illuminated is called the Krishna Pakṣa.
When the lunar journey during Śukla Pakṣa and Krīṣṇa Pakṣa is observed, it is seen that the Moon travels against the background of specific stars. The lunar orbit was highlighted by ancient Indian astronomers. They gave specific names to the stars / lunar mansions, to identify them. The Moon takes 27.3 days to complete one orbit around the earth. Thus the lunar orbit was divided into twenty-seven parts, each called a Nakṣatra. Every nakṣatra is identified and named after one of its prominent stars, which is also called a Yogatārā. Every nakṣatra consists of one, or more than one star. The Moon completes one orbit around the earth, after passing through the 27 nakṣatras in twenty-seven days, moving in a new nakṣatra every day.

Each nakṣatra consists of \( \frac{360}{27} = 13.33 \) degrees. (1 degree = 60 minutes).

Thus One nakṣatra spans \((13.33 \times 60)\) angular minutes = 800 angular minutes. This sums the average daily speed of the Moon as 800 angular minutes.

**Table No. 3: Nakṣatras and their Yogatārā**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Nakṣatra</th>
<th>Yogatārā</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aśvinī (अश्विनी)</td>
<td>β Arietis</td>
</tr>
<tr>
<td>2</td>
<td>Bharaṇī (भरणी)</td>
<td>41 Arietis</td>
</tr>
<tr>
<td>3</td>
<td>Krittikā (कृत्तिका)</td>
<td>Pleiades Eta Tauri</td>
</tr>
<tr>
<td>4</td>
<td>Rohiṇī (रोहिणी)</td>
<td>Aldebaran</td>
</tr>
<tr>
<td>5</td>
<td>Mrigashīrṣa (मृगशीर्ष)</td>
<td>λ Orionis</td>
</tr>
<tr>
<td>6</td>
<td>Ārdrā (आद्रा)</td>
<td>Alhena γ Gemini</td>
</tr>
<tr>
<td>7</td>
<td>Punarvasu (पुनर्वसु)</td>
<td>Pollux</td>
</tr>
<tr>
<td>8</td>
<td>Puṣya (पुष्य)</td>
<td>δ Cancri</td>
</tr>
<tr>
<td>Sl. No.</td>
<td>Nakṣatra</td>
<td>Yogatārā</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>9</td>
<td>Āśleṣā (आश्लेषा)</td>
<td>Zeta Hydrae (ζ Hya)</td>
</tr>
<tr>
<td>10</td>
<td>Maghā (मघा)</td>
<td>Regulus</td>
</tr>
<tr>
<td>11</td>
<td>Pūrvā Phālgunī (पूर्वाफाळगुणी)</td>
<td>θ Leonis</td>
</tr>
<tr>
<td>12</td>
<td>Uttarā Phālgunī (उत्तराफाळगुणी)</td>
<td>Denebola</td>
</tr>
<tr>
<td>13</td>
<td>Hasta (हस्त)</td>
<td>δ Corvi</td>
</tr>
<tr>
<td>14</td>
<td>Citrā (चित्रा)</td>
<td>Spica</td>
</tr>
<tr>
<td>15</td>
<td>Svātī (स्वाती)</td>
<td>Arcturus</td>
</tr>
<tr>
<td>16</td>
<td>Viśākhā (विशाखा)</td>
<td>α Librae</td>
</tr>
<tr>
<td>17</td>
<td>Anurādhā (अनुराधा)</td>
<td>δ Scorpionis</td>
</tr>
<tr>
<td>18</td>
<td>Jyeṣṭhā (ज्येष्ठा)</td>
<td>α Scorpionis</td>
</tr>
<tr>
<td>19</td>
<td>Mūla (मूल)</td>
<td>λ Scorpionis</td>
</tr>
<tr>
<td>20</td>
<td>Pūrvā Āśadhā (पूर्वाईशधा)</td>
<td>λ Sagittarii</td>
</tr>
<tr>
<td>21</td>
<td>Uttarā Āśadhā (उत्तराईशधा)</td>
<td>π Sagittarii</td>
</tr>
<tr>
<td>22</td>
<td>Śrāvaṇa (श्रवण)</td>
<td>α Aquilae</td>
</tr>
<tr>
<td>23</td>
<td>Dhaniṣṭhā (धनिष्ठा)</td>
<td>α Delphinus</td>
</tr>
<tr>
<td>24</td>
<td>Śatatārakā (शततारका)</td>
<td>γ Aquarii</td>
</tr>
<tr>
<td>25</td>
<td>Pūrvā Bhādrapadā (पूर्व भाद्रपदा)</td>
<td>α Pegasi</td>
</tr>
<tr>
<td>26</td>
<td>Uttarā Bhādrapadā (उत्तरभाद्रपदा)</td>
<td>γ Pegasi</td>
</tr>
<tr>
<td>27</td>
<td>Revatī (रेवती)</td>
<td>ζ Piscium</td>
</tr>
</tbody>
</table>

The luminosity of the stars in every nakṣatra is different. While marking the position of a yogatārā of a nakṣatra, ancient Indians have considered it's distance from the vernal equinox. The distance of each yogatārā from the vernal equinox on the ecliptic is known as the ‘Bhōga’ (celestial longitude) of that star. The celestial longitude of the Vernal equinox is considered as zero, after which, the first nakṣatra is named as aśvinī. Bhōga (celestial longitude) of aśvinī
nakśatra is 13 degrees 20 minutes. Celestial longitudes span from zero degrees to 360 degrees.

In various ancient texts on astronomy from the Vedāṅga period, the vernal equinox is denoted lying in different nakśatras. Thus in some methods of measurement of time the first nakśatra is considered as Kṛttikā; while in some, Dhanishtḥā is considered as the first. Modern system considers the aśvinī as the first nakśatra.

The term Śara’ (celestial or ecliptic latitude) measures the angular distance of an object from the ecliptic towards the north (positive) or south (negative) of the ecliptic pole. Śara’ of Pūṣya, Maghā, Śatārakā and Revatī nakśatras is zero degrees. It means that the stars mentioned above lie over the ecliptic. The stars in all the other nakśatras lie either to the north or to the south of the ecliptic.

The Bhōga and Śara are also used to represent the positions of the Moon, Sun and the other planets in the sky.

Every day, the Moon is moving eastwards in the sky away from the Sun. During the Kṛṣṇa Pakṣa, the Moon wanes and gets closer to the Sun, and one day the Moon and the Sun appear to be aligned together. During this day, the value of celestial longitude of moon and Sun becomes same/equal, i.e the east-west distance between the moon and Sun is equal to zero at a specific moment. Before that moment, the Moon is towards the west of the Sun. After that moment, the Moon shifts to the east of the Sun. Upon observing a total solar eclipse, we can experience this moment.

**Amāvāsyā - (New Moon day)**

The Sanskrit word ‘Am’ means - with; ‘vās’ means to live.

‘Sūryacandramasōryaḥ Paraḥ Sannikarṣaḥ Sāmāvāsyā’

(The closest proximity of the Sun and the Moon is called the New Moon.)

According to an ancient scripture, the tithi at which the Moon is not visible in the sky is called the new Moon.
**Paurnimā (Pūnimā / Pūrnamāśi / Paurnamāśi):**

This is the day on which the full Moon appears. It is the last *tīthī* of the month ending with the full Moon. The word 'māsa' also means the Moon, thus *Pūrnamāśi* is also called a full Moon. The full Moon is actually a moment in which the Earth is located between the Sun and the Moon and the angular distance of the Sun and the Moon as measured from the earth is 180 degrees. Thus they form an opposition. On this day, the lunar hemisphere facing Earth – the near side – is completely Sunlit and appears as a circular disk.

**********
Tithī (Lunar day)

A Tithī is an important unit used in the Indian chronometry. Just as the date is used to represent a day in the Gregorian calendar; similarly a tithī is used in the Indian calendar. A day in the Gregorian calendar consists of twenty-four hours. However, the tithī in the Indian calendar depends entirely upon the lunar location in the sky.

The Sun and Moon happen to be apparently moving from the west to the east on the celestial background. The Moon appears to move faster than the Sun. Thus the relative speed of the Moon with respect to the Sun can be calculated as follows, which is closely related with the concept of the tithī.

\[
\text{Relative speed of the moon w.r.t. the Sun per day} = \text{Relative speed of the moon w.r.t. the Earth per day} - \text{Relative speed of the Sun w.r.t the Earth per day}
\]

**Relative speed of the moon w.r.t. the Earth per day:** The Moon takes about twenty-seven days to complete a rotation around the Earth. This means that the Moon takes twenty-seven days to complete a span of 360 degrees.

Relative speed of the moon w.r.t the Earth per day = 360 degrees / 27 days
= 13.33 degrees per day
≈ 13 degrees per day

**Relative speed of the Sun w.r.t. the Earth per day** - The earth takes 365 days to complete a rotation around the Sun. This means the earth takes 365 days to complete a span of 360 degrees. Thus when viewed from the Earth, the Sun appears to move against the background of the stars.
Relative speed of the Sun w.r.t the Earth per day = $\frac{360 \text{ degrees}}{365 \text{ days}}$

= 0.986 days

~1 degree per day

\[
\begin{array}{|c|c|}
\hline
\text{Relative speed of the moon w.r.t the Sun per day} & 13 \text{ degrees per day} - 1 \text{ degree per day} \\
\hline
\end{array}
\]

= 12 degrees per day

This means that the angular distance between the Sun and the Moon is approximately twelve degrees per day. The time it takes for the longitudinal angle between the Moon and the Sun to increase by 12° is called a tithī. The Sun and the Moon appear to align on the same ecliptic longitude on a New Moon day. The Moon then moves away from the Sun faster. On the tithī of śukla pratipadā, the angular distance between the Sun and the Moon is 12°. Similarly it is 24° on the tithī of dvitīyā, 36° on the tithī of tr̥tīyā. Thus on the fifteenth tithī of the full Moon, the angular distance between the Moon and the Sun is 180°.

**The Time Period of a tithī**

The Moon revolves around the Earth in an elliptical orbit. Therefore, its angular speed changes constantly per day. When the Moon is closest to the earth, its apparent angular speed is 15.33 degrees per day, while when it is farthest, the apparent angular speed of the Moon is about 11.33 degrees per day. The tithī is defined as the time taken by the moon to span an angular distance of 12 degrees w.r.t. the Sun. But depending upon the speed of the Moon, this time period varies from 28 hours to 20 hours. A lunar month has 30 tithīs. Since the duration of the tithī is less than 24 hours, tithī vṛddhi and tithī kṣaya occur.

**Tithī vṛddhi and Tithī kṣaya (Rise and Decay in a Tithī)**

‘यां तिथिः समनुप्राप्य उदयं याति भास्करः’

‘Yāṁ tithiṁ samanuprāpya udayaṁ yāti bhāskaraḥ’
The meaning of above verse is, "The \textit{tithi} running during the Sunrise is the \textit{tithi} of that day"

\textit{Figure No. 5: tithi vrddhi}

On days, when a \textit{tithi} is completed under two solar days, \textit{tithi vrddhi} is said to have occurred. (one which comprises two sunrises).

\textit{Figure No. 6: tithi k\textsc{sha}ya}

If the Moon spans two \textit{nak\textsc{sh}atras} between two sunrises of two consecutive days, a \textit{tithi} is dropped or \textit{k\textsc{sha}ya} occurs. In Figure No. 6, \textit{t\textsc{ti}y\textsc{a} tithi} is running at the time of Sunrise on 29th. Shortly thereafter, the Moon enters its fourth \textit{tithi}, the \textit{caturthi}. On 30th, the Moon moves 60 degrees away from the Sun before Sunrise on the 30th; i.e, the fifth \textit{tithi} of \textit{pa\textsc{n}cam\textsc{i}} has started. So the \textit{t\textsc{ti}y\textsc{a}} has
started on 29th; and pañcamī has started on 30th. In the process, caturthī has vanished or tithī kṣaya has occurred.

In a normal year, the tithī vrddhi takes place seven times, while the tithī kṣaya occurs 13 times.
Māsa (Month)

The chronometric unit that comes after the fortnight, is the māsa or a month. Months associated with the seasons or ṛtu have been mentioned in the Vedic literature. The position of the Sun gives an idea of the seasons. The taittirīya saṃhitā consists of a verse which mentions the six ṛtu and twelve māsa.

मधुशच माधवशच वासंतिकावृतू सुक्रशच शृष्टिशच श्रीष्मावृतू |
नाभशच नभस्यशच वार्षिकावृतू ईशघोरशच शारदावृतू |
सहशच सहस्यशच हैमंत्रवृतू तपशच तपस्यशच शैशिरावृतू ||

Taittirīya Saṃhitā 4:4:11

Among these, Madhu, Mādhava, śukra, śuci, Nabhas, Nabhasya, īśa, ūrj, Sahas, Sahasya, Tapas, Tapasya are the names of the twelve mās. All these names have Vedic origin and are directly related to the seasons. It was difficult to tell where exactly a season ends and the next one begins, making it impossible to distinguish these mās. Over time, the names of the mās based on the seasons were replaced by the names of the lunations adapted from the nakṣatras. There are two types of māsa, the Cāndramāsa and the Sauramāsa.

Cāndramāsa or Lunar month

According to the ‘Sūrya Siddhānta’ and other ancient Indian texts, the lunar months based on motion of the Moon may have come into existence during the Vedāṅga jyotiṣa period, i.e around 1500 BC. The nakṣatras were formed consisting of the brightest stars in the lunar pathway. The months have been
named after the nakṣatra in the lunar background on the corresponding full moon day. The Moon crosses the 27 nakṣatras twelve times annually. These nakṣatras after which the months have been named, are not equidistant from each other. Also, the orbiting speed of the Moon doesn't remain constant. In addition, the nākṣatra lunar month consists of 27.3 days and the coincidental lunar month consists of 29.53 days. The east-west distance between the Moon and the Sun becomes zero at one point on the day of the new Moon. Such two consecutive days occur after an average of 29.53 days. All this has an effect on the occurrence of any nakṣatra on the day of the lunar full Moon.

Table No. 4: Cāndramāsa and Nakṣatras on the Full Moon Day

<table>
<thead>
<tr>
<th>Cāndramāsa</th>
<th>Nakṣatra on Purṇimā</th>
<th>Cāndramāsa</th>
<th>Nakṣatra on Purṇimā</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caitra</td>
<td>Caitrā/ Svātī</td>
<td>Aśvin</td>
<td>Aśvinī/Bharaṇī</td>
</tr>
<tr>
<td>Vaiśākha</td>
<td>Viśākhā/ Anurādhā</td>
<td>Kārtika</td>
<td>Kṛttikā/Rohiṇī</td>
</tr>
<tr>
<td>Jyeṣṭha</td>
<td>Jyeṣṭhā/ Mūlā</td>
<td>Mārgaśīrṣa</td>
<td>Mṛgaśīrṣa / ādrā</td>
</tr>
<tr>
<td>Āśāṛ āśāḍha</td>
<td>Pūrvāśadha/ Uttarāśadha</td>
<td>Pauṣa</td>
<td>Punarvasu/ Puṣya</td>
</tr>
<tr>
<td>Śrāvaṇa śrāvaṇa</td>
<td>Sravaṇa/ Dhaniṣṭhā</td>
<td>Māgha</td>
<td>śleṣā /Maghā</td>
</tr>
<tr>
<td>Bhāḍrapadāa Bhāḍrapadāa</td>
<td>Pūrvābhāḍrapada/ Uttarābhāḍrapada</td>
<td>Phālguna</td>
<td>PūrvāPhālguni/ Uttara Phālguni</td>
</tr>
</tbody>
</table>

There are two types of lunar months, Amānt and Pūrṇimānt. Pūrṇimānt months are used extensively in Northern India while Amānt months are used extensively in South India.

Amānt -
This is the month which ends with the new Moon. The Amānt month is considered from a new Moon day to the next new moon day. The first fortnight of this month is śuklapakṣa and the second fortnight is Krishnapakṣa.
**Pūrṇimānt** -
This is the month ending with *Pūrṇimā* or the full Moon. The time period from one full Moon to another is known as the *Pūrṇimānt* month. In this month the first fortnight is the *Krishnapakṣa* and the second fortnight is the *śuklapakṣa*.

**Naming a lunar month:** An important rule was set to determine the names of the lunar months in order to establish the relationship between the lunar month and the Sun, and to avoid any confusion created by the location of the Moon on the full Moon day. According to this, when the Sun enters *meṣa rāśi* in the lunar month ending with the new Moon, that *'amānta cāndramāsa*', should be called *Caitra*. In the same way, the names of the lunar months or the *cāndramāsas* should be determined according to the solar transits through the next signs. This was one of the first attempts to interrelate the solar year and lunar year. When the Sun enters the *nakṣatra aśvinī*, it is said to be a *'meṣa sankrānti*. (Aries transit). *Caitrā nakṣatra* is situated at 180 degrees or exactly opposite from the starting point of *aśvinī nakṣatra*. The time period during which the *Caitrā nakṣatra* rises to the east at the Sunset, is called the month of *Caitra*. The *nakṣatras* corresponding to each month given in the table above, rise at the time of the Sunset in that month and remain in the sky throughout the night.

**Yutikālin Cāndramāsa (Coincidental lunar month)**
On each new Moon, the Sun and Moon are in the same direction, thus the Moon is not visible on that day. On this day, at a specific moment the east-west distance between the Sun and the Moon becomes zero. The time period ranging from a new Moon to the next new moon is known as the coincidental lunar month, which is used for civil purpose. The coincidental lunar month consists of 29.530589 days.

**Sāṃpātīya Cāndramāsa (Tropical lunar month)**
The time taken by the Moon to return to the Vernal Equinox in the sky is called the tropical lunar month. This lunar month consists of 27.321582 days.

**Nākṣatriya cāndramāsa (Nākṣatriya Lunar Month):**
The time taken by the Moon to return again to a particular *nakṣatra* or lunar mansion is called a *Nākṣatriya cāndramās*. The *Nākṣatriya* lunar month consists of 27.321662 days.
Upabhūviya cāndramāsa (Subtropical Lunar Month):
The time it takes for the Moon to return to the apogee point (earth's closest proximity), is called the subtropical lunar month. The subtropical lunar month consists of 27.554550 days.

Sauramāsa (Solar month)
Just as the Amānt and Pūrmimānt lunar months are considered; similarly, the practice of considering the solar months based on the location of the Sun in the sky is prevalent in some parts of India. As the earth revolves around the Sun, the Sun appears to move in the sky along the ecliptic. The 360 degrees ecliptic has been further divided into twelve parts. Each part consists of thirty degrees and is called a zodiac sign or rāśi. Solar transit from one zodiac sign to the next is called as a sankramaṇa. This Solar transit in the sign of Capricorn is called The Makara sankrānti. Today, the Makara sankrānti falls on the 14th and 15th of January. Thus, every month a sankrānti occurs and those sankrāntis are named after the corresponding solar month. E.g. 'meṣa sankrānti' in April, Vṛṣabha sankrānti in May.

Table No. 5: Solar Months and the Days of Solar Transits

<table>
<thead>
<tr>
<th>Day of Solar transit</th>
<th>Solar Transit and Solar Month</th>
<th>Transit (saṃkrāṃti)</th>
<th>Day of Solar transit</th>
<th>Solar Transit and Solar Month</th>
<th>Transit (saṃkrāṃti)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13/14 April</td>
<td>Aries (Meṣa)</td>
<td>Meṣa saṃkrāṃti</td>
<td>14/15 May</td>
<td>Taurus (Vṛṣabha)</td>
<td>Vṛṣabha saṃkrāṃti</td>
</tr>
<tr>
<td>15/16 June</td>
<td>Gemini (Mithuna)</td>
<td>Mithuna saṃkrāṃti</td>
<td>16/17 July</td>
<td>Cancer (Karka)</td>
<td>Karka saṃkrāṃti</td>
</tr>
<tr>
<td>16/17 August</td>
<td>Leo (Siṃha)</td>
<td>Siṃha saṃkrāṃti</td>
<td>16/17 September</td>
<td>Virgo (Kanyā)</td>
<td>Kanyā saṃkrāṃti</td>
</tr>
<tr>
<td>17/18 October</td>
<td>Libra (Tulā)</td>
<td>Tulā saṃkrāṃti</td>
<td>16/17 November</td>
<td>Scorpio (Vṛścika)</td>
<td>Vṛścika saṃkrāṃti</td>
</tr>
<tr>
<td>15/16 December</td>
<td>Sagittarius (Dhanu)</td>
<td>Dhanu saṃkrāṃti</td>
<td>14/15 January</td>
<td>Capricorn (Makara)</td>
<td>Makara saṃkrāṃti</td>
</tr>
<tr>
<td>12/13 February</td>
<td>Aquarius (kumbha)</td>
<td>Kumbha saṃkrāṃti</td>
<td>13/14 March</td>
<td>Pisces (mīna)</td>
<td>Mīna saṃkrāṃti</td>
</tr>
</tbody>
</table>
These months are decided and named based upon the apparent motion of the Sun on the stellar background. Although the zodiac signs are expressed technically in terms of degrees, they consist of specific clusters of stars. The Sun is in Gemini from June 15 to July 16. During this period, the earth is in perihelion within its orbit. Thus the duration of solar months of July and August is the maximum. The Sun is in Sagittarius from December 16 to January 14, during which the Earth is in aphelion with the Sun. Therefore, the duration of the solar months of December and January is the minimum.
We have studied the concepts of Tithṛddhi and Tithīkṣaya along with the tīthī. Just as the lunar motion from one sunrise to the next causes the tīthī vrddhi and tīthī kṣaya, similarly when the lunar month ends before the Sun has moved to a new zodiac sign, a thirteenth month has to be added to the lunar year. This extra month can also be called adhik māsa or asankrāntimāsa.

Cāndravarṣa - Lunar year (354 days):
The coincidental lunar month consists of 29.53 days on average. Thus a lunar year consists of twelve lunar months, or 354 days.

Saurvarṣa - Solar year (365.2564 days):
The Earth takes 365.2564 days to complete an orbit around the Sun. We can derive the average days of a solar month by dividing the total number of the days in a year by twelve. The average duration of a solar month is thirty days, ten hours, twenty-nine minutes and four seconds (30d 10h 29m 4s).

Indian Luni - Solar Chronometry:
The lunar year is shorter than the solar year by eleven days. This excess of eleven days, causes unalignment between the pure lunar year and the seasons, and the occurrence of the lunar festivals eleven days earlier.

Assuming that in the year 2020, dīpāvalī commences on 14th November, thus it will happen eleven days earlier i.e. on the day of 3rd November in 2021. If we continue the same chronology, then in the year 2031, dīpāvalī will commence on 25th July and the alignment of festivals with the seasons will be disrupted. Thus ancient Indian astronomers came up with an innovative idea to keep the lunar festivals in alignment with the seasons. They added a month to a specific lunar year after a certain period of time. This month is called adhik māsa. This lunar year consists of thirteen months instead of twelve.
Method to identify *Adhik māsa* or the intercalary month:

The rule to identify the *adhik māsa* is as follows - the lunar month in which no *sankrānti* is observed or the solar month in which two new moons are observed, is called an *adhik māsa*.

![Image of solar transits and new moons](image)

**Figure No. 7: Identifying the Adhik Māsa**

Figure No. 6 shows the solar transits and New Moons between September 2020 and December 2020.

Two New Moons occur during the Virgo transit. Therefore, the lunar month starting from the first new Moon is considered as an *Adhik aśvin* and the lunar month starting from the second new Moon is considered as *Nija aśvin*.

The earth revolves around the Sun in an elliptical orbit. Therefore, some solar months are shorter while some are longer. The shortest solar month consists of 29 days, ten hours and 48 minutes (29d 10h 48m); the largest solar month consists of 31 days, ten hours and 48 minutes (31d 10h 48m).

The Moon revolves around the earth in an elliptical orbit. Therefore, the duration of the lunar months is also not the same. The shortest lunar month consists of
29.26 days (29d 5h 54m 14.4s) and the longest lunar month consists of 29.80 days (29d 19h 36m 28.8s).

After how many solar months does the intercalary month or the *adhik māsa* occur?

A solar year consists of 365.2564 days.
The average duration of a solar month consists of $\frac{365.2564}{12} = 30.4380$ days.
Thus the lunar month is $(30.4380-29.53) = 0.908$ days shorter than the solar month.
Thus the number of solar months covered in 29.53 days $= \frac{29.53}{0.908} = 32.522$ solar months i.e. 2.71 solar years.

After how many lunar months does the intercalary month or the *adhik māsa* occur?

Since the lunar year is eleven days shorter than the solar year, number of lunar months required to be completed in order to add one intercalary lunar month is $\frac{29.53}{11} = 2.68$.
Thus a deficit of one lunar month is created after two years and eight months. Therefore, an intercalation to this lunar year is done in order to align it with the seasons.

A need for an intercalation is created after every 2.68 lunar years or 2.71 solar years because of the motion of the Sun and the Moon.

The table no. 6 shows that a total seven *adhik māsas* occur in the span of 19 years. The *Jyeṣṭha* month gets intercalated four times, the month of Āśārh gets intercalated three times, the month of *aśvin* and Śrāvaṇa get intercalated twice and the months of *Caitra*, *Vaiśākha* and *Phālguna* get intercalated once.
### Table No. 6: Adhik Māsa occurring between 2010 to 2050

<table>
<thead>
<tr>
<th>Year</th>
<th>Saka</th>
<th>Adhik māsa</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1932</td>
<td>Vaiśākha</td>
</tr>
<tr>
<td>2012</td>
<td>1934</td>
<td>Bhādrapadaa</td>
</tr>
<tr>
<td>2015</td>
<td>1937</td>
<td>Āsārh</td>
</tr>
<tr>
<td>2018</td>
<td>1940</td>
<td>Jyeṣṭha</td>
</tr>
<tr>
<td>2020</td>
<td>1942</td>
<td>Aśvin</td>
</tr>
<tr>
<td>2023</td>
<td>1945</td>
<td>Śrāvaṇa</td>
</tr>
<tr>
<td>2026</td>
<td>1948</td>
<td>Jyeṣṭha</td>
</tr>
<tr>
<td>2029</td>
<td>1951</td>
<td>Caitra</td>
</tr>
<tr>
<td>2031</td>
<td>1953</td>
<td>Bhādrapadaa</td>
</tr>
<tr>
<td>2034</td>
<td>1956</td>
<td>Āsārh</td>
</tr>
<tr>
<td>2037</td>
<td>1959</td>
<td>Jyeṣṭha</td>
</tr>
<tr>
<td>2039</td>
<td>1961</td>
<td>Aśvin</td>
</tr>
<tr>
<td>2042</td>
<td>1964</td>
<td>Āsārh</td>
</tr>
<tr>
<td>2045</td>
<td>1967</td>
<td>Jyeṣṭha</td>
</tr>
<tr>
<td>2047</td>
<td>1969</td>
<td>Phālguna</td>
</tr>
<tr>
<td>2050</td>
<td>1972</td>
<td>Śrāvaṇa</td>
</tr>
</tbody>
</table>
The earth revolves around the Sun in an elliptical orbit having eccentricity 0.0167. An ellipse has two foci. The Sun is considered to be at one of these foci. Thus the distance between the earth and the Sun varies every day. On a specific day (January 4) The distance between the Sun and the Earth is minimal (147.5 million Km), i.e. the Earth is in the Perihelion with the Sun. Similarly, the distance between the Sun and the earth is maximum when it is in aphelion, i.e. (152.6 million km).

The solar month is shortest when the earth is in the perihelion. While the duration of the solar month is longest when the earth is in the aphelion. Therefore, the occurrence of Jyeṣṭha and Āsāḍha months is more frequent. When the earth is in perihelion with the Sun, the Pauṣa māsa never appears as an extra month. Also the extra months, Mārgaśīrṣa and Maghā appear least frequently.

(The Hijri chronology is based on the classical lunar year. Therefore, the Hijri calendar recedes by eleven days every year. For more information refer to the Islamic Chronology text.)

***************
The smallest solar month consists of 29 days, 10 hours and 48 minutes (29d 10h 48m). If the largest lunar month incorporates the smallest solar month, then a new moon will not occur in this month. If there are two New Moons then adhik māsa is considered. If New Moon doesn't occur, kṣayamāsa is considered.

While the Sun is in sagittarius, the earth is in aphelion with the Sun and the lunar month is Pauṣa. Thus Pauṣa māsa is dropped or is a kṣayamāsa. Mārgaśīrṣa and Maghā are rarely dropped. The adhik māsa is added before and after the kṣayamāsa, in order to coordinate it with the seasonal cycle.

The year in which the kṣayamāsa occurs doesn't consist of 11 months. The occurrence of an adhikmāsa before and after the kṣayamāsa makes 13 total months in that year. In the recent history, examples of kṣayamāsa were observed in the month of Mārgaśīrṣa in 1963 AD and month of Magh in 1983 AD. The next kṣayamāsa will appear in 2123 AD.
In any chronometry, the year or a month has to be started from a specific point of reference of time. These reference points can be determined with the help of apparent orbits of the Sun and the Moon. The spring equinox or an autumnal equinox for the Sun and Full moon/new moon, or a distant star for the Moon, can be used as the reference points. Let's know the methods adopted in different chronometries around the world.

**Tropical Year:**

It is defined as the mean interval between two successive passages of the Sun through the Vernal equinox point. It consists of 365.2422 days. As the seasonal cycle commences from the Vernal Equinox point, the tropical year is considered extremely useful and important.

**Julian Year:**

The old Julian calendar consisted of 365.25 days. The leap year used to occur after every four years, thus 25 leap years used to occur in hundred years. The Julian calendar became out of practice after the Gregorian calendar was introduced.

**Gregorian Year:**

In 1582, Pope Gregory updated the calendar. It was accepted as a civil calendar worldwide. The normal year consists of 365 days while the leap year consists of 366 days. The Gregorian year consists of 365.2425 days. There is a difference of 0.0003 days in the Gregorian year and the Tropical year.
Solar year / Sidereal Year:

It is defined as the mean interval between two successive passages of the Sun through a specific Nakshatra. The Sidereal Year consists of 365.2564 days.

Lunar year:

The moon completes a rotation around the Earth in 29.530589 days. It takes 354.367068 days for the moon to complete twelve rotations around the Earth. Thus the classical lunar calendars (i.e. Islamic Calendar) consider a lunar year of 354 or 355 days.

The Anomalistic Year:

'The Perihelion' is the point of closest proximity of the Sun to the Earth. Every year, around January 4, the Sun is the closest to the Earth. It is defined as the mean interval between two successive passages of the Sun through the aphelion. This period is 365.2596 days.

Eclipse Year:

The Moon's apparent path intersects the ecliptic obliquely at two points called the nodes. These nodes are called the North/ascending node (Rāhu), and the South/descending node (Ketu). Thus the eclipse year is defined as the mean interval between two successive passages of the Sun through the ascending node. This period is 346.6201 days, which is comparatively smaller than other years. As Rāhu is in retrograde motion, the Sun requires comparatively less time to return to that point. The eclipse year is used to predict eclipses as well as in ecliptic mathematics.
11

Samvatsara

The ancient Indian chronometry considers a special time period called the *samvatsara* comparable to Year. The word *samvatsara* literally means the 'year'. But it carries a significant relation with the 60-year-long cycle of Jupiter. Each year of this cycle is assigned a specific name. Jupiter orbits the Sun five times in 60 years and returns to its initial position. Thus a *samvatsara* is 1/12th of the time taken by Jupiter to complete its orbit around the Sun.

Jupiter orbits the Sun in 11.8626 (about 12) years.

Thus one *samvatsara* consists of $11.86260/12 = 0.98855$ years.

Because of this difference, within 86 *Samvatsara*, 85 years are completed. In order to establish one to one relationship between the *Samvatsara* and the year, one *Samvatsara* is dropped within 85 years.

According to the "Sūrya Siddhānta", a *samvatsara* is defined as the time period taken by Jupiter to traverse a *rāsi* or angular distance of 30 degrees.

Bhaskaracharya has defined the *samvatsara* as,

‘ब्रह्मस्पते: मध्यमराशीभोगं संवत्सर संहितिका वेदांती’

'bṛhaspate: madhyamarāśībhogaṃ samvatsara saṃhitikā vedānti’

Thus a *samvatsara* is 1/12th of the time taken by Jupiter to complete its orbit around the Sun. These ideas became outdated in course of time.

In South India, the beginning of the *samvatsara* is marked by *varṣa pratipadā* and it ends with that lunar year. In North India, the *samvatsara* commences with dīpāvalī *pāḍavā*. This method is more scientific. The South Indian *samvatsara* no longer relates with the Jupiter *samvatsara*.
'सम्यक् वसन्ति मासादया: अस्मिन्
'samyak vasanti māsādayāh asmin'

The saṃvatsara is the one which completely accommodates māsa and other the Indian chronological units.

The period of sixty years is very important in human life. In the past it was customary to tell the saṃvatsara of birth instead of age.

Śālivāhana and Vikram saṃvat, other śakas and saṃvatsara

- Šālivāhana saka saṃvat: Šālivāhana saka is associated with the Sātavahana kings of Central India. This shaka was started in the year 78 AD. Thus Subtracting 78 or 77 from the AD number gives the Šālivāhana Saka number.

- Vikram saṃvat: The new year of Vikram saṃvatsar begins on the Dīpāvalī Padva (Kārtik śukla pratipadā-Bali pratipadā). If we add 56 or 57 to the number of AD, then we get Vikram saṃvat number. 
  Vikram saṃvat - 135 = Śaka saṃvat.

- Kalchuri saṃvat: This is called Chedi saṃvat or Trikutak saṃvat. It is found in rock inscriptions in Gujarat, Konkan and Madhya Pradesh. If we add 249 in the Kalchuri saṃvat, then we get number of AD.

- Kaliyuga saṃvat: This is called the Mahābhārata saṃvat or Yudhiṣṭhira saṃvat. Kaliyuga saṃvatsara is mentioned in astrological texts and inscriptions. It started in the year 3102 BC (February 17). If we add 3102 in the year number of AD, 3043/44 in the number of Vikram saṃvat and 3179/80 in the number of Saka saṃvat, we obtain the year of Kaliyuga saṃvat. (According to other sources, Yudhiṣṭhira Saka started 3044 years after the beginning of Kali Yuga.)

- Gāṅgeya saṃvat: This is a saṃvat started by the king of Kalinganagar in Tamil Nadu. It is used in many places in southern India. If we add 579 in the figure of Gāṅgeya saṃvat, we get the number of AD.

- Gupta saṃvat: This is called Guptakāla or Guptavarṣa or Valbhi saṃvat. It must have been started by a Gupta king. It was used from Nepal to Gujarat. If we add 320 in the year of Gupta saṃvat, we get the year in AD.
**Cālukya Vikram saṃvat:** This saṃvat was started by the 6th Vikramāditya, the Chālukya Solanki king of Kalyanpur in Andhra Pradesh. This saṃvat is also known as Cālukya Vikramakāla, Cālukya Vikram Varṣa or Veer Vikram Kāl. If we add 1076 in this saṃvat number, we get year in AD.

- **Tamil Year:** It starts on or around April 14.
- **Persian new year:** The Persian New Year begins on March 21 around the world, in India and Pakistan it usually begins on August 17.
- **Barhaspatya saṃvat:** It depends upon the Rising and setting of Jupiter in the sky.
- **Rajyabhishek saṃvat:** The saṃvat which started after the coronation of Chhatrapati Shivaji Maharaj. It started in the month of June, 1674 AD.
- **Veeranirvana saṃvat:** Its Sana number = 69/70 + Vikram saṃvat.
- **Shahur (Suhur / Suhur) saṃvat:** Suhur saṃvat is usually obtained after subtracting 599/ 600 years from Vikram saṃvat. In the letters during the Peshwa period, the dates were mentioned in the form of Suhur saṃvat.
- **Saptarshi saṃvat:** Began in the year 3076 BC.

The names of Śālivāhana Saka saṃvatsara - These names may have been derived from certain events that occurred in a particular year. This is mentioned in Jātaka Khāṃḍa of Bhṛgu Saṃhitā. This period might be about 2000 to 2500 years. The names given below are of 'lunar years'. There are total 60 saṃvatsaras. At the end of these sixty saṃvatsaras (i.e. after the last 'dropped year') a new saṃvatsara called Prabhav begins again. The number of AD is given in brackets.

1. **Prabhava** (1927-28, 1987-88)
2. **Vibhava** (1928-29, 1988-89)
3. **Pramoda** (1929-30, 1989-90)
4. **śukla** (1930-31, 1990-91)
6. **Aṅgirā** (1932-33, 1992-93)
7. **śrīmukha** (1933-34, 1993-94)
8. **Bhāva** (1934-35, 1994-95)
10. **Dhāṭr** (1936-37, 1996-97)
11. īśvara (1937-38, 1997-98)
27. Vijaya (1953-54, 2013-2014)
34. śārvari (1960-61, 2020-2021)
36. śubhakṛta (1962-63, 2022-2023)
37. śobhana (1963-64, 2023-2024)
39. Viśvāvasu (1965-66, 2025-2026)
40. Parābhava (1966-67, 2026-2027)
41. Plavamga (1967-68, 2027-2028)
42. Kīlaka (1968-69, 2028-2029)
43. Saumya (1969-70, 2029-2030)
44. Sādhāraṇa (1970-71, 2030-2031)
45. Virodhakṛta (1971-72, 2031-2032)
46. Paridhāvi (1972-73, 2032-2033)
47. Pramādī (1973-74, 2033-2034)
48. ānaṃda (1974-75, 2034-2035)
49. **Rākṣasa** (1975-76, 2035-2036)
50. **Nala** (1976-77, 2036-2037)
51. **Piṅgala** (1977-78, 2037-2038)
52. **Kala(Yukta)** (1978-79, 2038-2039)
53. **Siddhārtha** (1979-80, 2039-2040)
54. **Raudra** (1980-81, 2040-2041)
55. **Durmati** (1981-82, 2041-2042)
56. **Dudumbhi** (1982-83, 2042-2043)
57. **Rudhirodgārī** (1983-84, 2043-2044)
58. **Raktākṣi** (1984-85, 2044-2045)
59. **Krodhana** (1985-86, 2045-2046)
60. **Kṣaya** (1986-87, 2046-2047)

The Śālivāhana saṃvatsara is named after one of the below 60 names.

**How to derive the name of a Śālivāhana saṃvatsara?**
Add 12 in the number of Śālivāhana saka. Divide it by 60. Add the remainder in the number of the Prabhav saṃvatsara, the corresponding name will be the required Śālivāhana saṃvatsara.

For example,

On the day of Gudi padva in 2013, Saka 1935 had started.
1935+12 = 1947
1947÷60 = 32 (remainder of 27)

**Vijaya** is the 27th saṃvatsara.
Thus, On the day of Gudi padva in 2013, Saka 1935 was named Vijaya.
Similarly **Jaya** was the saṃvatsara in 2014
**Manmatha** was the saṃvatsara in 2015.

**How to derive the name of a Vikram saṃvatsara?**
Add 9 to the number of Vikram saṃvatsara. Divide this sum by 60. Add the remainder in the number of the Prabhav saṃvatsara, the corresponding name will be the Vikram saṃvatsara.
For example,

On the day of *dīpāvalī* (Kārtika śukla pratipadā) in 2013, Vikram saṃvat 2070 had started.

2070+9 = 2079

2079÷60 = 34 (remainder of 39)

Viśvāvasū is the 39th saṃvatsara commenced on the day of *dīpāvalī* in 2013.
Similarly *Parābhava* was the Vikram saṃvatsara in 2014
*Plavaṃga* was the Vikram saṃvatsara in 2015.

- **Srṣti saṃvat** : (according to Hindu chronology): 19555885121
- **Kalpābda**: 1972949121 (according to Hindu chronology)
- **Chinese saṃvat**: 96002318
- **Parsi saṃvat**: 1899123
- **Egyptian saṃvat**: 27674
- **Turkish saṃvat**: 7627
- **Adam saṃvat**: 7372
- **Iranian saṃvat**: 6022
- **Jewish saṃvat**: 5781
- **Śrīkrṣṇa saṃvat**: 5246
- **Yudhisthira saṃvat**: 5121
- **Kaliyuga saṃvat**: 5121
- **Saptarshī saṃvat**: 5096
- **Ibrahim saṃvat**: 4460
- **Greek year**: 3593
- **Moses Year**: 3659
- **Roman year**: 2771
- **Mahavira saṃvat**: 2615
- **Buddhist saṃvat** 2595
- **Burmese Year**: 2561
- **Veer Nirvana saṃvat**: 2547
- **Malayaketū Saka**: 2332
- **Śaṃkarācārya saṃvat**: 2300
- **Parthian saṃvat**: 2267
- **Vikram saṃvat**: 2077
- **2020 A.D.** (2020 A.D. according to Christian chronology)
- **Java Year**: 1946
Measurement of Time

- Śālivāhana Saka: 1942
- Kalchuri saṃvat: 1778
- Vallabhi saṃvat: 1700
- Hijri year: 1441 (according to Islamic chronology)
- Bangla saṃvat: 1431
- Harshabda saṃvat: 1413
Astronomers follow two main systems of presenting the planets as they are in the sky, which are known as the Sāyana system and Nirayana system. The word ‘ayana’ which is common between the two, literally means ‘movement’. We use the words Uttarāyaṇa and Dakṣināyaṇa frequently. Uttarāyaṇa means moving towards North while Dakṣināyaṇa means moving towards South.

**Sāyana: (Sah+ayana)** This literally means ‘movement along with’ the vernal equinoxes. The Vernal Equinox is not fixed. It precesses 50.2 angular seconds every year. When the positions of heavenly bodies are measured by considering this movement, it is called the Sāyana system.

**Nirayana: (Nir+ayana)** This literally means ‘no movement’ or neglecting the precession of equinoxes. When positions of heavenly bodies are measured from a fixed point of reference, (without considering the precession of the vernal equinox), it is called Nirayana system. This point has been fixed on 21st March in the Gregorian calendar, thus it uses the Nirayana system.

**Why does the Vernal Equinox shift?**

Earth's axis of rotation is tilted 23.5 degrees from the plane of its orbit around the Sun. It completes a rotation around itself (like a vortex) in 25722 years. The star aligned with the axis of rotation towards the North is called the Pole star. At present, it is Polaris. The rotation of the earth's axis also causes the reference pole star to change over time. This motion of the Earth's axis is called 'Precession of the equinoxes'.

Measurement of Time
Ecliptic:

It is the great circle on the celestial sphere representing the Sun's apparent path during the year. Along with the Sun, the Moon and other planets travel along the same trajectory in the sky. The ecliptic has been divided in twelve segments of 30-degrees and each segment is called *rāshī* (a zodiac sign).

Celestial equator:

The Celestial equator is the apparent celestial projection of the Earth's equator in the sky. (The equator is itself perpendicular to the axis of rotation of the earth.) The equator divides the earth into the Northern hemisphere and the Southern hemisphere. Similarly, the celestial equator divides this imaginary mega-circle into two equal halves, namely the northern and the southern sky.
The celestial equator is currently inclined by about 23.44° to the ecliptic plane. These two celestial circles intersect at two points. One of these points of intersection is called the Vernal equinox and another is called the Autumnal equinox. The precession of equinoxes does not change the plane of the ecliptic; but the location of the celestial equator keeps on changing frequently. That is why the position of the vernal equinox also changes.

**How to measure the precession of equinoxes?**

- It takes 25722 years for the axis of the earth to complete 360 degrees. Thus in 71.45 (~ 72) years, the vernal equinox recedes by a degree.

- A zodiac sign consists of 30 degrees over the ecliptic. There are 12 such zodiac signs. Therefore, it takes 2143.5 ($25722/12$) years for the vernal equinox to pass through one zodiac sign.

- A *nakśatra* spans 13.33 degrees on the ecliptic. There are 27 such *nakśatras*. It takes 952.66 ($25722/27$) years for the vernal equinox to pass through one *nakśatra*.

The vernal equinox was situated in front of the *Citrā* star in the *Vedāṅga Jyotiṣa* period of Indian astronomy. Therefore, this point was considered as the origin of Aries or *meśa rāśi*. Afterwards, the vernal equinox started receding backwards due to the precession of equinoxes. Today, the vernal equinox has receded backward by 24 degrees from its initial position. This has caused a gap of twenty four degrees between Sāyana Aries and *Nirayana* Aries. This difference is remarkably observed between the occurrence of *Makar Saṃkrāṃti* (January 14) and the beginning of the winter solstice (December 22). Once upon a time, *Makar Saṃkrāṃti* and *Uttarāyaṇa* or winter solstice used to begin on the same day.
Uttarāyaṇa and Dakṣiṇāyana are two important concepts in Indian chronometry. They carry religious significance. On the day of Uttarāyaṇa, ancient Indians used to perform religious deeds and holy sacrifices. The spring equinox, the autumnal equinox, the summer solstice day and the winter solstice day are the four major phases in the annular circummotion around the Sun.

The equator is considered as 0° (zero degrees). Throughout the year, the Sun travels from 23° 26′ 22″ N (Tropic of Cancer) to 23° 26′ 22″ S (Tropic of Capricorn).

**Spring Equinox:**

Presently, the Sun arrives at the vernal equinox on March 20th/21st. On this day, the Sun rises in the exact east. Day and night are of equal duration of twelve hours. On this day, the Sun is situated over the equator and is travelling towards the north.

**The point of onset of the Dakṣiṇāyana or the winter solstice:**

While travelling northwards, the Sun falls on the Tropic of Cancer on 21/22 June. On this day, Sunrise and Sunset occur far northward of the East and West. The longest day and shortest night of the year in the northern hemisphere, occurs on this day. Sunset does not happen on the North Pole during this period. Thus the Sun is in the sky for the whole 24 hours. On the South Pole Sunrise doesn't occur and the night is of 24 hours duration. The Tropic of Cancer is situated 23° 26′ 22″ (about twenty-five degrees) towards the North of the equator.
Figure No. 10 shows the change in the durations of day and night throughout the year. These are the local time figures for Nagpur, a city in India. The longest day in June and the longest night in December can be easily observed in this figure.

**Uttarāyaṇa and Dakṣiṇāyana**

Figure No. 10: Graphical representation of durations of Sunrises and Sunsets over the year.

**Autumnal equinox:**

From June 21/22, the Sun starts moving southward from the Tropic of Cancer. On September 22, the Sun rises on the exact east. On this day, the day and night are of the same duration and the Sun falls on the equator. The southward journey of the Sun continues.

The point of onset of the Uttarāyaṇa or the Summer solstice

On December 21/22, the Sun falls on the Tropic of Capricorn. The Sunrise on this day occurs in the extreme south of the east. The duration of the day in the Northern Hemisphere is the shortest; thus the night is very long. The Sun begins to ascend towards the north after this day. Sunset does not happen at the south pole on this day, so the Sun is present in the sky for 24 hours. Simultaneously the Sun does not rise at the North Pole, and the night lasts for 24 hours during
this period. The Tropic of Capricorn is 23° 26' 22" (about twenty three and a half) degrees away towards the south of the equator.

Throughout the year, the Sun travels from 23° 26' 22" S (about twenty-three and a half degrees) to 23° 26' 22" degrees N (about twenty-three and a half degrees). This has created a cycle of seasons on earth. At present, the Earth's axis is tilted by 23° 26' 22" degrees (about twenty-five degrees). This tilt varies from 22.1 degrees to 24.5 degrees in a span of about forty thousand years.
The history of Indian astronomy starts right from the Vedic period. The uninterrupted tradition that has been blooming since the Vedic period is still prevalent in India in the form of the *Pañcāṅga*. After the development of modern astronomy in the West, somewhere around 1790, the Almanac started to be published in order to locate the planets, Moon and the Sun in the sky easily.

The calendar was adapted in the Western world around 300 AD. The Indians started publication of *Dinadarśikā* (calendar) in the British period (nineteenth century) on the basis of western calendars.

India is a multilingual country, thus different methods of chronology have been adopted. Therefore, various *Pañcāṅga* and calendars in various regional languages are prevalent in different states of India.

The *Pañcāṅga* consists of five limbs or components, namely *Vāra*, *tīthī*, *nakśatra*, *karaṇa* and *yoga*, which have astronomical significance. Similarly *karaṇa* and *yoga* have astrological significance. In addition to this, the almanac gives the 'accurate positions' of the Moon, Sun and the planets in the sky and is used for sky observations. In the same way, the *Pañcāṅga* gives information about eclipses of Moon-Sun-planets, planetary conjunctions, rising-setting of celestial bodies, retrograde and normal motion.

**Vedic Period:**

The use of *pañcāṅga* must have been started from the Vedic period. The solar year has been mentioned in *Vedas*; So are the lunar months. *Uttarāyana* and *Dakṣināyana*, the six seasons and the twenty-seven *nakśatras*, were observed at different times of the year. The full Moon months were being considered.
**Vedāṅga jyotiṣa Period:**

The time from 1500 BC to 400 AD is known as the *Vedāṅga Jyotiṣa* period. The sage Lagadha compiled a treatise called *RigJyotiṣa*, which consists of 36 verses, while *Yajas Jyotiṣa* consists of 43 verses. The concepts used in the *vedāṅga jyotiṣa* are as follows:

1. In *vedāṅga jyotiṣa* a *yug* was considered to be of duration of five years. These five years were known as *Saṃvatsara, Parivatsara, Idāvatsara, Anuvatsara and Idavatsara*. They believed that the Moon and the Sun reunite in a point in the sky after a period of five years.
2. A *yuga* consisted of 1830 days and 1860 tithīs.
3. In a *yuga* 62 lunar months and 60 solar months were considered.
4. In a *yuga*, 30 *kṣaya tithīs* were considered.
5. There were 67 months based on *nakśatras* in a *yuga*. Thus the Moon travelled through $67 \times 27 = 1809$ *nakśatras*.
6. A *yuga* consisted of two *adhik māsa*.
7. *Uttarāyaṇa* used to start in *Dhaniṣṭha nakṣatra*.
8. The Indian new year would commence from the tithī of *Magh śukla pratipadā*
9. The zodiac signs were not mentioned in *Vedāṅga Jyotiṣa*

**Siddhānta Jyotiṣa period:**

In the year 499 AD, Aryabhata wrote the first treatise over the *Siddhānta jyotiṣa* called the *Āryabhaṭīya*. After that, Varāhamihira compiled a book called *Pañcasiddhāntikā*, which included the five principles of *Paitāmaha, Vaśiṣṭha, Romaka, Poliśa, Surya*. Of these, only "*Sūrya Siddhānta*" survived over the time. It was constantly being improved until 1000 AD. All the topics related to measurement of time in modern astronomy have been covered in 'Sūrya Siddhānta'. It consists of 14 chapters and 500 verses. It covers a wide range of topics such as the average speed, their actual positions, directions, location, time, eclipses, planetary conjunctions, Moon-Sun rise, various instruments and different methods of measuring time. The time period of orbital motion of the
Sun, Moon and planets mentioned in the ‘Sūrya Siddhānta’ are as the Table No.7.

Table No.7: The time period of orbital motion of the Sun, Moon and planets

<table>
<thead>
<tr>
<th>Object</th>
<th>Period (As per Sūrya Siddhānta’)</th>
<th>Period (Modern)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>365.25875 Days</td>
<td>365.2564 Days</td>
<td>0.00235 Days</td>
</tr>
<tr>
<td>Moon</td>
<td>27.32167 Days</td>
<td>27.32166 Days</td>
<td>0.00001 Days</td>
</tr>
<tr>
<td>Mercury</td>
<td>87.9697 Days</td>
<td>87.96928 Days</td>
<td>0.00042 Days</td>
</tr>
<tr>
<td>Venus</td>
<td>224.69856 Days</td>
<td>224.7007 Days</td>
<td>0.00214 Days</td>
</tr>
<tr>
<td>Mars</td>
<td>686.99725 Days</td>
<td>686.97945 Days</td>
<td>0.0178 Days</td>
</tr>
<tr>
<td>Jupiter</td>
<td>4332.32065 Days</td>
<td>4332.58480 Days</td>
<td>0.26415 Days</td>
</tr>
<tr>
<td>Saturn</td>
<td>10765.77307 Days</td>
<td>10759.21971 Days</td>
<td>6.55336 Days</td>
</tr>
</tbody>
</table>

The complex planetary mathematical calculations which consisted of the Yuga, Mahayuga, Manvantara, Kalpa, etc., were introduced from the Siddhānta jyotiṣa texts. The ancient astronomers had understood that if we consider the farthest reference point in the past for Mathematical calculations, we get more accurate results. Considering the continuous recession of the vernal equinox, some adaptations had to be done in the Mathematical rules to determine the accurate positions of the Sun, Moon and the planets. After immense research, these mathematical adaptations were noted and formulated by the ancient Indian astronomers. Ganesh Daivajna wrote the treatise called the ‘Grah Lāghav’ in 1520 AD. In this book, he avoided the use of trigonometry. While doing the planetary mathematics of the Moon, the Sun and other planets, a fixed reference position is considered on a specific date. Considering this reference point, the present position is obtained. While doing this, the difference between the actual date and the reference date and the planetary velocities are considered. This leads to larger mathematical figures, which make the calculations complicated. To avoid this, Ganesh Daivadnya considered an eleven year cycle. There are 4016 days in 11 years. Ganesh Daivadnya ensured through his formula, that the maximum difference of the number of days...
in the reference date and present date, while doing the planetary mathematics of the Moon, the Sun and other planets, will not exceed 4016. His work is still relevant and useful to the almanacists.

In modern period, great Astronomers like Kero Laxman Chhatre, Visaji Raghunath Lele, Vinayak Shastri Khanapurkar, Venkatesh Bapuji Ketkar, Shankar Balkrishna Dixit, Lokmanya Bal Gangadhar Tilak, Bapu dev Shastri, Sudhakar Dwivedi, Raghunaath Acharya have done tremendous work. The present version of pañcāṅga is the result of their extensive efforts.

***************
After independence, in order to introduce a scientific method of chronometry and a calendar based on it, the Council of Scientific and Industrial Research (CSIR) of the Government of India started to make efforts. Under the chairmanship of Meghnath Saha, 'Calendar Reform Committee' was established in 1952.

The members of this committee were as follows: Dr. Meghnath Saha (President), N. C. Lahiri (Secretary), Prof. A. C. Banerjee, Dr. K. L. Daptary, J. S. Karandikar, Prof. R. V. Vaidya, Dr. Gorakh Prasad.

**Purpose of the committee:** To examine all the popular calendars in the country, to carry out an in depth scientific research on the *pancânga* and to provide a uniform and accurate *pancânga*.

The committee handed over its detailed report to the Government on 14 September 1954. The Government of India accepted the report and announced a new national calendar and the chronometry from March 22, 1957. The Reserve Bank gave orders to all the banks nationwide to accept all economic transactions according to this calendar.

*The Indian National calendar didn't attain the required fame and pursuance as it was different from the popular regional calendars which had the connection to the religious rituals or practices followed by common man in day to day life.*

On the day of *Bharatiya Saur Caitra suddha 1, Saka 1878*; i.e. on March 21, 1956, the committee proposed that the Indian national calendar would be published and issued by the Government of India. The following points were considered.
1) *Ayanamsa* should be fixed as 23 degrees 15 minutes as on the day of March 21, 1956.

2) Annual rate of precession of equinoxes should be considered as 50.27 angular seconds.

3) As the Śālivāhana Śaka is used in most of the states of India, it should be used for measurement of years. The Śālivāhana Śaka chronology started in 78 AD.

4) The new year must start from the Spring Equinox day. Thus the time period between two consecutive spring equinox days, should be considered as a year. This year, known as the tropical year will consist of 365.2422 days.

5) Based on the leap year, the onset of the new year will be on 21/22 March.

6) Indian national calendar has been aligned with the Gregorian Calendar. Thus the leap year should be considered according to the Gregorian calendar.

7) The new year will commence from the month of Solar Caitra. The number of days in each month will be as follows: *Caitra* 30/31, *Vaiśākha*, *Jyeṣṭha*, *Āsārh*, *Śrāvaṇa*, *Bhādrapada* will consist of 31 days, while *aśvin*, *Kārtik*, *Mārgaśīrṣa*, *Pauṣa*, *Māgha*, *Phālguna* will consist of thirty days. When the Earth is close to the Sun (perihelion), it possesses a faster orbital speed, and when the Earth is far from the Sun (aphelion), it possesses a slower orbital speed, thus the time varies inversely proportional to the speed.

8) Indian Standard Time will be calculated on the basis of reference of 82.30' E longitude, and 23.11' N longitude (the coordinates of the city of Prayagraj).

9) New day will start at midnight.
Table No. 8: Month according to the Indian National Calendar

<table>
<thead>
<tr>
<th>Solar Month</th>
<th>Celestial latitudes of Sun from Vernal Equinox</th>
<th>Period of the Solar Month</th>
<th>Month according to the Indian National Calendar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaiśākha</td>
<td>0 - 30 degrees</td>
<td>30h11m25.2s</td>
<td>Caitra</td>
</tr>
<tr>
<td>Jyeṣṭha</td>
<td>30 - 60 degrees</td>
<td>30h23m29.6s</td>
<td>Vaiśākha</td>
</tr>
<tr>
<td>Āsārh</td>
<td>60-90 degrees</td>
<td>31h08m10.1s</td>
<td>Jyeṣṭha</td>
</tr>
<tr>
<td>Śrāvaṇa</td>
<td>90-120 degrees</td>
<td>31h10m54.6s</td>
<td>Āsārh</td>
</tr>
<tr>
<td>Bhādrapada</td>
<td>120-150 degrees</td>
<td>31h06m53.1s</td>
<td>Śrāvaṇa</td>
</tr>
<tr>
<td>Aśvin</td>
<td>150-180 degrees</td>
<td>30h21m18.7s</td>
<td>Bhādrapada</td>
</tr>
<tr>
<td>Kārtika</td>
<td>180-210 degrees</td>
<td>30h08m58.2s</td>
<td>Aśvin</td>
</tr>
<tr>
<td>Mārgaśīrṣa</td>
<td>210-240 degrees</td>
<td>29h21m14.6s</td>
<td>Kārtika</td>
</tr>
<tr>
<td>Pauṣa</td>
<td>240-270 degrees</td>
<td>29h13m08.7s</td>
<td>Mārgaśīrṣa</td>
</tr>
<tr>
<td>Māgha</td>
<td>270- 300 degrees</td>
<td>29h10m38.3s</td>
<td>Pauṣa</td>
</tr>
<tr>
<td>Phālguna</td>
<td>300-330 degrees</td>
<td>29h14m18.5s</td>
<td>Māgha</td>
</tr>
<tr>
<td>Caitra</td>
<td>330-360 degrees</td>
<td>29h23m18.9s</td>
<td>Phālguna</td>
</tr>
</tbody>
</table>

***************
The globe of earth is divided into imaginary circles known as the latitudes and longitudes. They are used to determine exact locations of any object or place on earth's surface. The latitudes are circles parallel to the equator, while longitudes are lines running from the north pole to the south pole.

The imaginary line passing through the city of Greenwich has been considered as the line of reference. The longitudes are measured up to 180 degrees to the east and the west of this line. As the earth rotates from the west to the east, thus a new longitude faces the Sun once in the 24 hours.

**The Prime Meridian:** In astronomy, the meridian is the great circle passing through the celestial poles, as well as the zenith and nadir of an observer's location.

Consequently, it contains the north and south points on the horizon, and it is perpendicular to the celestial equator and horizon. When the Sun reaches the Zenith, it is said to be noontime on that meridian.

Noontime in New Delhi (77.1025° E), happens to be evening in Tokyo (139.6503° E), morning time in London (0.1278° W) and midnight in New York (74.0060 W).

While considering the time measurements globally, it becomes difficult to use local time at different locations. Therefore, a standard time has been decided to mark the timing in different locations. This standard time is called the Universal Time / UT. For common purposes, Greenwich Mean Time (GMT) is used. UT is used for scientific measurements.

For the measurement of time to be smooth and sustained; time zones have been decided over the globe. A zone consisting of 15 longitudes from the Greenwich longitude has been considered as the first time zone. Similarly
twenty four time zones have been considered across the globe. Standard meridians are situated at every longitudinal displacement of 15° from the prime meridian (e.g., 15° W, 30° W, 45° W, etc.) The standard meridians also determine the local time in the specific time zone. The boundaries of each time zone are marked at longitudinal displacement of 7.5° about the west and east of the standard meridian. The time measurement in each time zone is done with the help of the middlemost meridian of that time zone.

For ex. In the time zone ranging from 7.5° E to 7.5° W, the time is measured in terms of the prime meridian in Greenwich or (0°) meridian.

In the time zone ranging from 7.5° W to 22.5° W, the time is measured in terms of the (-1) time zone. The time in this zone is shown shorter than the Greenwich standard time by one hour. Similarly the subsequent time zones towards the east of Greenwich are considered as +1 and +2. The time in those zones is more than the Greenwich mean time.

The International Date Line (IDL) is the longitude located halfway from the prime meridian at about 180° east (or west) of Greenwich. It is also known as the line of demarcation, and passes through the pacific ocean. When the IDL is crossed, a change in day occurs.

Figure No. 11: Time Zones across the World
## Table No 9: The Time Zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>GMT +/-</th>
<th>Text Indicator</th>
<th>Zone</th>
<th>GMT +/-</th>
<th>Text Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5W to 7.5E</td>
<td>0</td>
<td>Z</td>
<td>7.5W to 22.5W</td>
<td>-1</td>
<td>N</td>
</tr>
<tr>
<td>7.5E to 22.5E</td>
<td>+1</td>
<td>A</td>
<td>22.5W to 37.5W</td>
<td>-2</td>
<td>O</td>
</tr>
<tr>
<td>22.5E to 37.5E</td>
<td>+2</td>
<td>B</td>
<td>37.5W to 52.5W</td>
<td>-3</td>
<td>P</td>
</tr>
<tr>
<td>37.5E to 52.5E</td>
<td>+3</td>
<td>C</td>
<td>52.5W to 67.5W</td>
<td>-4</td>
<td>Q</td>
</tr>
<tr>
<td>52.5E to 67.5E</td>
<td>+4</td>
<td>D</td>
<td>67.5W to 82.5W</td>
<td>-5</td>
<td>R</td>
</tr>
<tr>
<td>67.5E to 82.5E</td>
<td>+5</td>
<td>E</td>
<td>82.5W to 97.5W</td>
<td>-6</td>
<td>S</td>
</tr>
<tr>
<td>82.5E to 97.5E</td>
<td>+6</td>
<td>F</td>
<td>97.5W to 112.5W</td>
<td>-7</td>
<td>T</td>
</tr>
<tr>
<td>97.5E to 112.5W</td>
<td>+7</td>
<td>G</td>
<td>112.5W to 127.5W</td>
<td>-8</td>
<td>U</td>
</tr>
<tr>
<td>112.5E to 127.5E</td>
<td>+8</td>
<td>H</td>
<td>127.5W to 142.5W</td>
<td>-9</td>
<td>V</td>
</tr>
<tr>
<td>127.5E to 142.5E</td>
<td>+9</td>
<td>I</td>
<td>142.5W to 157W</td>
<td>-10</td>
<td>W</td>
</tr>
<tr>
<td>142.5E to 157W</td>
<td>+10</td>
<td>K</td>
<td>157.5W to 172.5W</td>
<td>-11</td>
<td>X</td>
</tr>
<tr>
<td>157.5E to 172.5E</td>
<td>+11</td>
<td>L</td>
<td>172.5W to 180</td>
<td>-12</td>
<td>Y</td>
</tr>
<tr>
<td>172.5E to 180</td>
<td>+12</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each country selects a specific longitude for the reference of its time zone as per its convenience and determines the standard time of the country according to that longitude. India's wide terrain is situated within 67.7 degrees east to 97.25 degrees east longitudes. It is situated within the E and F (+5 and +6) time zones. Many countries in the world have fixed more than one time zones for their terrain. However, India has chosen 82.5 degrees east longitude as a reference line for its time zone. This longitude (82.5 degrees E) is situated to the east of Greenwich or 5.30 hours earlier.
Thus Indian standard time is fixed as +5.5 (+5 hours 30 minutes). The rotation of the earth around itself is completed in 24 hours. It means that the earth completes a rotation of 360° in 24 hours. Thus it takes an hour to travel over a 15° angle or four minutes to rotate over a 1° angle. The simple calculation of GMT + (longitude x 4) is used to decide the time over a specific longitude or meridian.

For ex. Indian reference longitude is 82.5°
82.5 x 4 = 330 = 5 hours 30 minutes.
Thus when it is 12:00 am in Greenwich, the time in India is 5:30 am.
The Gregorian calendar was created by modifying the Julian calendar. Julius Caesar started the Julian calendar in 45 BC. The Sun used to be on the Vernal equinox on 25th March at that time. 370 years later, in the year 325 AD, the spring equinox began to happen on March 21. Every year the vernal equinox precesses backward by about 50.2 angular seconds. This means that after about seventy-two years the vernal equinox point deviates by one degree.

The year in the Julian calendar consists of 365.25 days. However, the tropical year consists of 365.2422 days. The difference between these two years is 0.0078 days. Thus an annual error of 11 minutes and 14 seconds in the Julian calendar, causes a difference of one day between the tropical and Julian years every 128 years.

At the Council of Nicaea held in 325 AD, an important Christian holiday of Easter, was decided to be celebrated on March 21, as the spring equinox of that year happened to be on March 21. In 700 AD, the spring solstice occurred on March 18, whereas, in 1100 AD, it occurred on March 15, and in 1550 AD on March 11. This way, the season of the Easter or spring festival would have shifted in winter as the spring solstice was receding, which was not appropriate. Various scholars noticed these astronomical reasons and asked the Pope to interfere in the calendar.

Around 1275 AD, well-known philosopher Roger Bacon suggested amendments in the calendar, which were ignored. In 1344 AD, Pope Clement appointed a committee of astronomers to revise the calendar. However, due to various disagreements, the calendar could not be revised. In 1475 AD, Pope Sixtus tried again. Finally, in 1572, Pope Gregory XIII attempted to revise the calendar. Under the leadership of Christopher Clavius, a committee of eminent astronomers, mathematicians, and theologians was formed. The main difficulty in creating an accurate calendar was the incomplete day of 0.2422 in the tropical year. They realised that the calendar for the common use should consist of full
days; at the same time, the incomplete day can't be ignored. The spring equinox happened to be on March 11 in 1572. Christopher Clavius accepted the challenge of accurate measurement of the tropical year. The tropical year in 1580-1581 was decided to consist of 365.242546296 days. On February 24, 1582, Pope Gregory XIII accepted the report of the Clavius Committee and announced that its implementation would begin on October 4, 1582. This announcement is called 'Papal bull'.

The difference of 0.2425 days between the tropical year (365.2425 days) and the regular year (365 days) is difficult to account for every year. This difference tends to be 97 days in total 400 years. (0.2425 x 400 = 97). These missing 97 days of the calendar had to be compensated by considering 97 'leap years' in 400 years. In the prevailing Julian calendar of that time, the difference of 0.25 days per year was being compensated by considering 100 leap days in 400 years. Thus to reduce the number of leap days by 3 to to make it 97, a new rule was introduced in the prevailing rules for the leap year. It was proposed that centenary years which are not divisible by 400 should not be considered leap years. Therefore, even if the years 1700, 1800, 1900 are divisible by 4, they will not be considered leap years as they are not divisible by 400. Due to this amendment proposed by Clavious, at least for the next 3550 years, the Sun would enter the vernal equinox on March 21.

Important decisions in Papal Bull:

- The 10 days in the month of October in 1582 were removed. It was Thursday on October 4th. The next day was assumed to be October 15th, the friday. Therefore, the vernal equinox, which had occurred on March 11, in 1582, would come once again on March 21, in 1583. Also, the order of weekdays would be followed. As a result, the dates from 5 October to 14 October would not exist in 1582.
- Two rules must be followed to determine the leap year.
  A) To consider a year as the leap year, it should be divisible by 4, but not by 100.
  B) If the year is divisible by 400, it will be considered as a leap year.
- Julius Caesar had considered January as the beginning of the new year. But in the sixth century, the church had considered the beginning of the new year on 25 March. In the Gregorian calendar, the beginning of the year was once again introduced on 1st January. The distance
between the Sun and Earth is minimal in early January; thus suggestion of astronomers to begin the new year in January was accepted.

- The Sunday after the full Moon, which falls after the Sun enters the spring equinox is known as Easter Sunday. This traditional rule was continued to be accepted.

The Gregorian calendar was immediately accepted by all Catholic countries. But the protestant countries refused to accept the new calendar. In Germany, riots broke out over the calendar issue, as some organizations were Catholic and others Protestant. The global empire, England was a Protestant country and did not accept the Gregorian calendar until September 3, 1752. The country later adopted the Gregorian calendar, reducing the month of September in 1752 by 11 days. Following England, the British India accepted the Gregorian calendar in 1752. China accepted this calendar in 1912. After the Russian revolution, the Gregorian calendar was accepted in Soviet Russia in February 1918. Today, the Gregorian calendar is used worldwide.

In the Gregorian calendar, the words BC and AD are used to number years. It was assumed that the year 1 AD began after the year 1 BC. Therefore, the year 0 does not exist. Since the terms BC and AD are not accepted by some religions, the method of numbering years is being used under the name Common Era (CE). In this method, the year 1 BC is considered to be 0 CE. Of course, this shows that 25 BC is the year -24 CE (minus twenty four CE). In astronomical mathematics, year numbers are represented by the Common Era (CE).

**Errors in the Gregorian calendar:**

- The year of the Gregorian calendar consists of 365.2425 days, while the tropical year consists of 365.2422 days. The difference between these two years is 0.0003 days or about 26 seconds. Thus after about three thousand years, the vernal equinox will shift by one day.
- The number of days in all the months are not equal, they vary from 28 to 31.
- Therefore, the number of days in a quarter year varies from 90 to 92 days.
- Number of days in the six months i.e. from January to June is 181, and the number of days in the period of July to December is 184.
• Due to the holiday on Sunday, the actual working days vary from 24 to 27 in each month.

• Although the word December means the tenth one, it is actually the twelfth month. This is true for every month from September.

• The important festival of Easter can happen anytime from March 22 and April 25.

India was ruled by English and Portuguese rulers during this period. The Portuguese began using the Gregorian calendar from 1582; The British, however, continued to use the Julian calendar till 1752. So let's take a look at an example of how Indian historians get confused when writing the dates of certain events.

According to Indian chronology, the birthday of Chhatrapati Shivaji Maharaj was on Phālgun Vadya Tṛṭīyā, Śālivāhana Saka 1551, (Śuklanām Saṃvatsar). The date is March 2, 1630, according to the Gregorian calendar, and February 19, 1630, according to the Julian calendar. This has caused a lot of confusion in history.

*************
Six different chronometric units are used in every chronometric system, to record the time and date of an event. These are 1) Year, 2) Month, 3) Day, 4) Hour, 5) Minute and 6) Second. The Gregorian calendar is widely accepted in modern world. But according to it, the number of days in each month varies. Also total number of days in a year vary from 365 to 366. It becomes very difficult to do the astronomical calculations, using all such variable chronometric units. The concept of the Julian dates was first proposed in 1583 by Joseph Scaliger, a chronometrist. According to it, Julian date is considered as 1, on 1 January 4712 BC, and each day is counted in subsequent order. Accordingly, the Julian date on November 30, 2020 is 2459183.5. This is also called the Julian day number.

While making astronomical calculations regarding the conjunctions or oppositions of planets and stars, the time difference between two specific events (the time gap within occurrence of one event and the other), is often derived in the form of Julian day number. In order to derive the positions of the planets, Moon and the Sun in the sky, as well as to record the pulsating brightness of the variable stars in astronomical events, various astronomical calculations are done. The time of various astronomical events is noted for this purpose, in the form of Julian day number. The date in the Gregorian calendar can be easily calculated using the Julian day number.

Julian day numbers are not related to any calendar. All the six chronometric units are denoted in the form of a number. This method is used to easily measure the time difference between two events.
Example 1
A total solar eclipse was observed from India on 16th February 1980. The next total solar eclipse was observed on 24 October 1995. Thus, for 5729 days in between these events, no total solar eclipse was observed in India. How to calculate the number of days?

- According to the regular calendar, the number of days after 16th February in the year 1980, and the number of days of the years from 1981 to 1994, will have to be added to the number of days till October 24 in the year 1995, to get the total of 5729. A leap will have to be compensated within.
- If the Julian day number method is used, then this figure can be determined in one step.

16 February 1980 = Julian Day number 2444285.5
24 October 1995 = Julian Day number 2450014.5
Subtracting these two Julian Day numbers,
\[(2444285.5 - 2450014.5) = 5729\]
Thus, we find the time difference between the two total solar eclipses as 5729 days.

Example 2
How many days after India received independence, it was declared as a republic?
Indian Independence Day: 15th August 1947 = Julian Day number 2432412.5
Republic day: 26 January 1950 = Julian Day number 2433307.5
The difference between the two is 894.
Thus India was declared as a republic nation after 894 days from the day it was declared independent.

The Julian day number also accommodates a number of hours, minutes and seconds in a day. The day in a Gregorian calendar starts at midnight and ends after twenty-four hours. When the Julian day number was proposed, the day used to start at noon. Thus in every Julian day number, a fraction of 0.5 can be observed.
Example

India became independent on 15th August 1947 at midnight. When it was midnight, the International standard time on August 14 was 6:30 pm (18:30 pm) according to the world standard time. This can be represented by the Julian day number as 2432412.27083. The number 2432412 represents August 14, 1947; and the fraction 0.27083 represents six hours and thirty minutes after 12 noon.

The Julian day number can be derived from the date of the Gregorian calendar as follows:

\[
J = \text{Int} \left(365.25 \times Y\right) + \text{int} \left(30.6001 \times (m+1)\right) + D + 1720994.5 + B
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>Julian number of days</td>
</tr>
<tr>
<td>Y</td>
<td>Year Number in Gregorian Calendar</td>
</tr>
<tr>
<td>M</td>
<td>Month Number. (1 = January, 2 = February ... ... 12 = December)</td>
</tr>
<tr>
<td>m</td>
<td>M. if M &gt; 2</td>
</tr>
<tr>
<td>m</td>
<td>M+12 if M ≤ 2</td>
</tr>
<tr>
<td>y</td>
<td>Y if M &gt; 2</td>
</tr>
<tr>
<td>y</td>
<td>Y-1, if M ≤ 2</td>
</tr>
<tr>
<td>D</td>
<td>Number of day in a month.</td>
</tr>
<tr>
<td>INT</td>
<td>Integral part of the number or Z</td>
</tr>
<tr>
<td>B</td>
<td>2-A + INT (A/4)</td>
</tr>
<tr>
<td>A</td>
<td>INT (y/100)</td>
</tr>
</tbody>
</table>

1720994.5 is a constant, which is the total number of days, since the day when the Julian day number system started (1 January 4712 BC) to 31 December 1.
Example 1

Obtain the Julian day number on 30 November 2020

Y = 2020
M = 11
m = 11
y = 2020
D = 30
A= INT (y / 100)= INT(2020/100) = INT(20.20) =20
B= 2 - A + INT(A / 4)
   = 2 - 20 + INT (20/4)
   = 2 - 20 + 5
   = - 13

J = INT(365.25x2020)+INT(30.6001x(11+1)+ 30 +1720994.5 - 13
J = INT(737805) + INT(367.20212) + 30 + 1720994.5 - 13
J= 737805 + 367+ 30 + 1720994.5 - 13
J = 2459183.5

The day of 30 November 2020 is denoted by the Julian day number 2459183.5.

Example 2

To Find the Julian day number for the day January 26, 1950

Y = 1950 , M = 1, D = 26
M ≤2 thus y = 1949 and m = 13
A = 19, B = -13

J = INT(365.25 x y) +INT(30.6001 x (m+1)) + D + 1720994.5 + B
J = INT(365.25x1949) + INT(30.6001x(14)) + 26 + 1720994.5 - 13
J= 711872 + 428 + 26 + 1720994.5 - 13
J = 2433307.5

*************
The Islamic Calendar started from the day of Friday, 16th July 622. Actually it was a Thursday, but as per the Islamic traditional beliefs it was considered a Friday because it started after the Sunset. Thus, the first day of Islamic calendar was considered as a Friday.

As per the Indian calendar, 16 July 622 was the day of Śrāvaṇa Śukla Pratipadā, Śālivāhana Saka 544. The Islamic calendar is called Hijri year. Hijri calendar was first published by Caliph Umar in 639 AD. Hijri year 17 was running at that time.

Islamic calendar is fully based on the Lunar cycle. The coincidental lunar month consists of (29.53 days) 29 days is 12 hours and 44 minutes. Therefore, days have been adjusted by considering the 30 and 29 days interspersed between the twelve months of the year.

Thus, 354 days of the year are adjusted and a fraction of 0.36 days is left. Thus practically one day is considered instead of this fraction, and an extra day is added in the leap year. In the Islamic calendar, odd months consist of 30 days, while even months consist of 29 days.

The chronometry shown in Table No. 10 was designed using the 29 days and 12 hours of the lunar month. But the lunar month consists of 29.53 days. The 44 minutes omitted per month become 11 days after 30 years. So one day is added after 11 years in every thirty-year cycle. In the 2nd, 5th, 7th, 10th, 13th, 16th, 18th, 21st, 24th, and 26th year, the twelfth month of the Dhū al-Ḥijjah is considered to be 30 days instead of 29.
Table No. 10: Months and Number of days according to the Islamic Calendar

<table>
<thead>
<tr>
<th>Number of month</th>
<th>Name of month</th>
<th>No. of days in the month</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Muharram</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Safar</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>Rabi' al-awwal</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Rabi' ath-thānī</td>
<td>29</td>
</tr>
<tr>
<td>5</td>
<td>Jumada al-awwal</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>Jumādā al-ākhirah</td>
<td>29</td>
</tr>
<tr>
<td>7</td>
<td>Rajab</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>Sha'aban</td>
<td>29</td>
</tr>
<tr>
<td>9</td>
<td>Ramadan</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>Shawwal</td>
<td>29</td>
</tr>
<tr>
<td>11</td>
<td>Dhū al-Qa'dah</td>
<td>30</td>
</tr>
<tr>
<td>12</td>
<td>Dhū al-Ḥijjah</td>
<td>29/30</td>
</tr>
</tbody>
</table>

Every day in the Muslim calendar begins after sunset and ends at the next sunset. The beginning of the month is when the feeble crescent moon of Pratipadā appears in the sky. Although this rule applies to all months, it is strictly observed during the months of Muharram and Ramadan. Muslim clergyman or a moulana starts the month observing the crescent moon in the sky after the new moon. The moon of Pratipadā can be seen only if the moon rises past fifty minutes after sunset. Otherwise the month starts on the next day i.e. Dvitiyā.
Extra month is not considered in Islamic calendar. Therefore, the lunar calendar recedes by 11 days, compared to the seasonal cycle every year. So all the Muslim festivals happen in every season during the 33 years.
The need to correct the numerous errors in the Gregorian calendar, had been noticed widely. But traditional beliefs and religious tendencies made it difficult to implement the reforms. A meeting of the United Nations Economic and Social Council was held in 1954. It discussed the Universal Calendar created by the World Calendar Association. On behalf of India, Dr. Meghnad Saha was present in this meeting. India had consented to this calendar. But the majority of other countries in the world voted and the topic was closed before it even came into existence.

The pros of the proposed calendar were:

1) There was no need to reprint the calendar every year as it would remain the same.

2) The year was divided into four equal parts. Each quarter year consisted of 91 days, 13 weeks, and three months.

3) 26 working days were mandatory each month. (Five Sundays in a 31-day month and four Sundays in a 30-day month)

4) The beginning of each year was to be on January 1, and that day was to be Sunday.

5) Every quarter of the year was to begin on a Sunday.

6) The 365th day (last day) would come after December 30 every year and it would be celebrated as a holiday without being assigned any weekday.

7) The leap year was to be extended one day after the last day of June and no weekday was to be assigned to it.
8) The proposed calendar was to remain constant and perpetual.

9) The months of January, April, July, and October would consist of 31 days, and the month would begin on Sunday.

10) The months of February, May, August, and November were supposed to have 30 days, supposed to start on Wednesday.

11) The months of March, June, September, and December were supposed to be 30 days long, supposed to start on Friday.

***************
Modern Chronometry

1 Picosecond = $10^{-12}$ Second
1 Nanosecond = $10^{-9}$ Second
1 Microsecond = $10^{-6}$ second
1 Millisecond = $10^{-3}$ second
1 Centisecond = $10^{-2}$ second
1 Decisecond = $10^{-1}$ second
1 Second = 10 Deciseconds
1 Minute = 60 Seconds
1 Hour = 60 minutes
1 day = 24 hours
1 week = 7 days
1 year (Tropical) = 365.2422 days
The Aphelion and Perihelion days with time in the upcoming years

1. The Aphelion is the point in the orbit of an object where it is farthest from the Sun.
2. The point in orbit where an object is nearest to the sun is called the perihelion.

<table>
<thead>
<tr>
<th>Year</th>
<th>Perihelion</th>
<th>Time in UT</th>
<th>Aphelion</th>
<th>Time in UT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>January 5</td>
<td>07:48</td>
<td>July 4</td>
<td>11:35</td>
</tr>
<tr>
<td>2022</td>
<td>January 4</td>
<td>06:55</td>
<td>July 4</td>
<td>07:11</td>
</tr>
<tr>
<td>2023</td>
<td>January 4</td>
<td>16:17</td>
<td>July 6</td>
<td>20:07</td>
</tr>
<tr>
<td>2024</td>
<td>January 3</td>
<td>00:39</td>
<td>July 5</td>
<td>05:06</td>
</tr>
<tr>
<td>2025</td>
<td>January 4</td>
<td>13:28</td>
<td>July 3</td>
<td>19:55</td>
</tr>
<tr>
<td>2026</td>
<td>January 3</td>
<td>17:16</td>
<td>July 6</td>
<td>17:31</td>
</tr>
<tr>
<td>2027</td>
<td>January 3</td>
<td>02:33</td>
<td>July 5</td>
<td>05:06</td>
</tr>
<tr>
<td>2028</td>
<td>January 5</td>
<td>12:28</td>
<td>July 3</td>
<td>22:18</td>
</tr>
<tr>
<td>2029</td>
<td>January 2</td>
<td>18:13</td>
<td>July 6</td>
<td>05:12</td>
</tr>
</tbody>
</table>
The Equinoxes and Solstices in the upcoming years

1. Vernal Equinox :- The first point of intersection of the Ecliptic and the celestial equator.
2. Autumnal Equinox :- The second point of intersection of the Ecliptic and the celestial equator.
3. Summer Solstice :- The day when the Sun falls on the Tropic of Cancer.
4. Winter Solstice :- The day when the Sun falls on the Tropic of Capricorn.

<table>
<thead>
<tr>
<th>Year</th>
<th>Vernal Equinox</th>
<th>Summer Solstice</th>
<th>Autumnal Equinox</th>
<th>Winter Solstice</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>20 Mar 09:19 IST</td>
<td>21 Jun 03:13 IST</td>
<td>22 Sep 19:00 IST</td>
<td>21 Dec 15:32 IST</td>
</tr>
<tr>
<td>2021</td>
<td>20 Mar 15:07 IST</td>
<td>21 Jun 09:02 IST</td>
<td>23 Sep 00:51 IST</td>
<td>21 Dec 21:29 IST</td>
</tr>
<tr>
<td>2022</td>
<td>20 Mar 21:03 IST</td>
<td>21 Jun 14:43 IST</td>
<td>23 Sep 06:33 IST</td>
<td>22 Dec 03:18 IST</td>
</tr>
<tr>
<td>2023</td>
<td>21 Mar 02:54 IST</td>
<td>21 Jun 20:27 IST</td>
<td>23 Sep 12:19 IST</td>
<td>22 Dec 08:57 IST</td>
</tr>
<tr>
<td>2024</td>
<td>20 Mar 08:36 IST</td>
<td>21 Jun 02:20 IST</td>
<td>22 Sep 18:13 IST</td>
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</table>
### Sanskrit to English Transliteration

#### Vowels

<table>
<thead>
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<th>Transcription</th>
<th>Devanāgari</th>
<th>Transcription</th>
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<tbody>
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<td>ṭ ṭ</td>
<td>ः</td>
<td>ṭ̄ ṭ̄</td>
<td>ः</td>
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#### Consonants

<table>
<thead>
<tr>
<th>क</th>
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<th>ट</th>
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<th>ठ</th>
<th>ṭ̄ ṭ̄</th>
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<tr>
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<td>v V</td>
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<td>l L</td>
<td>व</td>
<td>v V</td>
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</table>
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