Frequently Asked Questions about Calendars
Version 2.8

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Introduction

This is the calendar FAQ. Its purpose is to give an overview of the Christian, Hebrew, Persian, and Islamic calendars in common use. It will provide a historical background for the Christian calendar, plus an overview of the French Revolutionary calendar, the Maya calendar, and the Chinese calendar.

Comments are very welcome. My e-mail address is given above.

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Changes in version 2.8

Chapter 3 added and the following chapters renumbered.
Section 2.2.4: Information about Scotland updated.
Section 2.8: Calendar myth attributed to Johannes de Sacrobosco.
Section 2.10: Added paragraph about Gregorian reform myth.
Section 2.13.2: Start of Passover corrected.
Section 2.13.5: Explanation of 1 day discrepancy modified.
Section 2.17: Emphasized that 2-digit ISO dates are not allowed.
Section 4.4: Less relevant information removed.
Section 5.5: Saudi rules updated.
Section 7.8: New algorithm.
Section 11.5: Book added.
A few minor corrections have been made.

Writing dates and years

Dates will be written in the British format (1 January) rather than the American format (January 1). Dates will occasionally be abbreviated: "1 Jan" rather than "1 January".

Years before and after the "official" birth year of Christ will be written "45 BC" or "AD 1997", respectively. I prefer this notation over the secular "45 BCE" and "1997 CE" (See also section 2.14.4.)

The 'mod' operator

Throughout this document the operator 'mod' will be used to signify the modulo or remainder operator. For example, 17 mod 7 = 3 because the result of the division 17/7 is 2 with a remainder of 3.

The text in square brackets

Square brackets [like this] identify information that I am unsure about and about which I would like more information. Please write me at claus@tondering.dk (and please include the word "calendar" in the subject line).

Contents

Chapter 1

What Astronomical Events Form the Basis of Calendars?

Calendars are normally based on astronomical events, and the two most important astronomical objects are the sun and the moon. Their cycles are very important in the construction and understanding of calendars.

Our concept of a year is based on the earth's motion around the sun. The time from one fixed point, such as a solstice or equinox, to the next is called a *tropical year*. Its length is currently 365.242190 days, but it varies. Around 1900 its length was 365.242196 days, and around 2100 it will be 365.242184 days. (This definition of the tropical year is not quite accurate, see section 1.1 for more details.)

Our concept of a month is based on the moon's motion around the earth, although this connection has been broken in the calendar commonly used now. The time from one new moon to the next is called a *synodic month*, and its length is currently 29.5305889 days, but it varies. Around 1900 its length was 29.5305886 days, and around 2100 it will be 29.5305891 days.

Note that these numbers are averages. The actual length of a particular year may vary by several minutes due to the influence of the gravitational force from other planets. Similarly, the time between two new moons may vary by several hours due to a number of factors, including changes in the gravitational force from the sun, and the moon's orbital inclination.

It is unfortunate that the length of the tropical year is not a multiple of the length of the synodic month. This means that with 12 months per year, the relationship between our month and the moon cannot be maintained.

However, 19 tropical years is 234.997 synodic months, which is very close to an integer. So every 19 years the phases of the moon fall on the same dates (if it were not for the skewness introduced by leap years). 19 years is called a Metonic cycle (after Meton, an astronomer from Athens in the 5th century BC).

So, to summarise: There are three important numbers to note:

> A tropical year is 365.24219 days.
> A synodic month is 29.53059 days.
> 19 tropical years is close to an integral number of synodic months.

The Christian calendar is based on the motion of the earth around the sun, while the months retain no connection with the motion of the moon.

On the other hand, the Islamic calendar is based on the motion of the moon, while the year has no connection with the motion of the earth around the sun.

Finally, the Hebrew calendar combines both, in that its years are linked to the motion of the earth around the sun, and its months are linked to the motion of the moon.

1.1 What are equinoxes and solstices?

Equinoxes and solstices are frequently used as anchor points for calendars. For people in the northern hemisphere:

- Winter solstice is the time in December when the sun reaches its southernmost latitude. At this time we have the shortest day. The date is near 21 December.
- Summer solstice is the time in June when the sun reaches its northernmost latitude. At this time we have the longest day. The date is near 21 June.
- Vernal equinox is the time in March when the sun passes the equator moving from the southern to the northern hemisphere. Day and night have approximately the same length. The date is near 20 March.
- Autumnal equinox is the time in September when the sun passes the equator moving from the northern to the southern hemisphere. Day and night have approximately the same length. The date is near 22 September.

For people in the southern hemisphere, winter solstice occurs in June, vernal equinox in September, etc.

The astronomical "tropical year" is frequently defined as the time between, say, two vernal equinoxes, but this is not actually true. Currently the time between two vernal equinoxes is slightly greater than the tropical year. The reason is that the earth's position in its orbit at the time of solstices and equinoxes shifts slightly each year (taking approximately 21,000 years to move all the way around the orbit). This, combined with the fact that the earth's orbit is not completely circular, causes the equinoxes and solstices to shift with respect to each other.

The astronomer's mean tropical year is really a somewhat artificial average of the period between the time when the sun is in any given position in the sky with respect to the equinoxes and the next time the sun is in the same position.

Chapter 2

The Christian Calendar

The "Christian calendar" is the term traditionally used to designate the calendar commonly in use, although it originated in pre-Christian Rome.

The Christian calendar has years of 365 or 366 days. It is divided into 12 months that have no relationship to the motion of the moon. In parallel with this system, the concept of *weeks* groups the days in sets of 7.

Two main versions of the Christian calendar have existed in recent times: The Julian calendar and the Gregorian calendar. The difference between them lies in the way they approximate the length of the tropical year and their rules for calculating Easter.

2.1 What is the Julian calendar?

The Julian calendar was introduced by Julius Caesar in 45 BC. It was in common use until the late 1500s, when countries started changing to the Gregorian calendar (section 2.2). However, some countries (for example, Greece and Russia) used it into the early 1900s, and the Orthodox church in Russia still uses it, as do some other Orthodox churches.

In the Julian calendar, the tropical year is approximated as $365\,{}^1\!/_4$ days = 365.25 days. This gives an error of 1 day in approximately 128 years.

The approximation $365\,{}^1\!/_4$ is achieved by having 1 leap year every 4 years.

2.1.1 What years are leap years?

The Julian calendar has 1 leap year every 4 years:

> Every year divisible by 4 is a leap year.

However, the 4-year rule was not followed in the first years after the introduction of the Julian calendar in 45 BC. Due to a counting error, every 3rd year was a leap year in the first years of this calendar's existence. The leap years were:

> 45 BC[1], 42 BC, 39 BC, 36 BC, 33 BC, 30 BC, 27 BC, 24 BC, 21 BC, 18 BC, 15 BC, 12 BC, 9 BC, AD 8, AD 12, and every 4th year from then on.

[1] Authorities disagree about whether 45 BC was a leap year or not.

There were no leap years between 9 BC and AD 8 (or, according to some authorities, between 12 BC and AD 4). This period without leap years was decreed by emperor Augustus in order to make up for the surplus of leap years introduced previously, and it earned him a place in the calendar as the 8th month was named after him.

It is a curious fact that although the method of reckoning years after the (official) birthyear of Christ was not introduced until the 6th century, by some stroke of luck the Julian leap years coincide with years of our Lord that are divisible by 4.

2.1.2 What consequences did the use of the Julian calendar have?

The Julian calendar introduces an error of 1 day every 128 years. So every 128 years the tropical year shifts one day backwards with respect to the calendar. Furthermore, the method for calculating the dates for Easter was inaccurate and needed to be refined.

In order to remedy this, two steps were necessary: 1) The Julian calendar had to be replaced by something more adequate. 2) The extra days that the Julian calendar had inserted had to be dropped.

The solution to problem 1) was the Gregorian calendar described in section 2.2.

The solution to problem 2) depended on the fact that it was felt that 21 March was the proper day for vernal equinox (because 21 March was the date for vernal equinox during the Council of Nicaea in AD 325). The Gregorian calendar was therefore calibrated to make that day vernal equinox.

By 1582 vernal equinox had moved $(1582 - 325)/128$ days = approximately 10 days backwards. So 10 days had to be dropped.

2.2 What is the Gregorian calendar?

The Gregorian calendar is the one commonly used today. It was proposed by Aloysius Lilius, a physician from Naples, and adopted by Pope Gregory XIII in accordance with instructions from the Council of Trent (1545-1563) to correct for errors in the older Julian Calendar. It was decreed by Pope Gregory XIII in a papal bull on 24 February 1582. This bull is named “Inter Gravissimas” after its first two words.

In the Gregorian calendar, the tropical year is approximated as $365\,{}^{97}\!/_{400}$ days = 365.2425 days. Thus it takes approximately 3300 years for the tropical year to shift one day with respect to the Gregorian calendar.

The approximation $365\,{}^{97}\!/_{400}$ is achieved by having 97 leap years every 400 years.

2.2.1 What years are leap years?

The Gregorian calendar has 97 leap years every 400 years:

> Every year divisible by 4 is a leap year.
> However, every year divisible by 100 is not a leap year.
> However, every year divisible by 400 is a leap year after all.

So, 1700, 1800, 1900, 2100, and 2200 are not leap years. But 1600, 2000, and 2400 are leap years.

(Destruction of a myth: There are no double leap years, i.e. no years with 367 days. See, however, the note on Sweden in section 2.2.4.)

2.2.2 Isn't there a 4000-year rule?

It has been suggested (by the astronomer John Herschel (1792-1871) among others) that a better approximation to the length of the tropical year would be $365\,{}^{969}\!/_{4000}$ days = 365.24225 days. This would dictate 969 leap years every 4000 years, rather than the 970 leap years mandated by the Gregorian calendar. This could be achieved by dropping one leap year from the Gregorian calendar every 4000 years, which would make years divisible by 4000 non-leap years.

This rule has, however, not been officially adopted.

2.2.3 Don't the Greeks do it differently?

When the Orthodox church in Greece finally decided to switch to the Gregorian calendar in the 1920s, they tried to improve on the Gregorian leap year rules, replacing the "divisible by 400" rule by the following:

> Every year which when divided by 900 leaves a remainder of 200 or 600 is a leap year.

This makes 1900, 2100, 2200, 2300, 2500, 2600, 2700, 2800 non-leap years, whereas 2000, 2400, and 2900 are leap years. This will not create a conflict with the rest of the world until the year 2800.

This rule gives 218 leap years every 900 years, which gives us an average year of $365\,{}^{218}\!/_{900}$ days = 365.24222 days, which is certainly more accurate than the official Gregorian number of 365.2425 days.

However, this rule is *not* official in Greece.

2.2.4 When did country X change from the Julian to the Gregorian calendar?

The papal bull of February 1582 decreed that 10 days should be dropped from October 1582 so that 15 October should follow immediately after 4 October, and from then on the reformed calendar should be used.

This was observed in Italy, Poland, Portugal, and Spain. Other Catholic countries followed shortly after, but Protestant countries were reluctant to change, and the Greek orthodox countries didn't change until the start of the 1900s.

Changes in the 1500s required 10 days to be dropped.
Changes in the 1600s required 10 days to be dropped.
Changes in the 1700s required 11 days to be dropped.
Changes in the 1800s required 12 days to be dropped.
Changes in the 1900s required 13 days to be dropped.

(Exercise for the reader: Why is the error in the 1600s the same as in the 1500s.)

The following list contains the dates for changes in a number of countries. It is very strange that in many cases there seems to be some doubt among authorities about what the correct days are. Different sources give very different dates in some cases. The list below does not include all the different opinions about when the change took place.

Albania: December 1912

Austria: Different regions on different dates
Brixen, Salzburg and Tyrol:
5 Oct 1583 was followed by 16 Oct 1583
Carinthia and Styria:
14 Dec 1583 was followed by 25 Dec 1583
See also Czechoslovakia and Hungary

Belgium: See the Netherlands

Bulgaria: 31 Mar 1916 was followed by 14 Apr 1916

Canada: Different areas changed at different times.
Newfoundland and Hudson Bay coast:
2 Sep 1752 was followed by 14 Sep 1752
Mainland Nova Scotia:
Gregorian 1605 - 13 Oct 1710
Julian 2 Oct 1710 - 2 Sep 1752
Gregorian since 14 Sep 1752
Rest of Canada:
Gregorian from first European settlement

China: The Gregorian calendar replaced the Chinese calendar in 1912, but the Gregorian calendar was not used throughout the country until the communist revolution of 1949.

Czechoslovakia (i.e. Bohemia and Moravia):
6 Jan 1584 was followed by 17 Jan 1584

Denmark (including Norway):
18 Feb 1700 was followed by 1 Mar 1700

Egypt: 1875

Estonia: 31 Jan 1918 was followed by 14 Feb 1918

Finland: Then part of Sweden. (Note, however, that Finland later became part of Russia, which then still used the Julian calendar. The Gregorian calendar remained official in Finland, but some use of the Julian calendar was made.)

France: 9 Dec 1582 was followed by 20 Dec 1582
Alsace: 5 Feb 1682 was followed by 16 Feb 1682
Lorraine: 16 Feb 1760 was followed by 28 Feb 1760
Strasbourg: February 1682

Germany: Different states on different dates:
Catholic states on various dates in 1583-1585
Prussia: 22 Aug 1610 was followed by 2 Sep 1610
Protestant states: 18 Feb 1700 was followed by 1 Mar 1700
(Many local variations)

Great Britain and colonies:
2 Sep 1752 was followed by 14 Sep 1752

Greece: [9 Mar 1924 was followed by 23 Mar 1924
(Some sources say 1916 and 1920)]

Hungary: 21 Oct 1587 was followed by 1 Nov 1587

Ireland: As Great Britain

Italy: 4 Oct 1582 was followed by 15 Oct 1582

Japan: The Gregorian calendar was introduced to supplement the traditional Japanese calendar on 1 Jan 1873.

Latvia: During German occupation 1915 to 1918

Lithuania: 1915

Luxemburg: 14 Dec 1582 was followed by 25 Dec 1582

Netherlands (including Belgium):
Zeeland, Brabrant, and the "Staten Generaal":
14 Dec 1582 was followed by 25 Dec 1582
Holland:
1 Jan 1583 was followed by 12 Jan 1583
Limburg and the southern provinces (currently Belgium):
20 Dec 1582 was followed by 31 Dec 1582
or
21 Dec 1582 was followed by 1 Jan 1583
Groningen:
10 Feb 1583 was followed by 21 Feb 1583
Went back to Julian in the summer of 1594
31 Dec 1700 was followed by 12 Jan 1701
Gelderland:
30 Jun 1700 was followed by 12 Jul 1700
Utrecht and Overijssel:
30 Nov 1700 was followed by 12 Dec 1700
Friesland:
31 Dec 1700 was followed by 12 Jan 1701
Drenthe:
30 Apr 1701 was followed by 12 May 1701

Norway: Then part of Denmark.

Poland: 4 Oct 1582 was followed by 15 Oct 1582

Portugal: 4 Oct 1582 was followed by 15 Oct 1582

Romania: 31 Mar 1919 was followed by 14 Apr 1919
[The Greek Orthodox parts of the country may have changed later.]

Russia: 31 Jan 1918 was followed by 14 Feb 1918
[In the eastern parts of the country the change may not have occurred until 1920.]

Scotland: See Great Britain

Spain: 4 Oct 1582 was followed by 15 Oct 1582

Sweden (including Finland):
17 Feb 1753 was followed by 1 Mar 1753 (see note below)

Switzerland:
Catholic cantons: 1583, 1584 or 1597
Protestant cantons:
31 Dec 1700 was followed by 12 Jan 1701
(Many local variations)

Turkey: Gregorian calendar introduced 1 Jan 1927

USA: Different areas changed at different times.
Along the Eastern seaboard: With Great Britain in 1752.
Mississippi valley: With France in 1582.
Texas, Florida, California, Nevada, Arizona, New Mexico: With Spain in 1582
Washington, Oregon: With Britain in 1752.
Alaska: October 1867 when Alaska became part of the USA.

Wales: See Great Britain

Yugoslavia: 1919

Sweden has a curious history. Sweden decided to make a gradual change from the Julian to the Gregorian calendar. By dropping every leap year from 1700 through 1740 the eleven superfluous days would be omitted and from 1 Mar 1740 they would be in sync with the Gregorian calendar. (But in the meantime they would be in sync with nobody!)

So 1700 (which should have been a leap year in the Julian calendar) was not a leap year in Sweden. However, by mistake 1704 and 1708 became leap years. This left Sweden out of synchronisation with both the Julian and the Gregorian world, so they decided to go *back* to the Julian calendar. In order to do this, they inserted an extra day in 1712, making that year a double leap year! So in 1712, February had 30 days in Sweden.

Later, in 1753, Sweden changed to the Gregorian calendar by dropping 11 days like everyone else.

2.3 What day is the leap day?

It is 24 February!

Weird? Yes! The explanation is related to the Roman calendar and is found in section 2.8.1.

From a numerical point of view, of course 29 February is the extra day. But from the point of view of celebration of feast days, the following correspondence between days in leap years and non-leap years has traditionally been used:

Non-leap year	Leap year
22 February	22 February
23 February	23 February
	24 February (extra day)
24 February	25 February
25 February	26 February
26 February	27 February
27 February	28 February
28 February	29 February

For example, the feast of St. Leander has been celebrated on 27 February in non-leap years and on 28 February in leap years.

Many countries are gradually changing the leap day from the 24th to the 29th. This affects countries such as Sweden and Austria that celebrate "name days" (i.e. each day is associated with a name).

2.4 What is the Solar Cycle?

In the Julian calendar the relationship between the days of the week and the dates of the year is repeated in cycles of 28 years. In the Gregorian calendar this is still true for periods that do not cross years that are divisible by 100 but not by 400.

A period of 28 years is called a *Solar Cycle*. The *Solar Number* of a year is found as:

$$SolarNumber = (year + 8) \bmod 28 + 1$$

In the Julian calendar there is a one-to-one relationship between the Solar Number and the day on which a particular date falls.

(The leap year cycle of the Gregorian calendar is 400 years, which is 146,097 days, which curiously enough is a multiple of 7. So in the Gregorian calendar the equivalent of the "Solar Cycle" would be 400 years, not $7 \times 400 = 2800$ years as one might be tempted to believe.)

2.5 What is the Dominical Letter?

Each ordinary (non-leap) year is assigned a letter in the range A to G which describes what days of the year are Sundays. This letter is called the "Dominical Letter" ("Sunday Letter") of the year.

It works in this manner: Assign the letter A to 1 January, B to 2 Jan, C to 3 Jan, ... G to 7 Jan, A to 8 Jan, B to 9 Jan, and so on, using the letters A to G and omitting the leap day.

In a year with Dominical Letter A, all days marked A are Sundays. In a year with Dominical Letter B, all days marked B are Sundays. And so on.

Leap years have two Dominical Letters, one which is used from the start of January until the leap day, and another one which is used for the rest of the year.

The Dominical Letter of 2006 is A. The Dominical Letters of 2008 will be F and E.

2.6 What day of the week was 2 August 1953?

To calculate the day on which a particular date falls, the following algorithm may be used (the divisions are integer divisions, in which remainders are discarded):

$$a = \frac{14 - month}{12}$$
$$y = year - a$$
$$m = month + 12a - 2$$

For Julian calendar: $d = \left(5 + day + y + \frac{y}{4} + \frac{31m}{12}\right) \bmod 7$

For Gregorian calendar: $d = \left(day + y + \frac{y}{4} - \frac{y}{100} + \frac{y}{400} + \frac{31m}{12}\right) \bmod 7$

The value of d is 0 for a Sunday, 1 for a Monday, 2 for a Tuesday, etc.

Example: On what day of the week was the author born?
My birthday is 2 August 1953 (Gregorian, of course).

$$\begin{aligned}
a &= \tfrac{14-8}{12} = 0 \\
y &= 1953 - 0 = 1953 \\
m &= 8 + 12 \times 0 - 2 = 6 \\
d &= \left(2 + 1953 + \tfrac{1953}{4} - \tfrac{1953}{100} + \tfrac{1953}{400} + \tfrac{31 \times 6}{12}\right) \bmod 7 \\
&= (2 + 1953 + 488 - 19 + 4 + 15) \bmod 7 \\
&= 2443 \bmod 7 \\
&= 0
\end{aligned}$$

I was born on a Sunday.

2.7 When can I reuse my 1992 calendar?

Let us first assume that you are only interested in which dates fall on which days of the week; you are not interested in the dates for Easter and other irregular holidays.

Let us further confine ourselves to the years 1901-2099.

With these restrictions, the answer is as follows:

- If year X is a leap year, you can reuse its calendar in year X+28.
- If year X is the first year after a leap year, you can reuse its calendar in years X+6, X+17, and X+28.
- If year X is the second year after a leap year, you can reuse its calendar in years X+11, X+17, and X+28.
- If year X is the third year after a leap year, you can reuse its calendar in years X+11, X+22, and X+28.

Note that the expression X+28 occurs in all four items above. So you can always reuse your calendar every 28 years.

But if you also want your calendar's indication of Easter and other Christian holidays to be correct, the rules are far too complex to be put to a simple formula. Sometimes calendars can be reused after just six years. For example, the calendars for the years 1981 and 1987 are identical, even when it comes to the date for Easter. But sometimes a very long time can pass before a calendar can be reused; if you happen to have a calendar from 1940, you won't be able to reuse it until the year 5280!

2.8 What is the Roman calendar?

Before Julius Caesar introduced the Julian calendar in 45 BC, the Roman calendar was a mess, and much of our so-called "knowledge" about it seems to be little more than guesswork.

Originally, the year started on 1 March and consisted of only 304 days or 10 months (Martius, Aprilis, Maius, Junius, Quintilis, Sextilis, September, October, November, and December). These 304 days were followed by an unnamed and unnumbered winter period. The Roman king Numa Pompilius (c. 715-673 BC, although his historicity is disputed) allegedly introduced February and January (in that order) between December and March, increasing the length of the year to 354 or 355 days. In 450 BC, February was moved to its current position between January and March.

In order to make up for the lack of days in a year, an extra month, Intercalaris or Mercedonius, (allegedly with 22 or 23 days though some authorities dispute this) was introduced in some years. In an 8 year period the length of the years were:

1: 12 months or 355 days
2: 13 months or 377 days
3: 12 months or 355 days
4: 13 months or 378 days
5: 12 months or 355 days
6: 13 months or 377 days
7: 12 months or 355 days
8: 13 months or 378 days

A total of 2930 days corresponding to a year of $366\,{}^1\!/_4$ days. This year was discovered to be too long, and therefore 7 days were later dropped from the 8th year, yielding 365.375 days per year.

This is all theory. In practice it was the duty of the priesthood to keep track of the calendars, but they failed miserably, partly due to ignorance, partly because they were bribed to make certain years long and other years short. Furthermore, leap years were considered unlucky and were therefore avoided in time of crisis, such as the Second Punic War.

In order to clean up this mess, Julius Caesar made his famous calendar reform in 45 BC. We can make an educated guess about the length of the months in the years 47 and 46 BC:

	47 BC	46 BC
January	29	29
February	28	24
Intercalaris		27
March	31	31
April	29	29
May	31	31
June	29	29
Quintilis	31	31
Sextilis	29	29
September	29	29
October	31	31
November	29	29
Undecember		33
Duodecember		34
December	29	29
Total	355	445

The length of the months from 45 BC onward were the same as the ones we know today. Occasionally one reads the following story:

> "Julius Caesar made all odd numbered months 31 days long, and all even numbered months 30 days long (with February having 29 days in non-leap years). In 44 BC Quintilis was renamed 'Julius' (July) in honour of Julius Caesar, and in 8 BC Sextilis became 'Augustus' in honour of emperor Augustus. When Augustus had a month named after him, he wanted his month to be a full 31 days long, so he removed a day from February and shifted the length of the other months so that August would have 31 days."

This story, however, has no basis in actual fact. It is a fabrication, possibly invented by the English-French scholar Johannes de Sacrobosco in the 13th century.

2.8.1 How did the Romans number days?

The Romans didn't number the days sequentially from 1. Instead they had three fixed points in each month:

"Kalendae" (or "Calendae"), which was the first day of the month.

"Idus", which was the 13th day of January, February, April, June, August, September, November, and December, or the 15th day of March, May, July, or October.

"Nonae", which was the 9th day before Idus (counting Idus itself as the 1st day).

The days between Kalendae and Nonae were called "the 5th day before Nonae", "the 4th day before Nonae", "the 3rd day before Nonae", and "the day before Nonae". (There was no "2nd day before Nonae". This was because of the inclusive way of counting used by the Romans: To them, Nonae itself was the first day, and thus "the 2nd day before" and "the day before" would mean the same thing.)

Similarly, the days between Nonae and Idus were called "the Xth day before Idus", and the days after Idus were called "the Xth day before Kalendae (of the next month)".

Julius Caesar decreed that in leap years the "6th day before Kalendae of March" should be doubled. So in contrast to our present system, in which we introduce an extra date (29 February), the Romans had the same date twice in leap years. The doubling of the 6th day before Kalendae of March is the origin of the word *bissextile*. If we create a list of equivalences between the Roman days and our current days of February in a leap year, we get the following:

7th day before Kalendae of March	23 February
6th day before Kalendae of March	24 February
6th day before Kalendae of March	25 February
5th day before Kalendae of March	26 February
4th day before Kalendae of March	27 February
3rd day before Kalendae of March	28 February
the day before Kalendae of March	29 February
Kalendae of March	1 March

You can see that the extra 6th day (going backwards) falls on what is today 24 February. For this reason 24 February is still today considered the "extra day" in leap years (see section 2.3). However, at certain times in history the second 6th day (25 Feb) has been considered the leap day.

Why did Caesar choose to double the 6th day before Kalendae of March? It appears that the leap month Intercalaris/Mercedonius of the pre-reform calendar was not placed after February, but inside it, namely between the 7th and 6th day before Kalendae of March. It was therefore natural to have the leap day in the same position.

2.9 What is the proleptic calendar?

The Julian calendar was introduced in 45 BC, but when historians date events prior to that year, they normally extend the Julian calendar backward in time. This extended calendar is known as the "Julian Proleptic Calendar".

Similarly, it is possible to extend the Gregorian calendar backward in time before 1582. However, this "Gregorian Proleptic Calendar" is not commonly used.

If someone refers to, for example, 15 March 429 BC, they are probably using the Julian proleptic calendar.

In the Julian proleptic calendar, year X BC is a leap year, if X-1 is divisible by 4. This is the natural extension of the Julian leap year rules.

2.10 Has the year always started on 1 January?

In some ways, yes. When Julius Caesar introduced his calendar in 45 BC, he made 1 January the start of the year, and it was always the date on which the Solar Number and the Golden Number (see section 2.13.3) were incremented.

However, the church didn't like the wild parties that took place at the start of the new year, and in AD 567 the council of Tours declared that having the year start on 1 January was an ancient mistake that should be abolished.

Through the middle ages various New Year dates were used. If an ancient document refers to year X, it may mean any of 7 different periods in our present system:

- 1 Mar X to 28/29 Feb X+1
- 1 Jan X to 31 Dec X
- 1 Jan X-1 to 31 Dec X-1
- 25 Mar X-1 to 24 Mar X
- 25 Mar X to 24 Mar X+1
- Saturday before Easter X to Friday before Easter X+1
- 25 Dec X-1 to 24 Dec X

Choosing the right interpretation of a year number is difficult, so much more as one country might use different systems for religious and civil needs.

The Byzantine Empire used a year starting on 1 Sep, but they didn't count years since the birth of Christ, instead they counted years since the creation of the world which they dated to 1 September 5509 BC.

Since about 1600 most countries have used 1 January as the first day of the year. Italy and England, however, did not make 1 January official until around 1750.

In England (but not Scotland) three different years were used:

- The historical year, which started on 1 January.
- The liturgical year, which started on the first Sunday in advent.
- The civil year, which
  from the 7th to the 12th century started on 25 December,
  from the 12th century until 1751 started on 25 March,
  from 1752 started on 1 January.

It is sometimes claimed that having the year start on 1 January was part of the Gregorian calendar reform. This is not true. This myth has probably started because in 1752 England moved the start of the year to 1 January and also changed to the Gregorian calendar. But in most other countries the two events were not related. Scotland, for example, changed to the Gregorian calendar together with England in 1752, but they moved the start of the year to 1 January in 1600.

2.11 Then what about leap years?

If the year started on, for example, 1 March, two months later than our present year, when was the leap day inserted?

[The following information is to the best of my knowledge true. If anyone can confirm or refute it, please let me know.]

When it comes to determining if a year is a leap year, since AD 8 the Julian calendar has always had 48 months between two leap days. So, in a country using a year starting on 1 March, 1439 would have been a leap year, because their February 1439 would correspond to February 1440 in the January-based reckoning.

2.12 What is the origin of the names of the months?

A lot of languages, including English, use month names based on Latin. Their meaning is listed below. However, some languages (Czech and Polish, for example) use quite different names.

January Latin: Januarius. Named after the god Janus.

February Latin: Februarius. Named after Februa, the purification festival.

March Latin: Martius. Named after the god Mars.

April Latin: Aprilis. Named either after the goddess Aphrodite or the Latin word *aperire*, to open.

May Latin: Maius. Probably named after the goddess Maia.

June Latin: Junius. Probably named after the goddess Juno.

July Latin: Julius. Named after Julius Caesar in 44 BC. Prior to that time its name was Quintilis from the word *quintus*, fifth, because it was the 5th month in the old Roman calendar.

August Latin: Augustus. Named after emperor Augustus in 8 BC. Prior to that time the name was Sextilis from the word *sextus*, sixth, because it was the 6th month in the old Roman calendar.

September Latin: September. From the word *septem*, seven, because it was the 7th month in the old Roman calendar.

October Latin: October. From the word *octo*, eight, because it was the 8th month in the old Roman calendar.

November Latin: November. From the word *novem*, nine, because it was the 9th month in the old Roman calendar.

December Latin: December. From the word *decem*, ten, because it was the 10th month in the old Roman calendar.

2.13 What is Easter?

In the Christian world, Easter (and the days immediately preceding it) is the celebration of the death and resurrection of Jesus in (approximately) AD 30.

2.13.1 When is Easter? (Short answer)

Easter Sunday is the first Sunday after the first full moon after vernal equinox.

2.13.2 When is Easter? (Long answer)

The calculation of Easter is complicated because it is linked to (an inaccurate version of) the Hebrew calendar.

Jesus was crucified immediately before the Jewish Passover, which is a celebration of the Exodus from Egypt under Moses. Celebration of Passover started on the 15th day of the (spring) month of Nisan. Jewish months start when the moon is new, therefore the 15th day of the month must be immediately after a full moon.

It was therefore decided to make Easter Sunday the first Sunday after the first full moon after vernal equinox. Or more precisely: Easter Sunday is the first Sunday after the "official" full moon on or after the "official" vernal equinox.

The official vernal equinox is always 21 March.

The official full moon may differ from the *real* full moon by one or two days.

(Note, however, that historically, some countries have used the *real* (astronomical) full moon instead of the official one when calculating Easter. This was the case, for example, of the German Protestant states, which used the astronomical full moon in the years 1700-1776. A similar practice was used in Sweden in the years 1740-1844 and in Denmark in the 1700s.)

The full moon that precedes Easter is called the *Paschal full moon*. Two concepts play an important role when calculating the Paschal full moon: The *Golden Number* and the *Epact*. They are described in the following sections.

The following sections give details about how to calculate the date for Easter. Note, however, that while the Julian calendar was in use, it was customary to use tables rather than calculations to determine Easter. The following sections do mention how to calculate Easter under the Julian calendar, but the reader should be aware that this is an attempt to express in formulas what was originally expressed in tables. The formulas can be taken as a good indication of when Easter was celebrated in the Western Church from approximately the 6th century.

2.13.3 What is the Golden Number?

Each year is associated with a *Golden Number*.

Considering that the relationship between the moon's phases and the days of the year repeats itself every 19 years (as described in chapter 1), it is natural to associate a number between 1 and 19 with each year. This number is the so-called Golden Number. It is calculated thus:

$$GoldenNumber = (year \bmod 19) + 1$$

In years which have the same Golden Number, the new moon will fall on (approximately) the same date. The Golden Number is sufficient to calculate the Paschal full moon in the Julian calendar.

2.13.4 How does one calculate Easter then?

Under the Julian calendar the method was simple. If you know the Golden Number of the year, you can find the Paschal full moon in this table:

Golden Number	Full moon	Golden Number	Full moon	Golden Number	Full moon
1	5 April	8	18 April	15	1 April
2	25 March	9	7 April	16	21 March
3	13 April	10	27 March	17	9 April
4	2 April	11	15 April	18	29 March
5	22 March	12	4 April	19	17 April
6	10 April	13	24 March		
7	30 March	14	12 April		

Easter Sunday is the first Sunday following the above full moon date. If the full moon falls on a Sunday, Easter Sunday is the following Sunday.

But under the Gregorian calendar, things became much more complicated. One of the changes made in the Gregorian calendar reform was a modification of the way Easter was calculated. There were two reasons for this. First, the 19 year cycle of the phases of moon (the Metonic cycle) was known not to be perfect. Secondly, the Metonic cycle fitted the Gregorian calendar year worse than it fitted the Julian calendar year.

It was therefore decided to base Easter calculations on the so-called Epact.

2.13.5 What is the Epact?

Each year is associated with an *Epact*.

The Epact is a measure of the age of the moon (i.e. the number of days that have passed since an "official" new moon[2]) on a particular date.

In the Julian calendar, the Epact is the age of the moon on 22 March.

In the Gregorian calendar, the Epact is the age of the moon at the start of the year.

The Epact is linked to the Golden Number in the following manner:

Under the Julian calendar, 19 years were assumed to be exactly an integral number of synodic months, and the following relationship exists between the Golden Number and the Epact:

$$Epact = (11 \times (GoldenNumber - 1)) \bmod 30$$

If this formula yields zero, the Epact is by convention frequently designated by the symbol * and its value is said to be 30. Weird? Maybe, but people didn't like the number zero in the old days.

Since there are only 19 possible golden numbers, the Epact can have only 19 different values: 1, 3, 4, 6, 7, 9, 11, 12, 14, 15, 17, 18, 20, 22, 23, 25, 26, 28, and 30.

In the Gregorian calendar reform, some modifications were made to the simple relationship between the Golden Number and the Epact.

In the Gregorian calendar the Epact should be calculated thus (the divisions are integer divisions, in which remainders are discarded):

[2] In this context a "new moon" is the first visible crescent moon. In modern calendars, a "new moon" is the completely invisble moon. The two differ by approximately one day, and this difference must be kept in mind when comparing the new moon calculations presented here to reality.

1. Use the Julian formula:

$$JulianEpact = (11 \times (GoldenNumber - 1)) \bmod 30$$

2. Calculate the so-called “Solar Equation”:

$$S = (3 \times century)/4$$

   The Solar Equation is an expression of the difference between the Julian and the Gregorian calendar. The value of S increases by one in every century year that is not a leap year.

   (For the purpose of this calculation $century = 20$ is used for the years 1900 through 1999, and similarly for other centuries, although this contradicts the rules in section 2.14.3.)

3. Calculate the so-called “Lunar Equation”:

$$L = (8 \times century + 5)/25$$

   The Lunar Equation is an expression of the difference between the Julian calendar and the Metonic cycle. The value of L increases by one 8 times every 2500 years.

4. Calculate the Gregorian epact thus:

$$GregorianEpact = JulianEpact - S + L + 8$$

   The number 8 is a constant that calibrates the starting point of the Gregorian Epact so that it matches the actual age of the moon on new year’s day.

5. Add or subtract 30 until GregorianEpact lies between 1 and 30.

In the Gregorian calendar, the Epact can have any value from 1 to 30.

Example: What was the Epact for 1992?

	$GoldenNumber = 1992 \bmod 19 + 1 = 17$
1.	$JulianEpact = (11 \times (17 - 1)) \bmod 30 = 26$
2.	$S = (3 \times 20)/4 = 15$
3.	$L = (8 \times 20 + 5)/25 = 6$
4.	$GregorianEpact = 26 - 15 + 6 + 8 = 25$
5.	No adjustment is necessary

The Epact for 1992 was 25.

2.13.6 How does one calculate Gregorian Easter then?

Look up the Epact in this table to find the date for the Paschal full moon:

Epact	Full moon	Epact	Full moon	Epact	Full moon
1	12 April	11	2 April	21	23 March
2	11 April	12	1 April	22	22 March
3	10 April	13	31 March	23	21 March
4	9 April	14	30 March	24	18 April
5	8 April	15	29 March	25	18 or 17 April
6	7 April	16	28 March	26	17 April
7	6 April	17	27 March	27	16 April
8	5 April	18	26 March	28	15 April
9	4 April	19	25 March	29	14 April
10	3 April	20	24 March	30	13 April

Easter Sunday is the first Sunday following the above full moon date. If the full moon falls on a Sunday, Easter Sunday is the following Sunday.

An Epact of 25 requires special treatment, as it has two dates in the above table. There are two equivalent methods for choosing the correct full moon date:

A) Choose 18 April, unless the current century contains years with an epact of 24, in which case 17 April should be used.

B) If the Golden Number is > 11 choose 17 April, otherwise choose 18 April.

The proof that these two statements are equivalent is left as an exercise to the reader. (The frustrated ones may contact me for the proof.)

Example: When was Easter in 1992?

In the previous section we found that the Golden Number for 1992 was 17 and the Epact was 25. Looking in the table, we find that the Paschal full moon was either 17 or 18 April. By rule B above, we choose 17 April because the Golden Number > 11.

17 April 1992 was a Friday. Easter Sunday must therefore have been 19 April.

2.13.7 Isn't there a simpler way to calculate Easter?

This is an attempt to boil down the information given in the previous sections (the divisions are integer divisions, in which remainders are discarded):

$$G = year \bmod 19$$

For the Julian calendar:

$$\begin{aligned} I &= (19G + 15) \bmod 30 \\ J &= (year + \tfrac{year}{4} + I) \bmod 7 \end{aligned}$$

For the Gregorian calendar:

$$\begin{aligned} C &= \tfrac{year}{100} \\ H &= \left(C - \tfrac{C}{4} - \tfrac{8C+13}{25} + 19G + 15\right) \bmod 30 \\ I &= H - \tfrac{H}{28}\left(1 - \tfrac{29}{H+1} \times \tfrac{21-G}{11}\right) \\ J &= \left(year + \tfrac{year}{4} + I + 2 - C + \tfrac{C}{4}\right) \bmod 7 \end{aligned}$$

Thereafter, for both calendars:

$$\begin{aligned} L &= I - J \\ EasterMonth &= 3 + \tfrac{L+40}{44} \\ EasterDay &= L + 28 - 31 \times \tfrac{EasterMonth}{4} \end{aligned}$$

This algorithm is based in part on the algorithm of Oudin (1940) as quoted in "Explanatory Supplement to the Astronomical Almanac", P. Kenneth Seidelmann, editor.

People who want to dig into the workings of this algorithm, may be interested to know that

G is the Golden Number-1

H is 23-Epact (modulo 30)

I is the number of days from 21 March to the Paschal full moon

J is the weekday for the Paschal full moon (0=Sunday, 1=Monday, etc.)

L is the number of days from 21 March to the Sunday on or before the Paschal full moon (a number between -6 and 28)

2.13.8 Isn't there an even simpler way to calculate Easter?

If we confine ourselves to the years 1900-2099 and consider only the Gregorian calendar, the formulas of the previous section can be further simplified thus:

$$
\begin{aligned}
H &= \Big(24 + 19 \times (\mathit{year} \bmod 19)\Big) \bmod 30 \\
I &= H - \tfrac{H}{28} \\
J &= \Big(\mathit{year} + \tfrac{\mathit{year}}{4} + I - 13\Big) \bmod 7 \\
L &= I - J \\
\mathit{EasterMonth} &= 3 + \tfrac{L+40}{44} \\
\mathit{EasterDay} &= L + 28 - 31 \times \tfrac{\mathit{EasterMonth}}{4}
\end{aligned}
$$

(Again, the divisions are integer divisions, in which remainders are discarded.)

2.13.9 Is there a simple relationship between two consecutive Easters?

Suppose you know the Easter date of the current year, can you easily find the Easter date in the next year? No, but you can make a qualified guess.

If Easter Sunday in the current year falls on day X and the next year is not a leap year, Easter Sunday of next year will fall on one of the following days: X-15, X-8, X+13 (rare), or X+20.

If Easter Sunday in the current year falls on day X and the next year is a leap year, Easter Sunday of next year will fall on one of the following days: X-16, X-9, X+12 (extremely rare), or X+19. (The jump X+12 occurs only once in the period 1800-2200, namely when going from 2075 to 2076.)

If you combine this knowledge with the fact that Easter Sunday never falls before 22 March and never falls after 25 April, you can narrow the possibilities down to two or three dates.

2.13.10 How frequently are the dates for Easter repeated?

The sequence of Easter dates repeats itself every 532 years in the Julian calendar. The number 532 is the product of the following numbers:

19 (the Metonic cycle or the cycle of the Golden Number)
28 (the Solar cycle, see section 2.4)

The sequence of Easter dates repeats itself every 5,700,000 years in the Gregorian calendar. Calculating this is not as simple as for the Julian calendar, but the number 5,700,000 turns out to be the product of the following numbers:

19 (the Metonic cycle or the cycle of the Golden Number)
400 (the Gregorian equivalent of the Solar cycle, see section 2.4)
25 (the cycle used in step 3 when calculating the Epact)
30 (the number of different Epact values)

2.13.11 What about Greek Orthodox Easter?

The Greek Orthodox Church does not always celebrate Easter on the same day as the Catholic and Protestant countries. The reason is that the Orthodox Church uses the Julian calendar when calculating Easter. This is case even in the churches that otherwise use the Gregorian calendar.

When the Greek Orthodox Church in 1923 decided to change to the Gregorian calendar (or rather: a Revised Julian Calendar), they chose to use the astronomical full moon as the basis for calculating Easter, rather than the "official" full moon described in the previous sections. And they chose the meridian of Jerusalem to serve as definition of when a Sunday starts. However, except for some sporadic use in the 1920s, this system was never adopted in practice.

2.13.12 Did the Easter dates change in 2001?

No.

At a meeting in Aleppo, Syria (5-10 March 1997), organised by the World Council of Churches and the Middle East Council of Churches, representatives of several churches and Christian world communions suggested that the discrepancies between Easter calculations in the Western and the Eastern churches could be resolved by adopting astronomically accurate calculations of the vernal equinox and the full moon, instead of using the algorithm presented in section 2.13.6. The meridian of Jerusalem should be used for the astronomical calculations.

The new method for calculating Easter should have taken effect from the year 2001. In that year the Julian and Gregorian Easter dates coincided (on 15 April Gregorian/2 April Julian), and it would therefore be a reasonable starting point for the new system.

However, the Eastern churches (especially the Russian Orthodox Church) are reluctant to change, having already experienced a schism in the calendar question. So nothing will happen in the near future.

If the new system were introduced, churches using the Gregorian calendar will hardly notice the change. Only once during the period 2001-2025 would these churches note a difference: In 2019 the Gregorian method gives an Easter date of 21 April, but the proposed new method gives 24 March.

Note that the new method makes an Easter date of 21 March possible. This date was not possible under the Julian or Gregorian algorithms. (Under the new method, Easter will fall on 21 March in the year 2877. You're all invited to my house on that date!)

2.14 How does one count years?

In about AD 523, the papal chancellor, Bonifatius, asked a monk by the name of Dionysius Exiguus to devise a way to implement the rules from the Nicean council (the so-called "Alexandrine Rules") for general use.

Dionysius Exiguus (in English known as Denis the Little) was a monk from Scythia, he was a canon in the Roman curia, and his assignment was to prepare calculations of the dates of Easter. At that time it was customary to count years since the reign of emperor Diocletian; but in his calculations Dionysius chose to number the years since the birth of Christ, rather than honour the persecutor Diocletian.

Dionysius (wrongly) fixed Jesus' birth with respect to Diocletian's reign in such a manner that it falls on 25 December 753 AUC (ab urbe condita, i.e. since the founding of Rome), thus making the current era start with AD 1 on 1 January 754 AUC.

How Dionysius established the year of Christ's birth is not known (see section 2.14.1 for a couple of theories). Jesus was born under the reign of king Herod the Great, who died in 750 AUC, which means that Jesus could have been born no later than that year. Dionysius' calculations were disputed at a very early stage.

When people started dating years before 754 AUC using the term “Before Christ”, they let the year 1 BC immediately precede AD 1 with no intervening year zero.

Note, however, that astronomers frequently use another way of numbering the years BC. Instead of 1 BC they use 0, instead of 2 BC they use -1, instead of 3 BC they use -2, etc.

See also section 2.14.2.

The earliest uses of BC dating are found in the works of the Venerable Bede (673-735).

In this section I have used AD 1 = 754 AUC. This is the most likely equivalence between the two systems. However, some authorities state that AD 1 = 753 AUC or 755 AUC. This confusion is not a modern one, it appears that even the Romans were in some doubt about how to count the years since the founding of Rome.

2.14.1 How did Dionysius date Christ’s birth?

There are quite a few theories about this. And many of the theories are presented as if they were indisputable historical fact.

Here are two theories that I personally consider likely:

1. According to the Gospel of Luke (3 : 1 & 3 : 23) Jesus was “about thirty years old” shortly after “the fifteenth year of the reign of Tiberius Caesar”. Tiberius became emperor in AD 14. If you combine these numbers you reach a birthyear for Jesus that is strikingly close to the beginning of our year reckoning. This may have been the basis for Dionysius’ calculations.

2. Dionysius’ original task was to calculate an Easter table. In the Julian calendar, the dates for Easter repeat every 532 years (see section 2.13.10). The first year in Dionysius’ Easter tables is AD 532. Is it a coincidence that the number 532 appears twice here? Or did Dionysius perhaps fix Jesus’ birthyear so that his own Easter tables would start exactly at the beginning of the second Easter cycle after Jesus’ birth?

2.14.2 Was Jesus born in the year 0?

No.

There are two reasons for this:

- There is no year 0.
- Jesus was born before 4 BC.

The concept of a year “zero” is a modern myth (but a very popular one). In our calendar, AD 1 follows immediately after 1 BC with no intervening year zero. So a person who was born in 10 BC and died in AD 10, would have died at the age of 19, not 20.

Furthermore, as described in section 2.14, our year reckoning was established by Dionysius Exiguus in the 6th century. Dionysius let the year AD 1 start one week after what he believed to be Jesus’ birthday. But Dionysius’ calculations were wrong. The Gospel of Matthew tells us that Jesus was born under the reign of king Herod the Great, who died in 4 BC. It is likely that Jesus was actually born around 7 BC. The date of his birth is unknown; it may or may not be 25 December.

2.14.3 When did the 3rd millennium start?

The first millennium started in AD 1, so the millennia are counted in this manner:

1st millennium:	1-1000
2nd millennium:	1001-2000
3rd millennium:	2001-3000

Thus, the 3rd millennium and, similarly, the 21st century started on 1 Jan 2001.

This is the cause of some heated debate, especially since some dictionaries and encyclopaedias say that a century starts in years that end in 00. Furthermore, the change 1999/2000 is obviously much more spectacular than the change 2000/2001.

Let me propose a few compromises:

Any 100-year period is a century. Therefore the period from 23 June 2004 to 22 June 2104 is a century. So please feel free to celebrate the start of a century any day you like!

Although the 20th century started in 1901, the 1900s started in 1900. Similarly, the 21st century started in 2001, but the 2000s started in 2000.

2.14.4 What do AD, BC, CE, and BCE stand for?

Years before the birth of Christ are in English traditionally identified using the abbreviation BC ("Before Christ").

Years after the birth of Christ are traditionally identified using the Latin abbreviation AD ("Anno Domini", that is, "In the Year of the Lord").

Some people, who want to avoid the reference to Christ that is implied in these terms, prefer the abbreviations BCE ("Before the Common Era" or "Before the Christian Era") and CE ("Common Era" or "Christian Era").

2.15 What is the Indiction?

The Indiction was used in the middle ages to specify the position of a year in a 15 year taxation cycle. It was introduced by emperor Constantine the Great on 1 September 312 and ceased to be used in 1806.

The Indiction may be calculated thus:

$$Indiction = (year + 2) \bmod 15 + 1$$

The Indiction has no astronomical significance.

The Indiction did not always follow the calendar year. Three different Indictions may be identified:

1. The Pontifical or Roman Indiction, which started on New Year's Day (being either 25 December, 1 January, or 25 March).

2. The Greek or Constantinopolitan Indiction, which started on 1 September.

3. The Imperial Indiction or Indiction of Constantine, which started on 24 September.

2.16 What is the Julian Period?

The Julian period (and the Julian day number) must not be confused with the Julian calendar.

The French scholar Joseph Justus Scaliger (1540-1609) was interested in assigning a positive number to every year without having to worry about BC/AD. He invented what is today known as the *Julian Period*.

The Julian Period probably takes its name from the Julian calendar, although it has been claimed that it is named after Scaliger's father, the Italian scholar Julius Caesar Scaliger (1484-1558).

Scaliger's Julian period starts on 1 January 4713 BC (Julian calendar) and lasts for 7980 years. AD 2005 is thus year 6719 in the Julian period. After 7980 years the number starts from 1 again.

Why 4713 BC and why 7980 years? Well, in 4713 BC the Indiction (see section 2.15), the Golden Number (see section 2.13.3) and the Solar Number (see section 2.4) were all 1. The next times this happens is $15 \times 19 \times 28 = 7980$ years later, in AD 3268.

Astronomers have used the Julian period to assign a unique number to every day since 1 January 4713 BC. This is the so-called Julian Day (JD). JD 0 designates the 24 hours from noon UTC on 1 January 4713 BC to noon UTC on 2 January 4713 BC.

This means that at noon UTC on 1 January AD 2000, JD 2,451,545 started.

This can be calculated thus:

> From 4713 BC to AD 2000 there are 6712 years.
> In the Julian calendar, years have 365.25 days, so 6712 years correspond to $6712 \times 365.25 = 2,451,558$ days. Subtract from this the 13 days that the Gregorian calendar is ahead of the Julian calendar, and you get 2,451,545.

Often fractions of Julian day numbers are used, so that 1 January AD 2000 at 15:00 UTC is referred to as JD 2,451,545.125.

Note that some people use the term "Julian day number" to refer to any numbering of days. NASA, for example, uses the term to denote the number of days since 1 January of the current year, counting 1 January as day 1.

2.16.1 Is there a formula for calculating the Julian day number?

Try this one (the divisions are integer divisions, in which remainders are discarded):

$$\begin{aligned} a &= \frac{14-month}{12} \\ y &= year + 4800 - a \\ m &= month + 12a - 3 \end{aligned}$$

For a date in the Gregorian calendar:

$$JD = day + \frac{153m+2}{5} + 365y + \frac{y}{4} - \frac{y}{100} + \frac{y}{400} - 32045$$

For a date in the Julian calendar:

$$JD = day + \frac{153m+2}{5} + 365y + \frac{y}{4} - 32083$$

JD is the Julian day number that starts at noon UTC on the specified date.

The algorithm works fine for AD dates. If you want to use it for BC dates, you must first convert the BC year to a negative year (e.g., 10 BC = -9). The algorithm works correctly for all dates after 4800 BC, i.e. at least for all positive Julian day numbers.

To convert the other way (i.e., to convert a Julian day number, JD, to a day, month, and year) these formulas can be used (again, the divisions are integer divisions):

For the Gregorian calendar:

$$\begin{aligned} a &= JD + 32044 \\ b &= \tfrac{4a+3}{146097} \\ c &= a - \tfrac{146097b}{4} \end{aligned}$$

For the Julian calendar:

$$\begin{aligned} b &= 0 \\ c &= JD + 32082 \end{aligned}$$

Then, for both calendars:

$$\begin{aligned} d &= \tfrac{4c+3}{1461} \\ e &= c - \tfrac{1461d}{4} \\ m &= \tfrac{5e+2}{153} \\ \\ day &= e - \tfrac{153m+2}{5} + 1 \\ month &= m + 3 - 12 \times \tfrac{m}{10} \\ year &= 100b + d - 4800 + \tfrac{m}{10} \end{aligned}$$

2.16.2 What is the modified Julian day number?

Sometimes a modified Julian day number (MJD) is used which is 2,400,000.5 less than the Julian day number. This brings the numbers into a more manageable numeric range and makes the day numbers change at midnight UTC rather than noon.

MJD 0 thus started on 17 Nov 1858 (Gregorian) at 00:00:00 UTC.

2.16.3 What is the Lilian day number?

The Lilian day number is similar to the Julian day number, except that Lilian day number 1 started at midnight on the first day of the Gregorian calendar, that is, 15 October 1582.

The Lilian day number was invented by Bruce G. Ohms of IBM in 1986. It is named after Aloysius Lilius mentioned in section 2.2.

2.17 What is the correct way to write dates?

The answer to this question depends on what you mean by "correct". Different countries have different customs.

Most countries use a day-month-year format, such as:

25.12.1998 25/12/1998 25/12-1998 25.XII.1998

In the U.S.A. a month-day-year format is common:

12/25/1998 12-25-1998

International standard ISO 8601 (see chapter 3) mandates a year-month-day format, namely either

1998-12-25 or 19981225.

This format is gaining popularity in some countries.

In all of these systems, the first two digits of the year are frequently omitted:

25.12.98 12/25/98 98-12-25

However, although the last form is frequently seen, it is not allowed by the ISO standard.

This confusion leads to misunderstandings. What is 02-03-04? To most people it is 2 Mar 2004; to an American it is 3 Feb 2004; and to a person using the international standard it could be 4 Mar 2002 (although a year specified with only two digits does not conform to the ISO standard).

If you want to be sure that people understand you, I recommend that you

- write the month with letters instead of numbers, and
- write the years as 4-digit numbers.

Chapter 3

ISO 8601

The Internatinal Organization for Standardization, ISO, has published a standard on how to write dates, times, and time intervals. This standard is known as ISO 8601. The text below refers to the third edition of that standard, which was published on 1 December 2004. Its title is: ISO 8601:2004, "Data elements and interchange formats – Information interchange – Representation of dates and times".

The text below is not an exhaustive description of everything you may find in ISO 8601; it does, however, try to capture the most important points.

3.1 What date format does the Standard mandate?

There are three basic formats: Calendar date, ordinal date, and week date.

A calendar date should be written as a 4-digit year number, followed by a 2-digit month number, followed by a 2-digit day number. Thus, for example, 2 August 1953 may be written:

19530802 or 1953-08-02

An ordinal date should be written as a 4-digit year number, followed by a 3-digit number indicating the number of the day within the year. Thus, for example, 2 August 1953 may be written:

1953214 or 1953-214

2 August is the 214th day of a non-leap year.

A week date should be written as a 4-digit year number, followed by a W, followed by a 2-digit week number followed by a 1-digit week day number (1=Monday, 2=Tuesday, ..., 7=Sunday). The week number is defined in section 7.7. Thus, for example, 2 August 1953 may be written:

1953W317 or 1953-W31-7

2 August was the Sunday of week 31 of 1953.

In all the examples above, the hyphens are optional.

Note that you must always write all the digits. Thus the year 47 must be written as 0047.

3.2 What time format does the Standard mandate?

A 24-hour clock must be used. A time is written as a 2-digit hour, followed by a 2-digit minute, followed by a 2-digit second, followed by a comma, followed by a number of digits indicating a fraction of a second. For example, thus:

140812,35 or 14:08:12,35

The fraction, the seconds, and the minutes may be omitted if less accuracy is required:

140812	or	14:08:12
1408	or	14:08
14		

In all the examples above, the colons are optional. The comma may be replaced by a period (.), but this is not recommended.

The time may optionally be followed by a time zone indication. For UTC, the time zone indication is the letter Z. For other time zones, the indication is a plus or minus followed by the time difference to UTC (plus for times east of Greenwich, minus for times west of Greenwich). For example:

1130Z	(11:30 UTC)
1130+0430	(11:30, at a location 4 and a half hours ahead of UTC)
1130-05	(11:30, at a location 5 hours behind of UTC)

3.3 What if I want to specify both a date and a time?

Date and time indications can be strung together by putting the letter T between them. For example, ten minutes to 7 p.m. on 2 August 1953 may be written as:

19530802T185000 or 1953-08-02T18:50:00

3.4 What format does the Standard mandate for a time interval?

There are several to choose from. A time interval can be specified as a starting time and an ending time or as a duration together with either a starting time and an ending time.

There are too many details to cover here, so I shall only give a few examples:

Using starting time and ending time:

1998-12-01T12:03/2004-04-02T14:12

Using starting time and duration:

1927-03-12T08:04/P1Y4M12DT6H30M9S

This last example should be read as the time interval starting on 12 March 1927 at 08:04 and lasting for 1 year, 4 months, 12 days, 6 hours, 30 minutes, and 9 seconds. The letter P following the slash indicates that a duration follows.

3.5 Can I write BC dates and dates after the year 9999 using ISO 8601?

Yes, you can.

The year 1 BC must be written as 0000. The year 2 BC must be written as -0001, the year 3 BC must be written as -0002 etc.

Years of more than 4 digits must be written with an initial plus sign. Thus the year AD 10000 must be written as +10000.

3.6 Can I write dates in the Julian calendar using ISO 8601?

No. The Standard requires that the Gregorian calendar be used for all dates. Dates before the introduction of the Gregorian calendar are written using the proleptic Gregorian calendar (see section 2.9). This is one of the few places where the proleptic Gregorian calendar is used.

Thus the Julian date 12 March 826 must be written as 0826-03-16, because its equivalent date in the Gregorian calendar is 16 March.

3.7 Does the Standard define the Gregorian calendar?

Yes, ISO 8601 specifies how the Gregorian calendar works. The specification is completely compatible with the calendar specified by Pope Gregory XIII in 1582, except that ISO 8601 does not concern itself with the calculation of Easter.

However, the calendar reference point used by the Standard is not Christ's birth but the date on which the metric convention (*Convention du Mètre*) was signed in Paris. The Standard defines that date to be 20 May 1875.

Similarly, the reference point of the week cycles is 1 January 2000, which is defined to be a Saturday.

Of course, these reference points are also completely compatible with common usage.

3.8 What does the Standard say about the week?

According to ISO 8601, Monday is the first day of the week.

Each week has a number. A week that lies partly in one year and partly in another is assigned a number in the year in which most of its days lie. The Standard specifies this by saying that week 1 of any year is the week that includes the first Thursday of that year.

More details can be found in chapter 7, which deals with the week in greater detail.

3.9 Why are ISO 8601 dates not used in this Calendar FAQ?

The Standard specifies how to write dates using only numbers. The Standard explicitly does not cover the cases where dates are written using words (such as January, February, etc.). In fact, the Standard itself makes frequent use of dates such as "20 May 1875" and "15 October 1582".

In other words, ISO 8601 helps people with data communication where it is natural to use all-number dates. In everyday language (spoken and written) we are free to use the terms we like best.

3.10 Where can I get the Standard?

If you are looking for a free copy somewhere on the internet, forget it! ISO makes money from selling copies of their standards.

ISO 8601:2004 can be bought from ISO at `http://www.iso.ch`. It is very expensive. The last time I checked, the price was 124 Swiss Francs (about U.S. $97) for a 33 page document.

Your local library may be able to find a copy for you.

Chapter 4

The Hebrew Calendar

The current definition of the Hebrew calendar is generally said to have been set down by the Sanhedrin president Hillel II in approximately AD 359. The original details of his calendar are, however, uncertain.

The Hebrew calendar is used for religious purposes by Jews all over the world, and it is the official calendar of Israel.

The Hebrew calendar is a combined solar/lunar calendar, in that it strives to have its years coincide with the tropical year and its months coincide with the synodic months. This is a complicated goal, and the rules for the Hebrew calendar are correspondingly fascinating.

4.1 What does a Hebrew year look like?

An ordinary (non-leap) year has 353, 354, or 355 days. A leap year has 383, 384, or 385 days. The three lengths of the years are termed, “deficient”, “regular”, and “complete”, respectively.

An ordinary year has 12 months, a leap year has 13 months.

Every month starts (approximately) on the day of a new moon.

The months and their lengths are:

Name	Length in a deficient year	Length in a regular year	Length in a complete year
Tishri	30	30	30
Heshvan	29	29	30
Kislev	29	30	30
Tevet	29	29	29
Shevat	30	30	30
(Adar I	30	30	30)
Adar II	29	29	29
Nisan	30	30	30
Iyar	29	29	29
Sivan	30	30	30
Tammuz	29	29	29
Av	30	30	30
Elul	29	29	29
Total:	353 or 383	354 or 384	355 or 385

The month Adar I is only present in leap years. In non-leap years Adar II is simply called "Adar".

Note that in a regular year the numbers 30 and 29 alternate; a complete year is created by adding a day to Heshvan, whereas a deficient year is created by removing a day from Kislev.

The alteration of 30 and 29 ensures that when the year starts with a new moon, so does each month.

4.2 What years are leap years?

A year is a leap year if the number *year mod 19* is one of the following: 0, 3, 6, 8, 11, 14, or 17.

The value for year in this formula is the "Anno Mundi" described in section 4.8.

4.3 What years are deficient, regular, and complete?

That is the wrong question to ask. The correct question to ask is: When does a Hebrew year begin? Once you have answered that question (see section 4.6), the length of the year is the number of days between 1 Tishri in one year and 1 Tishri in the following year.

4.4 When is New Year's day?

That depends. Jews have several different days to choose from. The most important are:

1 Tishri: *Rosh HaShanah.* This day is a celebration of the creation of the world and marks the start of a new calendar year. This will be the day we shall base our calculations on in the following sections.

1 Nisan: *New Year for Kings.* This is also the start of the religious year. Nisan is considered the first month, although it occurs 6 or 7 months after the start of the calendar year.

4.5 When does a Hebrew day begin?

A Hebrew-calendar day does not begin at midnight, but at either sunset or when three medium-sized stars should be visible, depending on the religious circumstance.

Sunset marks the start of the 12 night hours, whereas sunrise marks the start of the 12 day hours. This means that night hours may be longer or shorter than day hours, depending on the season.

4.6 When does a Hebrew year begin?

The first day of the calendary year, Rosh HaShanah, on 1 Tishri is determined as follows:

1. The new year starts on the day of the new moon that occurs about 354 days (or 384 days if the previous year was a leap year) after 1 Tishri of the previous year
2. If the new moon occurs after noon on that day, delay the new year by one day. (Because in that case the new crescent moon will not be visible until the next day.)
3. If this would cause the new year to start on a Sunday, Wednesday, or Friday, delay it by one day. (Because we want to avoid that Yom Kippur (10 Tishri) falls on a Friday or Sunday, and that Hoshanah Rabba (21 Tishri) falls on a Sabbath (Saturday)).
4. If two consecutive years start 356 days apart (an illegal year length), delay the start of the first year by two days.
5. If two consecutive years start 382 days apart (an illegal year length), delay the start of the second year by one day.

Note: Rule 4 can only come into play if the first year was supposed to start on a Tuesday. Therefore a two day delay is used rather than a one day delay, as the year must not start on a Wednesday as stated in rule 3.

4.7 When is the new moon?

A calculated new moon is used. In order to understand the calculations, one must know that an hour is subdivided into 1080 “parts”.

The calculations are as follows:

The new moon that started the year AM 1, occurred 5 hours and 204 parts after sunset (i.e. just before midnight on Julian date 6 October 3761 BC).

The new moon of any particular year is calculated by extrapolating from this time, using a synodic month of 29 days 12 hours and 793 parts.

Note that 18:00 Jerusalem time (15:39 UTC) is used instead of sunset in all these calculations.

4.8 How does one count years?

Years are counted since the creation of the world, which is assumed to have taken place in the autumn of 3760 BC. In that year, after less than a week belonging to AM 1, AM 2 started (AM = Anno Mundi = year of the world).

In the year AD 2006 we shall witness the start of Hebrew year AM 5767.

Chapter 5

The Islamic Calendar

The Islamic calendar (or Hijri calendar) is a purely lunar calendar. It contains 12 months that are based on the motion of the moon, and because 12 synodic months is only $12 \times 29.53 = 354.36$ days, the Islamic calendar is consistently shorter than a tropical year, and therefore it shifts with respect to the Christian calendar.

The calendar is based on the Qur'an (Sura IX, 36-37) and its proper observance is a sacred duty for Muslims.

The Islamic calendar is the official calendar in countries around the Gulf, especially Saudi Arabia (but see section 5.5). But other Muslim countries use the Gregorian calendar for civil purposes and only turn to the Islamic calendar for religious purposes.

5.1 What does an Islamic year look like?

The names of the 12 months that comprise the Islamic year are:

1.	Muharram	7.	Rajab
2.	Safar	8.	Sha'ban
3.	Rabi' al-awwal (Rabi' I)	9.	Ramadan
4.	Rabi' al-thani (Rabi' II)	10.	Shawwal
5.	Jumada al-awwal (Jumada I)	11.	Dhu al-Qi'dah
6.	Jumada al-thani (Jumada II)	12.	Dhu al-Hijjah

(Due to different transliterations of the Arabic alphabet, other spellings of the months are possible.)

Each month starts when the lunar crescent is first seen (by an actual human being) after a new moon.

Although new moons may be calculated quite precisely, the actual visibility of the crescent is much more difficult to predict. It depends on factors such as weather, the optical properties of the atmosphere, and the location of the observer. It is therefore very difficult to give accurate information in advance about when a new month will start.

Furthermore, some Muslims depend on a local sighting of the moon, whereas others depend on a sighting by authorities somewhere in the Muslim world. Both are valid Islamic practices, but they may lead to different starting days for the months.

5.2 So you can't print an Islamic calendar in advance?

Not a reliable one. However, calendars are printed for planning purposes, but such calendars are based on estimates of the visibility of the lunar crescent, and the actual month may start a day earlier or later than predicted in the printed calendar.

Different methods for estimating the calendars are used.

Some sources mention a crude system in which all odd numbered months have 30 days and all even numbered months have 29 days with an extra day added to the last month in "leap years" (a concept otherwise unknown in the calendar). Leap years could then be years in which the number *year mod 30* is one of the following: 2, 5, 7, 10, 13, 16, 18, 21, 24, 26, or 29. (This is the algorithm used in the calendar program of the Gnu Emacs editor.)

Such a calendar would give an average month length of 29.53056 days, which is quite close to the synodic month of 29.53059 days, so *on the average* it would be quite accurate, but in any given month it is still just a rough estimate.

Better algorithms for estimating the visibility of the new moon have been devised, and a number of computer programs with this purpose exist.

5.3 How does one count years?

Years are counted since the Hijra, that is, Mohammed's emigration to Medina in AD 622. On 16 July (Julian calendar) of that year, AH 1 started (AH = Anno Hegirae = year of the Hijra).

In the year AD 2006 we shall witness the start of Islamic year AH 1427.

Note that although only $2006 - 622 = 1384$ years have passed in the Christian calendar, 1426 years have passed in the Islamic calendar, because its year is consistently shorter (by about 11 days) than the tropical year used by the Christian calendar.

5.4 When will the Islamic calendar overtake the Gregorian calendar?

As the year in the Islamic calendar is about 11 days shorter than the year in the Christian calendar, the Islamic years are slowly gaining in on the Christian years. But it will be many years before the two coincide. The 1st day of the 5th month of AD 20874 in the Gregorian calendar will also be (approximately) the 1st day of the 5th month of AH 20874 of the Islamic calendar.

5.5 Doesn't Saudi Arabia have special rules?

[For civil (but not religious) purposes,] Saudi Arabia doesn't rely on a visual sighting of the crescent moon to fix the start of a new month. Instead they base their calendar on a calculated astronomical moon.

Since 2002 (AH 1423) the rule has been as follows: If on the 29th day of an Islamic month,

- the geocentric conjunction (that is, the new moon as seen from the centre of the earth) occurs before sunset, and
- the moon sets after the sun,

then the next day will be the first of a new month; otherwise the next day will be the last (30th) of the current month.

The times for the setting of the sun and the moon are calculated for the coordinates of Mecca.

Chapter 6

The Persian Calendar

The Persian calendar is a solar calendar with a starting point that matches that of the Islamic calendar. Apart from that, the two calendars are not related. The origin of the Persian calendar can be traced back to the 11th century when a group of astronomers (including the well-known poet Omar Khayyam) created what is known as the Jalaali calendar. However, a number of changes have been made to the calendar since then.

The current calendar has been used in Iran since 1925 and in Afghanistan since 1957. However, Afghanistan used the Islamic calendar in the years 1999-2002.

6.1 What does a Persian year look like?

The names and lengths of the 12 months that comprise the Persian year are:

1.	Farvardin	(31 days)	7.	Mehr	(30 days)
2.	Ordibehesht	(31 days)	8.	Aban	(30 days)
3.	Khordad	(31 days)	9.	Azar	(30 days)
4.	Tir	(31 days)	10.	Day	(30 days)
5.	Mordad	(31 days)	11.	Bahman	(30 days)
6.	Shahrivar	(31 days)	12.	Esfand	(29/30 days)

(Due to different transliterations of the Persian alphabet, other spellings of the months are possible.) In Afghanistan the months are named differently.

The month of Esfand has 29 days in an ordinary year, 30 days in a leap year.

6.2 When does the Persian year begin?

The Persian year starts at vernal equinox. If the astronomical vernal equinox falls before noon (Tehran true time) on a particular day, then that day is the first day of the year. If the astronomical vernal equinox falls after noon, the following day is the first day of the year.

6.3 How does one count years?

As in the Islamic calendar (section 5.3), years are counted since Mohammed's emigration to Medina in AD 622. At vernal equinox of that year, AP 1 started (AP = Anno Persico/Anno Persarum = Persian year).

Note that contrary to the Islamic calendar, the Persian calendar counts solar years. In the year AD 2006 we shall therefore witness the start of Persian year 1385, but the start of Islamic year 1427.

6.4 What years are leap years?

Since the Persian year is defined by the astronomical vernal equinox, the answer is simply: Leap years are years in which there are 366 days between two Persian new year's days.

However, basing the Persian calendar purely on an astronomical observation of the vernal equinox is rejected by many, and a few mathematical rules for determining the length of the year have been suggested.

The most popular (and complex) of these is probably the following:

The calendar is divided into periods of 2820 years. These periods are then divided into 88 cycles whose lengths follow this pattern:

29, 33, 33, 33, 29, 33, 33, 33, 29, 33, 33, 33, ...

This gives 2816 years. The total of 2820 years is achieved by extending the last cycle by 4 years (for a total of 37 years).

If you number the years within each cycle starting with 0, then leap years are the years that are divisible by 4, except that the year 0 is not a leap year.

So within, say, a 29 year cycle, this is the leap year pattern:

Year		Year		Year		Year	
0	Ordinary	8	Leap	16	Leap	24	Leap
1	Ordinary	9	Ordinary	17	Ordinary	25	Ordinary
2	Ordinary	10	Ordinary	18	Ordinary	26	Ordinary
3	Ordinary	11	Ordinary	19	Ordinary	27	Ordinary
4	Leap	12	Leap	20	Leap	28	Leap
5	Ordinary	13	Ordinary	21	Ordinary		
6	Ordinary	14	Ordinary	22	Ordinary		
7	Ordinary	15	Ordinary	23	Ordinary		

This gives a total of 683 leap years every 2820 years, which corresponds to an average year length of $365\,{}^{683}\!/\!_{2820} = 365.24220$ days. This is a better approximation to the tropical year than the 365.2425 days of the Gregorian calendar.

The current 2820 year period started in the year AP 475 (AD 1096).

This "mathematical" calendar currently coincides closely with the purely astronomical calendar. In the years between AP 1244 and 1531 (AD 1865 and 2152) a discrepancy of one day is seen twice, namely in AP 1404 and 1437 (starting at vernal equinox of AD 2025 and 2058). However, outside this period, discrepancies are more frequent.

Chapter 7

The Week

The Christian, the Hebrew, the Islamic, and the Persian calendars all have a 7-day week.

7.1 What is the origin of the 7-day week?

Digging into the history of the 7-day week is a very complicated matter. Authorities have very different opinions about the history of the week, and they frequently present their speculations as if they were indisputable facts. The only thing we seem to know for certain about the origin of the 7-day week is that we know nothing for certain.

The first pages of the Bible explain how God created the world in six days and rested on the seventh. This seventh day became the Jewish day of rest, the Sabbath, Saturday.

Extra-biblical locations sometimes mentioned as the birthplace of the 7-day week include: Babylon, Persia, and several others. The week was known in Rome before the advent of Christianity.

7.2 What do the names of the days of the week mean?

An answer to this question is necessarily closely linked to the language in question. Whereas most languages use the same names for the months (with a few Slavonic languages as notable exceptions), there is great variety in names that various languages use for the days of the week. A few examples will be given here.

Except for the Sabbath, Jews simply number their week days.

A related method is partially used in Portuguese and Russian:

English	Portuguese	Russian	Meaning of Russian name
Monday	segunda-feira	ponedelnik	After “do-nothing”
Tuesday	terça-feira	vtornik	Second
Wednesday	quarta-feira	sreda	Middle
Thursday	quinta-feira	chetverg	Fourth
Friday	sexta-feira	pyatnitsa	Fifth
Saturday	sabado	subbota	Sabbath
Sunday	domingo	voskresenye	Resurrection

Most Latin-based languages connect each day of the week with one of the seven "planets" of the ancient times: Sun, Moon, Mercury, Venus, Mars, Jupiter, and Saturn. French, for example, uses:

English	French	"Planet"
Monday	lundi	Moon
Tuesday	mardi	Mars
Wednesday	mercredi	Mercury
Thursday	jeudi	Jupiter
Friday	vendredi	Venus
Saturday	samedi	Saturn
Sunday	dimanche	(Sun)

The link with the sun has been broken in French, but Sunday was called *dies solis* (day of the sun) in Latin.

It is interesting to note that also some Asiatic languages (for example, Hindi, Japanese, and Korean) have a similar relationship between the week days and the planets.

English has retained the original planets in the names for Saturday, Sunday, and Monday. For the four other days, however, the names of Anglo-Saxon or Nordic gods have replaced the Roman gods that gave name to the planets. Thus, Tuesday is named after Tiw, Wednesday is named after Woden, Thursday is named after Thor, and Friday is named after Freya.

7.3 What is the system behind the planetary day names?

As we saw in the previous section, the planets have given the week days their names following this order:

Moon, Mars, Mercury, Jupiter, Venus, Saturn, Sun

Why this particular order?

One theory goes as follows: If you order the "planets" according to either their presumed distance from Earth (assuming the Earth to be the centre of the universe) or their period of revolution around the Earth, you arrive at this order:

Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn

Now, assign (in reverse order) these planets to the hours of the day:

1=Saturn, 2=Jupiter, 3=Mars, 4=Sun, 5=Venus, 6=Mercury, 7=Moon, 8=Saturn, 9=Jupiter, etc., 23=Jupiter, 24=Mars

The next day will then continue where the old day left off:

1=Sun, 2=Venus, etc., 23=Venus, 24=Mercury

And the next day will go

1=Moon, 2=Saturn, etc.

If you look at the planet assigned to the first hour of each day, you will note that the planets come in this order:

Saturn, Sun, Moon, Mars, Mercury, Jupiter, Venus

This is exactly the order of the associated week days.
Coincidence? Maybe.

7.4 Has the 7-day week cycle ever been interrupted?

There is no record of the 7-day week cycle ever having been broken. Calendar changes and reform have never interrupted the 7-day cycles. It is very likely that the week cycles have run uninterrupted at least since the days of Moses (c. 1400 BC), possibly even longer.

Some sources claim that the ancient Jews used a calendar in which an extra Sabbath was occasionally introduced. But this is probably not true.

7.5 Which day is the day of rest?

For the Jews, the Sabbath (Saturday) is the day of rest and worship. On this day God rested after creating the world.

Most Christians have made Sunday their day of rest and worship, because Jesus rose from the dead on a Sunday.

Muslims use Friday as their day of rest and worship. The Qur'an calls Friday a holy day, the "king of days".

7.6 What is the first day of the week?

The Bible clearly makes Saturday (the Sabbath) the last day of the week. Therefore it is common Jewish and Christian practice to regard Sunday as the first day of the week (as is also evident from the Portuguese names for the week days mentioned in section 7.2). However, the fact that, for example, Russian uses the name "second" for Tuesday, indicates that some nations regard Monday as the first day.

In international standard ISO 8601 (see chapter 3) the International Organization for Standardization has decreed that Monday shall be the first day of the week.

7.7 What is the week number?

International standard ISO 8601 (see chapter 3) assigns a number to each week of the year. A week that lies partly in one year and partly in another is assigned a number in the year in which most of its days lie. This means that

Week 1 of any year is the week that contains 4 January, or equivalently

> Week 1 of any year is the week that contains the first Thursday in January.

Most years have 52 weeks, but years that start on a Thursday and leap years that start on a Wednesday have 53 weeks.

Note: This week numbering system is not commonly used in the United States.

7.8 How can I calculate the week number?

If you know the date, you can calculate the corresponding week number (as defined in ISO 8601) as descibed below. (The divisions are integer divisions in which the remainder is discarded.)

For dates in January and February, calculate:

$$\begin{aligned}
a &= year - 1\\
b &= \tfrac{a}{4} - \tfrac{a}{100} + \tfrac{a}{400}\\
c &= \tfrac{a-1}{4} - \tfrac{a-1}{100} + \tfrac{a-1}{400}\\
s &= b - c\\
e &= 0\\
f &= day - 1 + 31 \times (month - 1)
\end{aligned}$$

For dates in March through December, calculate:

$$\begin{aligned}
a &= year\\
b &= \tfrac{a}{4} - \tfrac{a}{100} + \tfrac{a}{400}\\
c &= \tfrac{a-1}{4} - \tfrac{a-1}{100} + \tfrac{a-1}{400}\\
s &= b - c\\
e &= s + 1\\
f &= day + \tfrac{153 \times (month-3)+2}{5} + 58 + s
\end{aligned}$$

Then, for any month continue thus:

$$\begin{aligned}
g &= (a + b) \bmod 7\\
d &= (f + g - e) \bmod 7\\
n &= f + 3 - d
\end{aligned}$$

We now have three situations:

If $n < 0$, the day lies in week $53 - \frac{g-s}{5}$ of the previous year.
If $n > 364 + s$, the day lies in week 1 of the coming year.
Otherwise, the day lies in week $\frac{n}{7} + 1$ of the current year.

This algorithm gives you a couple of additional useful values:

d indicates the day of the week (0=Monday, 1=Tuesday, etc.)
$f + 1$ is the ordinal number of the date within the current year.

7.9 Do weeks of different lengths exist?

If you define a "week" as a 7-day period, obviously the answer is no. But if you define a "week" as a named interval that is greater than a day and smaller than a month, the answer is yes.

The ancient Egyptians used a 10-day "week", as did the French Revolutionary calendar (see section 8.1).

The Maya calendar uses a 13 and a 20-day "week" (see section 9.2).

The Soviet Union has used both a 5-day and a 6-day week. In 1929-30 the USSR gradually introduced a 5-day week. Every worker had one day off every week, but there was no fixed day of rest. On 1 September 1931 this was replaced by a 6-day week with a fixed day of rest, falling on the 6th, 12th, 18th, 24th, and 30th day of each month (1 March was used instead of the 30th day of February, and the last day of months with 31 days was considered an extra working day outside the normal 6-day week cycle). A return to the normal 7-day week was decreed on 26 June 1940.

Chapter 8

The French Revolutionary Calendar

The French Revolutionary Calendar (or Republican Calendar) was introduced in France on 24 November 1793 and abolished on 1 January 1806. It was used again briefly during the Paris Commune in 1871.

8.1 What does a Republican year look like?

A year consists of 365 or 366 days, divided into 12 months of 30 days each, followed by 5 or 6 additional days. The months were:

1.	Vendémiaire	7.	Germinal
2.	Brumaire	8.	Floréal
3.	Frimaire	9.	Prairial
4.	Nivôse	10.	Messidor
5.	Pluviôse	11.	Thermidor
6.	Ventôse	12.	Fructidor

The year was not divided into weeks, instead each month was divided into three *décades* of 10 days, of which the final day was a day of rest. This was an attempt to de-Christianize the calendar, but it was an unpopular move, because now there were 9 work days between each day of rest, whereas the Gregorian Calendar had only 6 work days between each Sunday.

The ten days of each décade were called, respectively, Primidi, Duodi, Tridi, Quartidi, Quintidi, Sextidi, Septidi, Octidi, Nonidi, Decadi.

The 5 or 6 additional days followed the last day of Fructidor and were called:

1. Fête de la vertu (Celebration of virtue)
2. Fête du génie (Celebration of genius)
3. Fête du travail (Celebration of labour)
4. Fête de l'opinion (Celebration of opinion)
5. Fête des récompenses (Celebration of rewards)
6. Jour de la révolution (Day of the revolution) (the leap day)

[There appears to be some confusion about which days were called "fête" and which were called "jour". I would appreciate information on this.]

Each year was supposed to start on autumnal equinox (around 22 September), but this created problems as will be seen in section 8.3.

8.2 How does one count years?

Years are counted since the establishment of the first French Republic on 22 September 1792. That day became 1 Vendemiaire of the year 1 of the Republic. (However, the Revolutionary Calendar was not introduced until 24 November 1793.)

8.3 What years are leap years?

Leap years were introduced to keep New Year's Day on autumnal equinox. But this turned out to be difficult to handle, because equinox is not completely simple to predict.

In fact, the first decree implementing the calendar (5 Oct 1793) contained two contradictory rules, as it stated that:

- the first day of each year would be that of the autumnal equinox
- every 4th year would be a leap year

In practice, the first calendars were based on the equinoxial condition.

To remove the confusion, a rule similar to the one used in the Gregorian Calendar (including a 4000 year rule as described in section 2.2.2) was proposed by the calendar's author, Gilbert Romme, but his proposal ran into political problems.

In short, during the time when the French Revolutionary Calendar was in use, the following years were leap years: 3, 7, and 11.

8.4 How does one convert a Republican date to a Gregorian one?

The following table lists the Gregorian date on which each year of the Republic started:

Year 1:	22 Sep 1792	Year 8:	23 Sep 1799
Year 2:	22 Sep 1793	Year 9:	23 Sep 1800
Year 3:	22 Sep 1794	Year 10:	23 Sep 1801
Year 4:	23 Sep 1795	Year 11:	23 Sep 1802
Year 5:	22 Sep 1796	Year 12:	24 Sep 1803
Year 6:	22 Sep 1797	Year 13:	23 Sep 1804
Year 7:	22 Sep 1798	Year 14:	23 Sep 1805

Chapter 9

The Maya Calendar

(I am very grateful to Chris Carrier for providing most of the information about the Maya calendar.)

Among their other accomplishments, the ancient Mayas invented a calendar of remarkable accuracy and complexity. The Maya calendar was adopted by the other Mesoamerican nations, such as the Aztecs and the Toltec, which adopted the mechanics of the calendar unaltered but changed the names of the days of the week and the months.

The Maya calendar uses three different dating systems in parallel, the *Long Count*, the *Tzolkin* (divine calendar), and the *Haab* (civil calendar). Of these, only the Haab has a direct relationship to the length of the year.

A typical Mayan date looks like this: 12.18.16.2.6, 3 Cimi 4 Zotz.

12.18.16.2.6 is the Long Count date.
3 Cimi is the Tzolkin date.
4 Zotz is the Haab date.

9.1 What is the Long Count?

The Long Count is really a mixed base-20/base-18 representation of a number, representing the number of days since the start of the Mayan era. It is thus akin to the Julian Day Number (see section 2.16).

The basic unit is the *kin* (day), which is the last component of the Long Count. Going from right to left the remaining components are:

uinal	(1 uinal = 20 kin = 20 days)
tun	(1 tun = 18 uinal = 360 days = approx. 1 year)
katun	(1 katun = 20 tun = 7,200 days = approx. 20 years)
baktun	(1 baktun = 20 katun = 144,000 days = approx. 394 years)

The kin, tun, and katun are numbered from 0 to 19.
The uinal are numbered from 0 to 17.
The baktun are numbered from 1 to 13.

Although they are not part of the Long Count, the Mayas had names for larger time spans. The following names are sometimes quoted, although they are not ancient Maya terms:

1 pictun = 20 baktun = 2,880,000 days = approx. 7885 years
1 calabtun = 20 pictun = 57,600,000 days = approx. 158,000 years
1 kinchiltun = 20 calabtun = 1,152,000,000 days = approx. 3 million years
1 alautun = 20 kinchiltun = 23,040,000,000 days = approx. 63 million years

9.1.1 When did the Long Count start?

Logically, the first date in the Long Count should be 0.0.0.0.0, but as the baktun (the first component) are numbered from 1 to 13 rather than 0 to 12, this first date is actually written 13.0.0.0.0.

The authorities disagree on what 13.0.0.0.0 corresponds to in our calendar. I have come across three possible equivalences:

13.0.0.0.0 = 8 Sep 3114 BC (Julian) = 13 Aug 3114 BC (Gregorian)
13.0.0.0.0 = 6 Sep 3114 BC (Julian) = 11 Aug 3114 BC (Gregorian)
13.0.0.0.0 = 11 Nov 3374 BC (Julian) = 15 Oct 3374 BC (Gregorian)

Assuming one of the first two equivalences, the Long Count will again reach 13.0.0.0.0 on 21 or 23 December AD 2012 – a not too distant future.

The date 13.0.0.0.0 may have been the Mayas' idea of the date of the creation of the world.

9.2 What is the Tzolkin?

The Tzolkin date is a combination of two "week" lengths.

While our calendar uses a single week of seven days, the Mayan calendar used two different lengths of week:

- a numbered week of 13 days, in which the days were numbered from 1 to 13
- a named week of 20 days, in which the names of the days were:

0.	Ahau	5.	Chicchan	10.	Oc	15.	Men
1.	Imix	6.	Cimi	11.	Chuen	16.	Cib
2.	Ik	7.	Manik	12.	Eb	17.	Caban
3.	Akbal	8.	Lamat	13.	Ben	18.	Etznab
4.	Kan	9.	Muluc	14.	Ix	19.	Caunac

As the named week is 20 days and the smallest Long Count digit is 20 days, there is synchrony between the two; if, for example, the last digit of today's Long Count is 0, today must be Ahau; if it is 6, it must be Cimi. Since the numbered and the named week were both "weeks", each of their name/number change daily; therefore, the day after 3 Cimi is not 4 Cimi, but 4 Manik, and the day after that, 5 Lamat. The next time Cimi rolls around, 20 days later, it will be 10 Cimi instead of 3 Cimi. The next 3 Cimi will not occur until 260 (or 13×20) days have passed. This 260-day cycle also had good-luck or bad-luck associations connected with each day, and for this reason, it became known as the "divinatory year."

The "years" of the Tzolkin calendar are not counted.

9.2.1 When did the Tzolkin start?

Long Count 13.0.0.0.0 corresponds to 4 Ahau. The authorities agree on this.

9.3 What is the Haab?

The Haab was the civil calendar of the Mayas. It consisted of 18 "months" of 20 days each, followed by 5 extra days, known as *Uayeb*. This gives a year length of 365 days.

The names of the month were:

1.	Pop	7.	Yaxkin	13.	Mac
2.	Uo	8.	Mol	14.	Kankin
3.	Zip	9.	Chen	15.	Muan
4.	Zotz	10.	Yax	16.	Pax
5.	Tzec	11.	Zac	17.	Kayab
6.	Xul	12.	Ceh	18.	Cumku

In contrast to the Tzolkin dates, the Haab month names changed every 20 days instead of daily; so the day after 4 Zotz would be 5 Zotz, followed by 6 Zotz ... up to 19 Zotz, which is followed by 0 Tzec.

The days of the month were numbered from 0 to 19. This use of a 0th day of the month in a civil calendar is unique to the Maya system; it is believed that the Mayas discovered the number zero, and the uses to which it could be put, centuries before it was discovered in Europe or Asia.

The Uayeb days acquired a very derogatory reputation for bad luck; known as "days without names" or "days without souls," and were observed as days of prayer and mourning. Fires were extinguished and the population refrained from eating hot food. Anyone born on those days was "doomed to a miserable life."

The years of the Haab calendar are not counted.

The length of the Tzolkin year was 260 days and the length of the Haab year was 365 days. The smallest number that can be divided evenly by 260 and 365 is 18,980, or 365×52; this was known as the Calendar Round. If a day is, for example, "4 Ahau 8 Cumku," the next day falling on "4 Ahau 8 Cumku" would be 18,980 days or about 52 years later. Among the Aztec, the end of a Calendar Round was a time of public panic as it was thought the world might be coming to an end. When the Pleiades crossed the horizon on 4 Ahau 8 Cumku, they knew the world had been granted another 52-year extension.

9.3.1 When did the Haab start?

Long Count 13.0.0.0.0 corresponds to 8 Cumku. The authorities agree on this.

9.4 Did the Mayas think a year was 365 days?

Although there were only 365 days in the Haab year, the Mayas were aware that a year is slightly longer than 365 days, and in fact, many of the month-names are associated with the seasons; Yaxkin, for example, means "new or strong sun" and, at the beginning of the Long Count, 1 Yaxkin was the day after the winter solstice, when the sun starts to shine for a longer period of time and higher in the sky. When the Long Count was put into motion, it was started at 7.13.0.0.0, and 0 Yaxkin corresponded with Midwinter Day, as it did at 13.0.0.0.0 back in 3114 B.C. The available evidence indicates that the Mayas estimated that a 365-day year precessed through all the seasons twice in 7.13.0.0.0 or 1,101,600 days.

We can therefore derive a value for the Mayan estimate of the year by dividing 1,101,600 by 365, subtracting 2, and taking that number and dividing 1,101,600 by the result, which gives us an answer of 365.242036 days, which is slightly more accurate than the 365.2425 days of the Gregorian calendar.

(This apparent accuracy could, however, be a simple coincidence. The Mayas estimated that a 365-day year precessed through all the seasons *twice* in 7.13.0.0.0 days. These numbers are only accurate to 2-3 digits. Suppose the 7.13.0.0.0 days had corresponded to 2.001 cycles rather than 2 cycles of the 365-day year, would the Mayas have noticed?)

Chapter 10

The Chinese Calendar

Although the People's Republic of China uses the Gregorian calendar for civil purposes, a special Chinese calendar is used for determining festivals. Various Chinese communities around the world also use this calendar.

The beginnings of the Chinese calendar can be traced back to the 14th century BC. Legend has it that the Emperor Huangdi invented the calendar in 2637 BC.

The Chinese calendar is based on exact astronomical observations of the longitude of the sun and the phases of the moon. This means that principles of modern science have had an impact on the Chinese calendar.

I can recommend visiting Helmer Aslaksen's web site at `http://www.chinesecalendar.net` for more information about the Chinese calendar.

10.1 What does the Chinese year look like?

The Chinese calendar – like the Hebrew – is a combined solar/lunar calendar in that it strives to have its years coincide with the tropical year and its months coincide with the synodic months. It is not surprising that a few similarities exist between the Chinese and the Hebrew calendar:

- An ordinary year has 12 months, a leap year has 13 months.
- An ordinary year has 353, 354, or 355 days, a leap year has 383, 384, or 385 days.

When determining what a Chinese year looks like, one must make a number of astronomical calculations:

First, determine the dates for the new moons. Here, a new moon is the completely "black" moon (that is, when the moon is in conjunction with the sun), not the first visible crescent used in the Islamic and Hebrew calendars. The date of a new moon is the first day of a new month.

Secondly, determine the dates when the sun's longitude is a multiple of 30 degrees. (The sun's longitude is 0 at Vernal Equinox, 90 at Summer Solstice, 180 at Autumnal Equinox, and 270 at Winter Solstice.) These dates are called the *Principal Terms* and are used to determine the number of each month:

Principal Term 1 occurs when the sun's longitude is 330 degrees.
Principal Term 2 occurs when the sun's longitude is 0 degrees.
Principal Term 3 occurs when the sun's longitude is 30 degrees.
etc.
Principal Term 11 occurs when the sun's longitude is 270 degrees.
Principal Term 12 occurs when the sun's longitude is 300 degrees.

Each month carries the number of the Principal Term that occurs in that month.

In rare cases, a month may contain two Principal Terms; in this case the months numbers may have to be shifted. Principal Term 11 (Winter Solstice) must always fall in the 11th month.

All the astronomical calculations are carried out for the meridian 120 degrees east of Greenwich. This roughly corresponds to the east coast of China.

Some variations in these rules are seen in various Chinese communities.

10.2 What years are leap years?

Leap years have 13 months. To determine if a year is a leap year, calculate the number of new moons between the 11th month in one year (i.e., the month containing the Winter Solstice) and the 11th month in the following year. If there are 13 new moons from the start of the 11th month in the first year to the start of the 11th month in the second year, a leap month must be inserted.

In leap years, at least one month does not contain a Principal Term. The first such month is the leap month. It carries the same number as the previous month, with the additional note that it is the leap month.

10.3 How does one count years?

Unlike most other calendars, the Chinese calendar does not count years in an infinite sequence. Instead years have names that are repeated every 60 years.

(Historically, years used to be counted since the accession of an emperor, but this was abolished after the 1911 revolution.)

Within each 60-year cycle, each year is assigned a name consisting of two components:

The first component is a *Celestial Stem*:

1.	jia	6.	ji
2.	yi	7.	geng
3.	bing	8.	xin
4.	ding	9.	ren
5.	wu	10.	gui

These words have no English equivalent.

The second component is a *Terrestrial Branch*:

1.	zi (rat)	7.	wu (horse)
2.	chou (ox)	8.	wei (sheep)
3.	yin (tiger)	9.	shen (monkey)
4.	mao (hare, rabbit)	10.	you (rooster)
5.	chen (dragon)	11.	xu (dog)
6.	si (snake)	12.	hai (pig)

The names of the corresponding animals in the zodiac cycle of 12 animals are given in parentheses.

Each of the two components is used sequentially. Thus, the 1st year of the 60-year cycle becomes jia-zi, the 2nd year is yi-chou, the 3rd year is bing-yin, etc. When we reach the end of a component, we start from the beginning: The 10th year is gui-you, the 11th year is jia-xu (restarting the Celestial Stem), the 12th year is yi-hai, and the 13th year is bing-zi (restarting the Terrestrial Branch). Finally, the 60th year becomes gui-hai.

This way of naming years within a 60-year cycle goes back approximately 2000 years. A similar naming of days and months has fallen into disuse, but the date name is still listed in calendars.

It is customary to number the 60-year cycles since 2637 BC, when the calendar was supposedly invented. In that year the first 60-year cycle started.

10.4 What is the current year in the Chinese calendar?

The current 60-year cycle started on 2 Feb 1984. That date bears the name bing-yin in the 60-day cycle, and the first month of that first year bears the name gui-chou in the 60-month cycle.

This means that the year bing-xu, the 22nd year in the 78th cycle, will start on 29 Jan 2006.

Chapter 11

Frequently Asked Questions about this FAQ

This chapter does not answer questions about calendars. Instead it answers questions that I am often asked about this document.

11.1 Why doesn't the FAQ describe calendar X?

I am frequently asked to add a chapter describing the Japanese calendar, the Ethiopian calendar, the Hindu calendar, etc.

But I have to stop somewhere. I have discovered that the more calendars I include in the FAQ, the more difficult it becomes to ensure that the information given is correct. I want to work on the quality rather than the quantity of information in this document. It is therefore not likely that other calendars will be added in the near future.

11.2 Why doesn't the FAQ contain information X?

Obviously, I cannot include everything. So I have to prioritize. The things that are most likely to be omitted from the FAQ are:

- Information that is relevant to a single country only.
- Views that are controversial and not supported by recognized authorities.

11.3 Why don't you reply to my e-mail?

I try to reply to all the e-mail I receive. But occasionally the amount of mail I receive is so large that I have to ignore some letters. If this has caused your letter to be lost, I apologize.

But please don't let this stop you from writing to me. I enjoy receiving letters, even if I can't answer them all.

11.4 How do I know that I can trust your information?

I have tried to be accurate in everything I have described. If you are unsure about something that I write, I suggest that you try to verify the information yourself. If you come across a recognized authority that contradicts something that I've written, please let me know.

11.5 Can you recommend any good books about calendars?

This is a big question because there are so many excellent books. At this point I shall only recommend three books:

- Edward M. Reingold & Nachum Dershowitz: *Calendrical Calculations. The Millennium Edition*. Cambridge University Press 2001. ISBN 0-521-77752-6.
  `http://emr.cs.iit.edu/home/reingold/calendar-book/second-edition/index.html`

  > This book contains a lot of information about a huge number of calendars. As the title indicates, it has a strong emphasis on algorithms for calendrical calculations, so if you want to use your computer to compute calendars, this is a great book.

- Bonnie Blackburn & Leofranc Holford-Stevens: *The Oxford Companion to the Year*. Oxford University Press 1999. ISBN 0-19-214231-3.

  > A very thorough (900+ pages) book about the history of calendars. The book includes a large collections about customs related to each day of the year.

- R. W. Bauer: *Calender for Aarene fra 601 til 2200*. First published in 1868. Reprinted 1993 by Dansk Historisk Fællesråd. ISBN 87-7423-083-2.

  > Unfortunately, this book is in Danish, but if you can read the Scandinavian languages, this book will provide you with a wealth of information, despite its age. Its main strength is a huge collection of tables of various calendars. It does, however, only describe the Christian calendar.

11.6 Do you know a web site where I can find information about X?

Probably not.

Good places to start your calendar search include:

`http://www.calendarzone.com`
`http://personal.ecu.edu/mccartyr/calendar-reform.html`

Chapter 12

Date

This version 2.8 of this document was finished on

> Thursday before the fourth Sunday in Advent, the 15th day of December anno ab Incarnatione Domini MMV, indict. XIII, epacta XIX, luna XIV, anno post Margaretam Reginam Daniae natam LXV, on the feast of Saint Nino.
>
> The 14th day of Kislev, Anno Mundi 5766.
>
> The 14th day of Dhu al-Qada, Anno Hegirae 1426.
>
> The 24th day of Azar, Anno Persico 1384.
>
> The 15th day of the 11th month of the year yi-you of the 78th cycle.
>
> Julian Day 2,453,720.