EXPLANATORY SUPPLEMENT

TO

THE ASTRONOMICAL EPHEMERIS

AND

THE AMERICAN EPHEMERIS AND NAUTICAL ALMANAC

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PREFACE

The purpose of this *Explanatory Supplement* is to provide the users of *The Astronomical Ephemeris* (prior to 1960 entitled *The Nautical Almanac and Astronomical Ephemeris*) and *The American Ephemeris and Nautical Almanac* with fuller explanations of their content, derivation, and use than can conveniently be included in the publications themselves. A rigorous treatment is given of the fundamental basis of the tabulations; this is supplemented by a detailed derivation, showing how each tabulated quantity is obtained from basic data. The use of the ephemerides is also explained and illustrated, but completeness is not attempted. Auxiliary tables, lists of constants, and miscellaneous data are added, partly for convenience of use with the Ephemeris and partly for reference.

By its nature this Supplement must primarily be a reference book. However, it is hoped that certain sections will come to be regarded as full, connected, and authoritative treatments of the subjects with which they deal, and that the tables and other data will prove of general use in astronomical computing. An account of its origins and much information of a general nature about the purpose and scope of the unified Ephemeris is given in section 1, " Introduction ".

Although published in the United Kingdom, the *Explanatory Supplement* has been prepared jointly by the Nautical Almanac Office, United States Naval Observatory, under the immediate supervision of its Director, Edgar W. Woolard, and by H.M. Nautical Almanac Office, Royal Greenwich Observatory, under the immediate supervision of its Superintendent, D. H. Sadler. It has been edited by G. A. Wilkins, assisted by Miss A. W. Springett.

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times of rising and setting, using the tabulated values of right ascension and declination. The Greenwich hour angle at H^h U.T. is:

$$h = \text{apparent sidereal time at } H^h \text{ U.T.} - \alpha \text{ at } (H^h + \Delta T) \text{ E.T.}$$

The motion in α in time ΔT is about $1^s.0$ to $1^s.6$ at the present time, and can either be neglected or applied later. The resulting zenith distances are interpolated to:

$$\begin{aligned} z &= 90^\circ\ 34' - \text{horizontal parallax} + \text{semi-diameter} \\ &= 90^\circ\ 34'.0013 - 0.727554\,\pi \end{aligned}$$

where π is the horizontal parallax, though a precision of 1′ suffices to give times to 1^m in many cases. Linear interpolation is sufficient for the low latitudes, but for latitudes above 30° it is necessary to calculate three or more altitudes and to use second differences to obtain the required accuracy.

14. THE CALENDAR

A. INTRODUCTION

A calendar is a system of reckoning time over extended intervals by combining days into various periods adapted to purposes of civil life, to fixing religious observances, or to meeting scientific needs. Three of the periods used in calendars, namely days, months, and years, are based on astronomical periods that are of importance for the practical activities of daily life. Others, such as the week, are artificial.

The calendarial reckoning is according to conventional calendar years and adopted historical eras. In constructing and regulating civil calendars, and fixing ecclesiastical calendars, a number of auxiliary cycles and periods are used. The principal chronological eras and cycles are listed in *A.E.*, page 1, and are followed by the Gregorian calendar for the current year.

The complexity of calendars is due mainly to the incommensurability of the astronomical periods on which they are based. The supply of light by the Sun and Moon is governed by the solar day and the synodic month, while the return of the seasons depends on the tropical year. The length of the synodic month is 29·530589 days, and of the tropical year 365·242199 days, for the epoch 1900; the very small and somewhat uncertain secular variations in the lengths of these periods are unimportant for chronological purposes. The number of lunations in a tropical year is 12·368267 at the epoch 1900.

References

Bouchet, U. *Hémérologie.* Paris, 1868.

Ginzel, F. K. *Handbuch der mathematischen und technischen Chronologie.* Leipzig, 1906–1914. This is the most comprehensive and detailed general treatise on calendars and chronological systems; it is extensively documented, and is a reliable source of information as far as historical knowledge extended at the date of its publication. (Reprinted, 1958.)

Schram, R. *Kalendariographische und chronologische Tafeln.* Leipzig, 1908. This contains tables of the principal calendars of ancient and modern times.

Encyclopaedia Britannica. The various articles on calendars and chronology in the 9th or 11th edition collectively constitute an additional excellent source of information.

Fotheringham, J. K. *The calendar.* This scholarly article was first printed in *The Nautical Almanac* for 1931 and was reprinted (with revision in 1935) each year until 1938. Some paragraphs of this section of the Supplement have been taken directly from this article.

Annuaire du Bureau des Longitudes (Paris), 1959, pages 107–162. This contains a study of various calendars and many useful tables, some of which have been included in this section.

B. HISTORICAL CALENDARS

The many calendars of historical times were lunar in origin, the year consisting usually of twelve months of about 30 days, with arbitrary or calculated intercalation of months or days to make the length of the year conform to the solar year. The Egyptian calendar was, up to the time of Julius Caesar's reform of the Roman calendar in 46 B.C., the only civil calendar in which the length of each month and year was fixed by rule, instead of being determined by the discretion of officials or by direct observation of some astronomical event.

1. The Egyptian calendar

The Egyptian year from an extremely remote date consisted of 12 months of 30 days each, followed by 5 additional days at the end of each year. This fixed calendar year of 365 days was not adjusted to the solar year by any intercalation; the Egyptian New Year consequently gradually retrograded through a complete circuit of the tropical year in a period of approximately 1460 years known as the Sothic cycle. The calendar year was divided into three seasons of four months each, called Flood time, Seed time, and Harvest time, corresponding to the annual cycle of the rise and fall of the Nile. The relation of the calendarial seasons to the natural seasons of the solar year was determined by the heliacal rising of Sirius (whose Egyptian name was Sothis), that is by the first appearance of the star in the morning sky after conjunction with the Sun; the mean interval between consecutive heliacal risings was $365^{d}.2507$ according to Schoch.

This calendar originated from one of the variants of the earlier lunar calendar which regulated festivals in relation to the phases of the Moon, and which was eventually systematized to bring it into a fixed relation to the civil calendar.

The advantages of the fixed Egyptian calendar for astronomical calculations were recognized by the Hellenistic astronomers, and it became the standard astronomical system; it was still used by Copernicus in his lunar and planetary tables.

An attempt by Ptolemy Euergetes in 238 B.C. to introduce a sixth additional day once in four years failed, but a renewed attempt under Augustus (26–23 B.C.) was more successful. An additional day was inserted at the close of the Egyptian year 23–22 B.C. on August 29 of what we call the Julian calendar, and at the close of every fourth year afterwards, so that the reformed or Alexandrian year began on August 30 of the Julian calendar in the year preceding a Julian leap year and on August 29 in all other years. The effect of this reform was to keep each Egyptian month fixed to the place in the natural year which it happened to occupy under the old calendar in the years 26–22 B.C. But the old calendar was not easily suppressed, and we find the two used side by side until A.D. 238 at least. The old calendar was probably the more popular, and was preferred by astronomers and astrologers. Ptolemy always used it, except in his treatise on annual phenomena, for which the new calendar was obviously more convenient. Theon in the fourth century A.D., though mentioning the old calendar, habitually used the new.

The old Egyptian calendar was adopted by the Persians, perhaps about 500 B.C., in a form that cannot now be accurately restored, and survives in a slightly modified form in the Armenian calendar, the three first months of the old Egyptian year corresponding exactly with the three last months of the Armenian year. These are followed in the Armenian calendar by the five additional days, so that for the remainder of the year the Armenian months began five days later than those of the old Egyptian calendar. The Alexandrian calendar is still the calendar of Ethiopia and of the Coptic church, and is used for agricultural purposes in Egypt and other parts of northern Africa.

References

Parker, R. A. The calendars of ancient Egypt. Oriental Institute of the University of Chicago, *Studies in Ancient Oriental Civilization*, no. 26, University of Chicago Press, 1950.

van der Waerden, B. L. Tables for the Egyptian and Alexandrian calendar. *Isis*, 47, 387–390, 1956. For conversions to the Julian calendar.

Schoch, K. *Die Länge der Sothisperiode beträgt* 1456 *Jahre*. Berlin-Steglitz (by the author), 1928.

2. The Babylonian calendar

The Babylonian year consisted of 12 lunar months, each fixed by actual observation of the first appearance of the lunar crescent in the evening sky, with the intercalation of an additional month when necessary to keep the calendar year in a definite relation to the seasons. The year began in the spring with the month Nisannu.

Up to about 480 B.C., the intercalations show no regularity whatever; but attempts appear to have been made to formulate fixed rules, and at some time very close to 380 B.C. a regular cycle of 7 intercalations at fixed intervals during each 19 years came to be used. The 19-year cycle had been introduced by Meton at Athens about 50 years earlier, but whether the Babylonians obtained it from the Greeks or discovered it independently is not known. This cycle equates 19 years to 235 lunations; it still survives in the modern Jewish calendar, with the same value for the length of the mean synodic month as in the Babylonian calendar.

The conversion of dates in the Babylonian calendar to their exact equivalents in the Julian proleptic calendar is in general very difficult, and often uncertain or impossible. The ancient calendars that were regulated either arbitrarily or by observation of the lunar crescent cannot be completely restored with certainty and correlated with other calendars unless historical records are extant that give a sufficiently complete continuous record of the length of every month and attest to all the intercalary months.

References

Parker, R. A., and Dubberstein, W. H. Babylonian chronology 626 B.C.–A.D. 75. *Brown University Studies*, 19, 1956. This is on the restoration and correlation of the Babylonian calendar; it is a revision of the earlier article in *Studies in Ancient Oriental Civilization*, no. 24, University of Chicago Press.

3. Greek calendars

Early Greek calendarial reckoning was rather chaotic. Each community had a separate calendar. All Greek calendars were lunar until the Roman period, and kept roughly in a fixed relation to the seasons by the intercalation of a thirteenth month when required; but the intercalations were determined by local public authorities, and were different in different calendars in addition to being irregular. There was also great variety in the season when the year began in different calendars.

From the sixth century B.C. onwards, a number of cycles were successively devised by the Greek astronomers as a basis for regulating the lunar calendar by fixed rules instead of by arbitrary intercalation. Among these, the Metonic and Callippic cycles came to be used by astronomers for dating observations, and appear to have been used over a period of several centuries extending into the Middle Ages to establish the dates of new moon for purposes of religious calendars. In the Metonic cycle, 19 years were equated to 235 months and to 6940 days; in the Callippic cycle, 76 years were equated to 940 lunations and to 27759 days, one day less than four Metonic cycles.

4. The Julian calendar

The Julian calendar was established in the Roman Empire by Julius Caesar in 46 B.C., by revising the ancient local calendar of the city of Rome, with the advice of the Alexandrian astronomer Sosigenes. Reaching its final form about A.D. 8, it was widely spread by the growth of the Empire; it remained in general use in the West during later centuries, until in 1582 it was further modified into the Gregorian calendar which has now come into almost worldwide use for civil purposes.

The Roman calendar was originally a lunar calendar, with arbitrary intercalation of months by the pontifical authorities. Under the pontificate of Julius Caesar, intercalation was neglected with such frequency that the calendar became about two months out of step with the solar year. To rectify the discrepancy, Caesar inserted intercalations into the year 46 B.C. that increased its length to 445 days, and instituted his reformed calendar beginning with 45 B.C.

In the Julian calendar, a mean length of 365·25 days for the year is adopted. The calendar year is adjusted to this mean value by inserting an intercalary day every fourth year; the intercalary year has 366 days, and each of the other three years has 365 days.

The year 45 B.C. was a Julian intercalary or leap year; but because of misunderstanding and confusion during the period following the adoption of the revised calendar, the intercalations were incorrectly made until the error was rectified in 8 B.C. by Augustus, who omitted further intercalations until A.D. 8. The adjustments actually made before the Augustan reform cannot be determined with certainty, and are ignored in the following sub-sections, but after A.D. 8 the Julian calendar was used without further change until the Gregorian reform in 1582.

The Christian era for the chronological reckoning of the years was first used by the Roman abbot Dionysius Exiguus, to designate the years in a table for determining the date of Easter that he prepared as a continuation of a previous table in which the years had been designated according to the era of Diocletian. In extending the table, he adopted 248 Diocletian era = A.D. 532. The year in which he prepared the table was six years before this, or A.D. 525; but how he determined the correspondence is unknown. His method for designating the years was adopted by others, and through increasing use during the next few centuries it became established in western Europe as a chronological era.

In this system, the Christian era begins with year A.D. 1; the immediately preceding year is designated 1 B.C. There is no year 0 in the chronological reckoning. For astronomical purposes, the year immediately preceding A.D. 1 is designated 0; the other years B.C. are denoted by negative numbers, each numerically one less than the designation in the historical reckoning. In the astronomical system the year preceding 0 is -1, and corresponds to 2 B.C. The year 0 was a leap year.

The first century of the Christian era ended with December 31 of A.D. 100, when the first one hundred years A.D. 1 to A.D. 100, inclusive, had been completed. Likewise, the nineteenth century ended with 1900 December 31; the twentieth century began with 1901 January 1, and the first half of the century ended with 1950 December 31. Considerable public controversy always attends these occasions.

The Christian era was adopted at different times in different countries with a variety of dates for the beginning of the year. The most common initial dates were December 25, January 1, March 1, and March 25. These different reckonings of the year were known as *styles*. Traditionally in the ancient Roman calendar, March had been the first month of the year, as reflected in the numerical names which still survive for the months September to December and in the position of the intercalary day at the end of February; but in 153 B.C., with a change in the date of entry into office of the consuls and other magistrates to January 1, this became the first day of the official year and came to be widely adopted during later centuries in western Europe as the calendar New Year. In Italy, however, down to the eighteenth century the years of the Christian era began in the Venetian style on March 1, in the Pisan style on the preceding March 25, and in the Florentine style on the following March 25, while at Rome different styles were used for different purposes. In England the Nativity style beginning on December 25 was superseded in the fourteenth century by the Annunciation style beginning on March 25, but the Circumcision style beginning on January 1 was substituted in 1752 by the Act that introduced the Gregorian calendar. In Scotland the year had begun officially on January 1 since 1600. The names old style and new style were, however, used to distinguish not the different dates for the beginning of the year, but the Julian and Gregorian calendars, each of which has been used with different initial dates.

The intercalary day was always inserted in every February which, if the years began with January 1, would fall in a year with a numerical designation divisible by 4. Consequently, when the actual beginning of the year was in March, the years divisible by 4 were not the leap years.

Preceding the Christian era, the rule that when the New Year is January 1 the years divisible by 4 are leap years is valid only if the *astronomical* designations of the years by negative numbers are used.

References

Barton, S. G. It's a date. *Scientific Monthly*, **65**, 408–414, 1947.

Barton, S. G. The Quaker calendar. *Proc. Amer. Phil. Soc.*, 93, 32–39, 1949.

C. THE GREGORIAN CALENDAR

The Gregorian calendar was instituted in 1582 by Pope Gregory XIII, primarily as a basis for regulating Easter and the ecclesiastical calendar. It is a solar calendar, distinguished principally by the system of intercalation adopted for keeping the calendar year in adjustment with the tropical year, and constructed by modifying the Julian calendar. The mean Julian calendar year of 365·25 days exceeds the length of the tropical year by about $11^m 14^s$. The continual accumulation of this excess amounts to about 3 days every 400 years, and causes a gradual progressive change in the calendar dates of the seasons. This defect in the Julian calendar had produced a very noticeable effect on the date of Easter. Since Easter was the Christian continuation of the Jewish Passover, the date was fixed by rules that were intended to keep it near the vernal equinox, because the Passover was observed on 14 Nisan, and in the ancient Jewish calendar the beginning of this month was determined by observation of the lunar crescent nearest the vernal equinox. In practice, the date of Easter was determined from tables in which the lunar months were based on the Metonic cycle and March 21 was adopted as a fixed date for the equinox. Consequently, as the actual vernal equinox gradually occurred earlier in the calendar, the date of Easter became progressively later relative to the seasons; by the sixteenth century, the equinox had fallen back to about March 11, and Easter was tending nearer and nearer toward the summer.

The Gregorian reform of the Julian calendar consisted of:

(i) omitting 10 days from the calendar reckoning, the day next after 1582 October 4 being designated 1582 October 15, for the purpose of restoring the date of the actual vernal equinox to March 21;

(ii) adopting a different rule for leap year, by omitting the intercalary day in

centurial years that are not divisible by 400, such as 1700, 1800, 1900, and 2100, in order to correct the error of the Julian calendar where an intercalary day is inserted every four years;

(iii) fixing rules for determining the date of Easter in the revised calendar.

The week was not modified in any way; special provision was made that the sequence of the days of the week was not broken.

The mean length of the Gregorian calendar year is 365·2425 days. At the completion of a 400-year calendar cycle, the cumulative discrepancy with the tropical year is only a few hours.

The authoritative treatise on the principles of this calendar and the associated ecclesiastical calendar is the book by Christoph Clavius, *Explicatio Romani Calendarii a Gregorio XIII P.M. restituti* (Rome, 1603), which is also included in Volume V of the collected works of Clavius published in 1612.

The Gregorian calendar was at once officially adopted for civil and religious purposes in Roman Catholic countries. During the following centuries, it came into almost universal use throughout the West, although with some diversity between civil and ecclesiastical practice; and it is widely used for some civil purposes in countries which have official native calendars.

The dates of the official adoption of the Gregorian calendar differed from country to country. In some regions, this calendar came into use gradually without official action. The introduction by legal action was in many cases not completely accepted among the people for a long period, and quite often did not affect ecclesiastical customs; for details, especially of the diverse church calendars, the references given at the end of this sub-section may be consulted, particularly Lange (**7**). In the Gregorian calendar, Easter has not in all cases been fixed strictly according to the Gregorian rules; in particular, it has occasionally been determined astronomically, e.g., by the German Protestants from 1700 to 1776, in Sweden from 1740 to 1844, and by the Eastern Orthodox Churches since 1923.

At a meeting of a Congress of the Orthodox Oriental Churches held in Constantinople in May, 1923, the Julian calendar was replaced by a modified Gregorian calendar in which century years are leap years only when division of the century number by 9 leaves a remainder of either 2 or 6, and Easter is determined by the astronomical Moon for the meridian of Jerusalem; see Milankovitch (**8**). The change was such that 1923 October 1, Julian calendar, became 1923 October 14 in the new calendar.

In the following list the dates of the official adoption of the Gregorian calendar are indicated in the form of double dates that give the corresponding Julian/Gregorian dates for the first day on which the Gregorian calendar was used. The authorities that were consulted are referred to by the numbers, in bold type, assigned to them in the list of references at the end of this sub-section. References **4** and **7** are considered to be the most reliable, while **6** and **12** should be reliable for the native countries of their authors; **10** is not documented.

List of dates of adoption of the Gregorian calendar

Alaska

1867 October 18, when Alaska was transferred to the United States under treaty of purchase from Russia, where the Julian calendar was still in use.

The Julian calendar dates had been in accordance with the reckoning to the west of the international date line. A further change was therefore made to conform to the reckoning east of the date line, and consequently the date was advanced by only 11 days instead of the 12 days by which the Gregorian calendar was then in advance of the Julian calendar.

Albania

1912 December, for civil purposes (Lange, 7).

American Colonies

1752 September 3/14, at the same time as in Great Britain.

Austria. See German States.

Belgium

Different sources disagree:

4 1582 December 22/1583 January 1 in Flanders, Brabant, Hainaut, and other southern provinces; 1583 February 11/21 in Liege Bishopric.

10 1582 December 15/25 in Flanders, Hainaut, Luxembourg, and other southern provinces.

3 1583 in Flanders.

Bulgaria

Different sources disagree:

3 1915

7 1916 April 1, for civil purposes. Double dating had already been in use for some time, but was excluded by the law introducing the Gregorian calendar.

Chinese Republic

Different statements are given in different sources:

11 1912 January 1, by Sün Yat Sen.

6 1912; but during 1912–1928, both the Gregorian date and the Chinese calendar date were carried on official documents.

12 1929 January 1.

Czechoslovakia. See German States.

Denmark

1700 February 19/March 1 (Ginzel, 4). Norway was then under Danish rule.

Egypt

1875, by ordinance of Ismail Pasha, for civil purposes (Lange, 7).

Esthonia

1918 January (Lange, 7).

Finland. See Sweden.

France. See also German States.

1582 December 10/20 in France and Lorraine, by edict of Henry III (Ginzel, 4).

German States, listed according to the countries within which they now lie:

		Source
Austria		
Brixen	1583 October 6/16	10
Carinthia	1583 December 15/25	4
Salzburg	1583 October 6/16	10
Styria	1583 December 15/25	4, 10
Tyrol	1583 October 6/16	4
Czechoslovakia		
Bohemia	1584 January 7/17	4, 10
Moravia	1584 January 7/17	4
France		
Alsace	after Peace of Munster (1648)	4
Strassburg (city of)	1682 February 6/16	4, 10
Strassburg (bishopric of)	1583 November 12/22	10
" " "	1583 November 17/27	4

		Source
Germany		
Aachen	1583 November 4/14	4
Augsburg	1583 February 14/24	4
Augsburg (bishopric of)	1583 February 14/24	10
Baden (marquisate of)	1583 November 17/27	4
Bavaria	1583 October 6/16	10
Bavarian bishoprics	1583 October 6/16	4
Cologne (city of)	1583 November 4/14	4, 10
Eichstadt	1583 October 6/16	10
Freising	1583 October 6/16	10
Hildesheim (bishopric of)	1631 March 16/26	4
Julich	1583 November 3/13	4
Lausitz	1584 January 7/17	10
Mainz (archbishopric of)	1583 November 12/22	4, 10
Munster (city and county of)	1583 November 17/27	4
Neuburg Palatinate	1615 December 14/24	4, 10
Osnabruck (city of)	1624	4
Paderborn (bishopric of)	1585 June 17/27	4, 10
Prussia (duchy of)	1610 August 23/September 2	4, 10
Regensburg	1583 October 6/16	10
Silesia	1584 January 13/23	4, 10
Trier (archbishopric of)	1583 October 5/15	4, 10
Westphalia (duchy of)	1584 July 2/12	4, 10
Wurzburg (bishopric of)	1583 November 5/15	4, 10
Kaiser and Parliament	1584 January 7/17	4
Protestant Germany	1700 February 19/March 1	10
Under Frederick the Great, Gregorian reckoning was adopted in 1775 under the name of " improved calendar ".		4
Switzerland		
Appenzell (Protestant half)	see below	
Basel, Bern, and Biel	1701 January 1/12*	4
Fribourg	1584 January 12/22	4
Geneva	1701 January 1/12*	4
Graubunden	see below	
Lucerne	1584 January 12/22	4
Mulhausen	1701 January 1/12*	4
Neuchatel	1701 January 1/12	10
Prattigau (" Ten Districts ")	1812	4
Sargans	1701 January 1/12	4
Schaffhausen	1701 January 1/12*	4
Schwyz	1584 January 12/22	4
Solothurn	1584 January 12/22	4
Thurgau	1701 January 1/12	10
Uri	1584 January 12/22	4
Valais	see below	
Zug	1584 January 12/22	4
Zurich	1701 January 1/12*	4
Federal congress	1583 November 10	4
Appenzell (Protestant half): separated from the Roman Catholic half in 1597 and remained on Julian calendar.		4
Graubunden: Gregorian calendar adopted at first only by Roman Catholic districts in upper Rhine valley. The others retained Julian calendar until into 18th century.		4
Valais: 1622, except Sitten, Siders, Leuk, Raron, Visp, Brieg and Goms which changed in 1656.		4

* Improved Weigel calendar.

Great Britain and Dominions

1752 September 3/14, by Act of Parliament passed 1751 March 18; at the same time, the beginning of the year was changed from March 25 to January 1, commencing with the year 1752.

Greece

See Milankovitch (8); a slightly modified form of the Gregorian calendar was introduced 1924 March 10/23.

Hungary

1587 October 22/November 1. (Schram, 10).

Italy

1582 October 5/15 (Ginzel, 4).

Japan

1873 January 1 (van Wijk, 12).

Jugoslavia

1919 (Fotheringham, 3, but see also Milankovitch, 8).

Latvia

The Gregorian calendar gradually came into use for civil purposes during the German occupation 1915–1918. (Lange, 7).

Lithuania

1915, by the Catholic Church, which represented three quarters of the population (Lange, 7).

Luxembourg

1582 December 15/25 (Schram, 10).

Netherlands

In the Catholic States, 1582–1583; in the Protestant States, 1700–1701; but different sources disagree on the exact dates. For minute details, see van Wijk, 12.

Norway. See Denmark.

Poland

1582 October 5/15 (Schram, 10). In the Russian part of Poland, the Gregorian calendar was introduced by the German occupation troops 1915 March 21 (Lange, 7).

Portugal

1582 October 5/15 (Ginzel, 4).

Roumania

1919 April 1/14 (*L'Astronomie: Bull. Soc. Astr. de France*, 33, 529, 1919).

Spain

1582 October 5/15 (Ginzel, 4).

Sweden

1753 February 18/March 1 (Schram, 10; Lange, 7). Finland was then a part of Sweden.

Switzerland. See German States.

Turkey

1927 January 1 (*Astr. Jahresber.*, 29, 48, 1927).

U.S.S.R.

1918 February 1/14 for civil purposes (Lange, 7; *Observatory*, 41, 146, 1918).

Equivalent dates in the Julian and the Gregorian calendars are frequently required. Both calendars were widely used for a long period after the Gregorian calendar was first introduced; for special purposes the Julian calendar is still of service, and occasionally the Gregorian proleptic calendar is used for dates before 1582. The 10 days difference between the two calendars at the time of the Gregorian reform increases by one at the bissextile, or intercalary, day in each centurial year after 1582 that is not divisible by 400; the difference is subtracted from a Gregorian date, added to a Julian date. Before 1582, the difference decreases. The year 0 is a leap year in the Gregorian proleptic calendar.

IN THE JULIAN AND GREGORIAN CALENDARS

Year (astronomical)	Date Julian	Diff. (days)	Date Gregorian	Year (astronomical)	Date Julian	Diff. (days)	Date Gregorian
			Astronomical years −500 to +300				
−500	March 5		February 28	−100	March 2		February 28
−500	March 6	5	March 1	−100	March 3	2	March 1
−300	March 3		February 27	+100	February 29		February 27
−300	March 4		February 28	+100	March 1		February 28
−300	March 5	4	March 1	+100	March 2	1	March 1
−200	March 2		February 27	+200	February 28		February 27
−200	March 3		February 28	+200	February 29		February 28
−200	March 4	3	March 1	+200	March 1	0	March 1
−100	March 1		February 27	+300	February 28		February 28
			A.D. 300 March 1 to 1582 October 4/14				
300	February 29		March 1	1000	February 29		March 6
300	March 1	1	March 2	1000	March 1	6	March 7
500	February 28		March 1	1100	February 28		March 6
500	February 29		March 2	1100	February 29		March 7
500	March 1	2	March 3	1100	March 1	7	March 8
600	February 28		March 2	1300	February 28		March 7
600	February 29		March 3	1300	February 29		March 8
600	March 1	3	March 4	1300	March 1	8	March 9
700	February 28		March 3	1400	February 28		March 8
700	February 29		March 4	1400	February 29		March 9
700	March 1	4	March 5	1400	March 1	9	March 10
900	February 28		March 4	1500	February 28		March 9
900	February 29		March 5	1500	February 29		March 10
900	March 1	5	March 6	1500	March 1	10	March 11
1000	February 28		March 5	1582	October 4		October 14
			1582 October 5/15 onwards				
1582	October 5	10	October 15	1800	February 29		March 12
1582	October 6	10	October 16	1800	March 1	12	March 13
1700	February 18		February 28	1900	February 16		February 28
	February 19	10	March 1		February 17	12	March 1
	February 28		March 10		February 28		March 12
1700	February 29		March 11	1900	February 29		March 13
1700	March 1	11	March 12	1900	March 1	13	March 14
1800	February 17		February 28	2100	February 15		February 28
	February 18	11	March 1		February 16	13	March 1
1800	February 28		March 11	2100	February 28		March 13

The differences are constant between each pair of dates given in the table. The sign of the difference can be obtained by inspection.

Except in the centurial years that are given above, the leap years (astronomical year divisible by 4) are common to both calendars.

Equivalent dates in the Julian and Gregorian calendars, extending backwards to the year −500 (= 501 B.C.) are listed in table 14.1; it is clear that for the years before A.D. 200 the difference must be added to the Gregorian date, or subtracted from the Julian date. Care should be taken to assign to February the proper number of days in each calendar; the change points (especially after 1582) are, however, clearly indicated.

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D. THE WEEK

The week was not originally an integral part of any calendar; in its present form, it gradually became established in the Roman calendar during the one or two centuries preceding the Christian era. The Mosaic Law enjoining an abstinence from work on every seventh day had established the 7-day period as a Jewish measure of time, and this Jewish week later passed into the Christian Church. Meanwhile, shortly before the Christian era, an astrological practice had arisen of attaching the names of the seven "planets", the term at that time including the Sun and Moon, in cyclic succession to successive days, in the order in which the planets were supposed to rule the days. The planetary designations for the days rapidly acquired a widespread popularity, and became the predominant usage throughout the Roman Empire. The coincidence in the number of days in this astrological cycle with the number of days in the entirely independent Jewish week led to the gradual establishment of the planetary week without official recognition, either civil or ecclesiastical.

Since first becoming established, the cyclic succession of the days of the week has not been altered, and no breaks in the sequence have occurred. In the Teutonic languages, the names of the Roman deities Mars, Mercury, Jupiter, and Venus have been replaced by their counterparts Tiu, Woden, Thor, and Freya.

The week, therefore, is a non-astronomical element of the calendar. The reckoning of time by weekly cycles in continuous succession is independent of the essentially astronomical reckoning by days, months, and years which is the principal basis of the calendar. The consequent complexity of the relation between the two reckonings causes difficulty in determining readily the day of the week that corresponds to any given calendar date. However, a table of dominical letters (see sub-section E) is essentially a calendar for the entire period covered by the table, and is easily used explicitly for this purpose with the aid of a simple auxiliary table (such as table 14.2). Nomograms have also been constructed; see, e.g., d'Ocagne, *Traité de Nomographie*, Paris, 1899; A. Saldaña, *Urania*, **38**, 20, 1953.

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Table 14.2. Perpetual calendar

This calendar gives the days of the week corresponding to the days of any month in the Julian or Gregorian calendars once the dominical letter for the year is known. [The dominical letter may be taken from table 14.5 (Julian) or table 14.9 (Gregorian); in leap years the first letter is to be used for January and February, the second for the remainder of the year.]

The column in which the dominical letter for the year is in the same line as the month for which the calendar is required gives the days of the week that correspond to the days of the month given at the left.

Month	Dominical Letter						
January, October	A	B	C	D	E	F	G
February, March, November	D	E	F	G	A	B	C
April, July	G	A	B	C	D	E	F
May	B	C	D	E	F	G	A
June	E	F	G	A	B	C	D
August	C	D	E	F	G	A	B
September, December	F	G	A	B	C	D	E

Day of Month					Day of Week						
1	8	15	22	29	Sun.	Sat.	Fri.	Thur.	Wed.	Tues.	Mon.
2	9	16	23	30	Mon.	Sun.	Sat.	Fri.	Thur.	Wed.	Tues.
3	10	17	24	31	Tues.	Mon.	Sun.	Sat.	Fri.	Thur.	Wed.
4	11	18	25		Wed.	Tues.	Mon.	Sun.	Sat.	Fri.	Thur.
5	12	19	26		Thur.	Wed.	Tues.	Mon.	Sun.	Sat.	Fri.
6	13	20	27		Fri.	Thur.	Wed.	Tues.	Mon.	Sun.	Sat.
7	14	21	28		Sat.	Fri.	Thur.	Wed.	Tues.	Mon.	Sun.