THE DIAL

Its background, history and use
by
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in Old Court Queens' College Cambridge

The Dial in Old Court
Queens' College

Introduction

The principle of the sundial was known to the Chinese as early as 2500 B.C. and sundials were widely used by the Greeks and Romans. In A.D. 606 the Pope is said to have ordered that sundials be placed on churches and this was probably the beginning of the long association of churches with sundials and clocks. The earliest known British dials originated in Anglo-Saxon times and are to be found on some ancient churches. A fine example dating from about A.D. 1060 exists in Kirkdale, Yorkshire. As late as the nineteenth century some people carried pocket sundials.

Sundials rely on the casting by the sun of a shadow, of a simple rod or other structure called the style (which projects from the surface), on to a calibrated background. The angle of the style to the horizontal must be the same as the latitude in which the dial is set up. The latitude of Cambridge is 52° 10′ and so the angle the style of Queens' dial makes with the wall surface is (90°–52° 10′) i.e. 37° 50′.

Dials in the College

There have been at least four (five, if the elaborated repainting of the 1642 dial in 1733 is regarded as a new dial) dials in the College at different times. The first known dial is said to have been erected around 1538 on the then bell-tower in Old Court and it is suggested that remnants of it can be seen in the Loggan print of 1685. In the same print of the College, Loggan also clearly showed, in what was then the Fellows' bowling green, a fine example of a garden sundial but all traces of this have long since disappeared. A third dial was at one time in Walnut Tree Court on the north wall which was eventually demolished to make way for the present Chapel.

The existing dial is now world-famous as an example of sundial art and is also a moondial. The 1685 Loggan print shows a dial in the same position and it probably first appeared in 1642. The Bursar's accounts for that year contain the following entry:

For stone and worke about y^e chappell diall ...	1	14	0
For giult for y^e diall	0	4	6
To y^e painter for diall	0	5	0
For y^e cock of y^e diall	0	18	0
For oyle and white lead and hire of haire cloths	0	6	0

The first item was the cost of providing a flat stone surface on which to paint. No doubt the painting was renewed several times but the repainting in 1733, probably a more elaborate version of the original, seems to have excited particular admiration. William Cole, a fellow of King's College at that time, wrote:

> Over y^{e} W. end [of the Chapel] is a small Tower and agst y^{e} side of it w^{ch} fronts y^{e} Court is lately placed a very handsome Clock, 1733, and directly under it on y^{e} Wall of y^{e} Chapel and over y^{e} Door w^{ch} leads to it is also lately painted a very elegant SunDial with all y^{e} signs. This is no small ornam^{t} to y^{e} Court to enliven it.

As in the case of the wooden bridge, the design has often been attributed erroneously to Sir Isaac Newton (*Newton's Dial*) but Newton died in 1727 and there is no evidence to suggest he was in any way concerned with either. In this century alone, repainting has taken place five times, the latest in 1971. The painted design of the dial as seen today is slightly displaced to the left of where it should be in relation to the style. This introduces other small reading errors additional to those mentioned below.

In the eighteenth and nineteenth centuries, the dial would have been used mainly to check the clock above. This was common practice at that time. Queens' dial, however, possesses a special feature. There is a small gilt painted ball on the style which makes it possible to extend the use of the dial to make a number of astronomical deductions.

Measurement of Time

For everyday use the measurement of time is based on the rotation of the earth. The interval between successive apparent transits of the sun across the meridian at any given place (i.e. across an imaginary line drawn through the north and south poles and that place) is known as the *apparent solar day*—apparent because the shadow of the style on the face of the dial depends on the position of the sun as it appears in the sky. However, because the earth's orbit round the sun is not a true circle but an ellipse and its axis of rotation is not perpendicular to the plane of its orbit, the daily interval is variable and the apparent solar day varies in length by as much as thirty-one minutes at the extremes in any one year. For practical purposes, therefore, the standard of time became the *mean solar day* which is the *average* of the intervals observed at any particular place during a whole year. Thus to obtain mean solar time a correction factor must be applied to the apparent solar time, which is that measured by a sundial. The sun obviously rises and sets at different times in different places and for centuries time was very much a local matter but the development of the railways finally forced the introduction of a standard time for the whole country. In 1880 the *mean solar day observed at Greenwich* (Greenwich Mean Time) was adopted as standard. A sundial reading at any place can always be converted to G.M.T. if the difference between the reading and G.M.T. on the same day is known. For Cambridge, the necessary correction factor (designated the equation of time by astronomers and usually denoted by E) as it varies throughout the year can be obtained effectively from the table on page 3.

In 1884 it was also agreed internationally that the meridian at Greenwich should be the zero meridian of longitude from which the longitudes of all other places are measured. At the same time the world was divided into twenty-four zones of 15° of longitude (equivalent to one hour of time since the earth turns 360° in twenty-four hours). Small countries like Britain fall within one 15° zone and thus have one standard time. Larger countries cover a number of zones and their time varies by one hour from zone to zone.

Reading the Dial

(1) To determine Time by Day

In the outer blue border, the hours are distinctly marked by Roman numerals in gilt. Immediately within this border, the intervals between the hours are subdivided into quarter hours by small black markings. The apparent solar time is obtained by estimating the position of the shadow of the style in relation to the quarter-hour divisions concerned. A rough estimate is quite adequate for it is difficult to ensure that the quarter-hour divisions are accurately marked.

In any event the time will not be the same as the Greenwich Mean Time shown by the clock above. The dial reading must be adjusted by applying the appropriate correction factor (E) from the table which shows the difference, to the nearest minute between apparent time and the mean solar day at Greenwich as it varies throughout the year.

As an example, if on 10th June the shadow of the style is estimated to fall at a point 4/15ths of the distance between the second and third quarter-hour marks dividing the hours of XI and XII, the apparent time is 11.34 a.m. From the table E is – 1 minute and so the Greenwich Mean Time is 11.33 a.m. As British Summer Time is observed in June, the clock above would show 12.33 p.m.

G.M.T. Correction Factor (Equation of Time) in minutes

Date		E	Date		E	Date		E	Date		E
Jan.	2	+ 4	April	1	+ 4	Aug.	17	+ 4	Nov.	11	– 16
Jan.	4	+ 5	April	5	+ 3	Aug.	22	+ 3	Nov.	17	– 15
Jan.	7	+ 6	April	8	+ 2	Aug.	26	+ 2	Nov.	22	– 14
Jan.	9	+ 7	April	12	+ 1	Aug.	29	+ 1	Nov.	25	– 13
Jan.	11	+ 8	April	15	0	Sept.	1	0	Nov.	29	– 12
Jan.	14	+ 9	April	20	– 1	Sept.	5	– 1	Dec.	1	– 11
Jan.	17	+ 10	April	25	– 2	Sept.	8	– 2	Dec.	4	– 10
Jan.	20	+ 11	May	2	– 3	Sept.	11	– 3	Dec.	6	– 9
Jan.	24	+ 12	May	15	– 4	Sept.	13	– 4	Dec.	9	– 8
Jan.	28	+ 13	May	28	– 3	Sept.	16	– 5	Dec.	11	– 7
Feb.	3	+ 14	June	4	– 2	Sept.	19	– 6	Dec.	13	– 6
Feb.	20	+ 14	June	10	– 1	Sept.	22	– 7	Dec.	15	– 5
Feb.	27	+ 13	June	14	0	Sept.	25	– 8	Dec.	17	– 4
Mar.	1	+ 12	June	20	+ 1	Sept.	28	– 9	Dec.	19	– 3
Mar.	8	+ 11	June	24	+ 2	Oct.	1	– 10	Dec.	21	– 2
Mar.	12	+ 10	June	29	+ 3	Oct.	4	– 11	Dec.	23	– 1
Mar.	16	+ 9	July	4	+ 4	Oct.	7	– 12	Dec.	25	0
Mar.	19	+ 8	July	10	+ 5	Oct.	11	– 13	Dec.	27	+ 1
Mar.	23	+ 7	July	19	+ 6	Oct.	15	– 14	Dec.	29	+ 2
Mar.	26	+ 6	Aug.	4	+ 6	Oct.	20	– 15	Dec.	31	+ 3
Mar.	29	+ 5	Aug.	12	+ 5	Oct.	27	– 16			

These values of E can be adopted for Cambridge since the City is near the Greenwich meridian. The slight adjustment for difference in longitude can be ignored.

(2) **To determine Time by Moonlight**

If the angular position of the moon relative to the sun is known—the *hour angle*—a sundial can also be used to tell the time by moonlight, provided this is strong enough to cast a shadow. As its title implies this angle is not measured in degrees but in hours and minutes (one hour is 15° being one twenty-fourth of a complete revolution). The apparent time is obtained by the simple addition of the hour angle to the time shown by the shadow of the style cast on the dial. G.M.T. can be deduced by the application of the appropriate correction factor from the table.

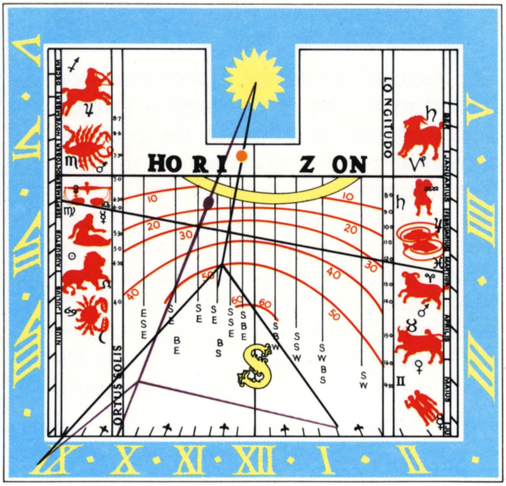

Figure 1

The set of figures below Queens' dial confirms its intended additional use as a moondial, for these are the hour angles throughout a lunar cycle. It is compiled on the assumption that the interval between one new moon and the next is exactly thirty days and that full moon occurs on the fifteenth day. In fact the lunar period is also variable due to the irregularity of the moon's movement and so no great degree of accuracy can be achieved.

On the night of 26th February 1948, at about 11 p.m. the moon was casting a shadow that gave the reading 9.35 p.m. on the outer scale. There was a full moon on Tuesday, 24th February at 5.16 p.m. so that the moon was about 15 + 2¼ days old. Its hour angle when seventeen days old (from the set of figures) was 1.36, and allowing twelve minutes for the quarter day, the hour angle at the time of observation was 1.48. The correction factor based on G.M.T. on 26th February was + 13 minutes, so that the G.M.T. was 9.35 + 1.48 + 0.13 = 11.36 p.m. In fact the clock showed 11.50. With so many varying factors involved you may well feel satisfied that the disparity of fourteen minutes is not greater.

(3) **To determine the Azimuth or Bearing of the Sun**

At the lower end of the set of vertical black lines on the dial are letters which refer to the points of the compass (e.g. S.W.—south-west, S.W.B.S.—south-west by south). The shadow of the small ball on a line or between two lines gives respectively the bearing of the sun direct or by estimation based on its position in relation to the two compass points concerned. Here in Figure 1 the bearing on 21 October 1987 at 9.45 a.m. local apparent time was between south-east and south-east by south.

(4) **To determine the Altitude of the Sun**

The altitude of the sun is its angular height above the horizon. This is given by the relative position of the ball's shadow within the red curves on the face of the dial. In Figure 1 the centre of the shadow is about 4/5ths of the distance between the 20 curve and the 10 curve. The sun was therefore approximately 18° above the horizon at 9.45 a.m. local apparent time on 21 October 1987.

(5) **To determine the Sign of the Zodiac in which the Sun lies**

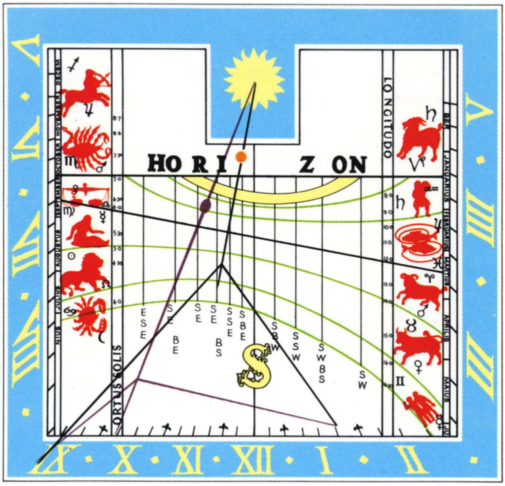

Figure 2

The ancients' knowledge of astronomy was limited to a band of the heavens through which passed the paths of the principal planets and of the moon and of the sun. The constellations (groups of stars) within this band were often named after animals and so the band became known as the Zodiac [Greek *zōdion*—sculptured figure of an animal]. It was divided into twelve equal parts and each part termed a *Sign of the Zodiac* and named after the constellation in it. The names are also associated with the seasons and with mythology.

The sun passes into each successive sign of the zodiac around the 21st of the relevant month. Following ancient custom, the cycle begins with the arrival of spring when the sun crosses the equator from the south to north to enter the Ram. The other signs follow in the order:

The Ram, the Bull, the Heavenly Twins,
And next the Crab the Lion shines,
The Virgin and the Scales,
The Scorpion, Archer and the Goat,
The Man that bears the Watering Pot,
And Fish with glittering scales.

(Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces.)

However, the historic correlation of the signs with their parent constellations has been gradually lost over the years. The earth's axis of spin is subject to a cyclic variation (*precession*) which in turn changes the position of the equator relative to the stars. Since the signs are invariably defined by reference to the *first point of Aries* when the sun crosses the equator in March each year, this movement of the equator also moves the signs relative to the constellations. The signs now lie to the west of the positions they had in ancient times.

The rate of change of the position of the earth's spin axis is very small (each cycle takes about 26,000 years to complete) but the cumulative effect becomes significant. Each sign of the zodiac has now moved back about 30° or one division so that, for example zodiacal Aries lies in the constellation of Pisces. The initial correspondence of signs and constellations around 200 B.C. will be restored in 25800 A.D. or thereabouts.

The sign of the zodiac can be read off the dial by observing the position of the shadow of the ball in the green curves. The straight black line between the Scales and the Virgin on the left and between the Fishes and the Ram on the right is also to be considered to be one of the set of green curves for this purpose. From 21st December to 21st June, when the days are lengthening, run your eyes from the shadow, between the curves, to the *right* side of the dial where the small drawing indicates the sign of the zodiac. If the days are shortening, the drawings on the *left* are the correct ones to use. In Figure 2 the position of the shadow indicates the sun was in Scorpio on 21 October 1987.

(6) **To determine the Date**

The date can also be deduced by reference to the position of the ball's shadow in relation to the green curves. To the right and left of the dial the names of the month appear vertically in Latin. JU-NIUS and DECEM-BER have been split to occur on each side of the dial. The estimated position of the shadow between relevant green lines will give the date within a day or two. The position of the shadow in Figure 2 indicates that the date was late October. No great accuracy can be expected [see Appendix (d)].

(7) **To estimate the Time of Sunrise, the Time of Sunset and the Length of the Day**

(a) Time of Sunrise/Sunset: On the left side of the dial is a column marked ORTUS SOLIS. Note the relative position of the shadow of the ball within the relevant green lines and then use the times given by the intersection of these with the column to estimate the time of sunrise. Apply the G.M.T. correction factor. Time of sunset is given by subtracting the observed and corrected time of sunrise from twelve hours. Figure 2 indicates that sunrise was around 7.20 – 0.15 (E) i.e. 7.05 a.m. on 21 October 1987 and sunset 12.00 – 7.20 – 0.15 (E) i.e. 4.25 p.m.

(b) Length of day: On the right of the dial is a column marked LONGITUDINO. This can be used to deduce the length of the day in hours between sunrise and sunset. Figure 2 shows the length of the day on 21 October 1987 was approximately 9 hours 20 minutes.

A Full Reading of the Dial

As an example of the full information which can be obtained from a reading of the dial, during the first half of the year, when the days are lengthening, the shadow of the ball is observed to lie on the intersection of the vertical black line marked S.W.B.S. and the red curve marked 50. The shadow of the style will cross the border at the 1.30 marking. The dial thus reveals in Figure 3 on page 7:

The sun lies in the direction south-west by south. (3)

Its altitude is 50° above the horizon. (4)

It lies in the sign of the zodiac Taurus or the Bull (on the right side of the dial since the days are lengthening). (5)

The date is approximately 6th May. (6)

The apparent time is 1.30 p.m. Since E is – 3 minutes on 6th May the G.M.T. is 1.30 – 0.03 = 1.27 p.m. (1)

The apparent time of sunrise is 4.25 a.m. and of sunset is 12.00 – 4.25 = 7.35 p.m. Correcting for the equation of time, the G.M.T. of sunrise is 4.22 a.m. and of sunset is 7.32 p.m. The length of the day is 15.00 hours. (7)

The numbers in brackets refer to the relevant paragraphs on Reading the Dial.

ACKNOWLEDGEMENTS

This account follows in the tradition of the work of Professor G. C. Shephard whose booklet on the dial was first published in 1948, whilst he was an undergraduate scholar of the College. Some of the examples used to illustrate the reading of the dial were first given by him. I am indebted also to Dr. Robin Walker, Junior Bursar of the College, for information based on his special knowledge of the dial and to Dr. Norman Hughes, Fellow of the College, and Dr. Bruce Elsmore, Mullard Radio Astronomy Observatory, for their helpful comments on the text. M.M.S.

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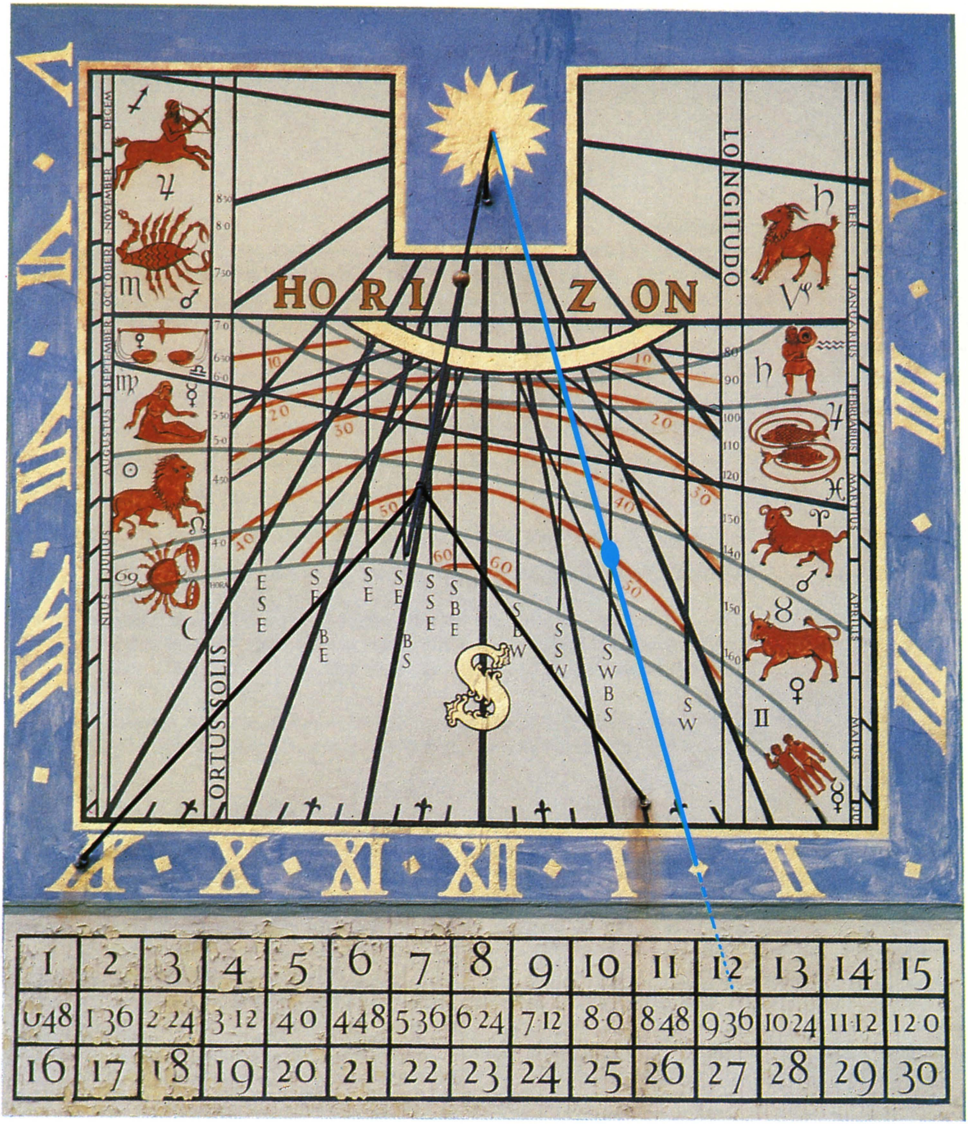


Figure 3 Shadows of supports of style omitted

APPENDIX

(a) **Additional radiating black lines**

Until recently there has been no satisfactory explanation of the possible use of the black lines which radiate from the point where the vertical north–south line intersects the horizon line. Computer simulations now confirm that these are indeed the 'temporary hour' lines which were in use until the eighteenth century when the day from sunrise to sunset was divided in twelve equal parts which obviously varied in length from day to day.

(b) **Astronomical symbols**

Astrologers believe that stars and planets influence human affairs and that particular associations of the signs of the zodiac with the sun or with the moon or another planet can enhance this influence.

In this connection Mars ♂ is associated with Aries ♈, Venus ♀ with Taurus ♉, Mercury ☿ with Gemini ♊, Moon ☾ with Cancer ♋, Sun ☉ with Leo ♌, Mercury ☿ with Virgo ♍, Venus ♁ with Libra ♎, Mars ♂ with Scorpio ♏, Jupiter ♃ with Sagittarius ♐, Saturn ♄ with Capricornus ♑, Saturn ♄ with Aquarius ♒, and Jupiter ♃ with Pisces ♓.

These twenty-four astronomical symbols, traditionally used by astrologers to denote each planet and sign of the zodiac, are distributed amongst the actual signs of the zodiac on the dial. They were restored in full in the 1968 repainting, some previously having been missing or corrupt.

(c) **The golden arc**

The golden arc which appears under HORIZON seems to be a decorative feature, but it also covers what would be a confusing intersection of lines in an area of the dial which is irrelevant and unnecessary for this latitude.

(d) **The coloured lines**

Computer simulations have established that the red and green lines, as now painted, are not precisely correct especially towards their ends. This contributes to inaccuracies.

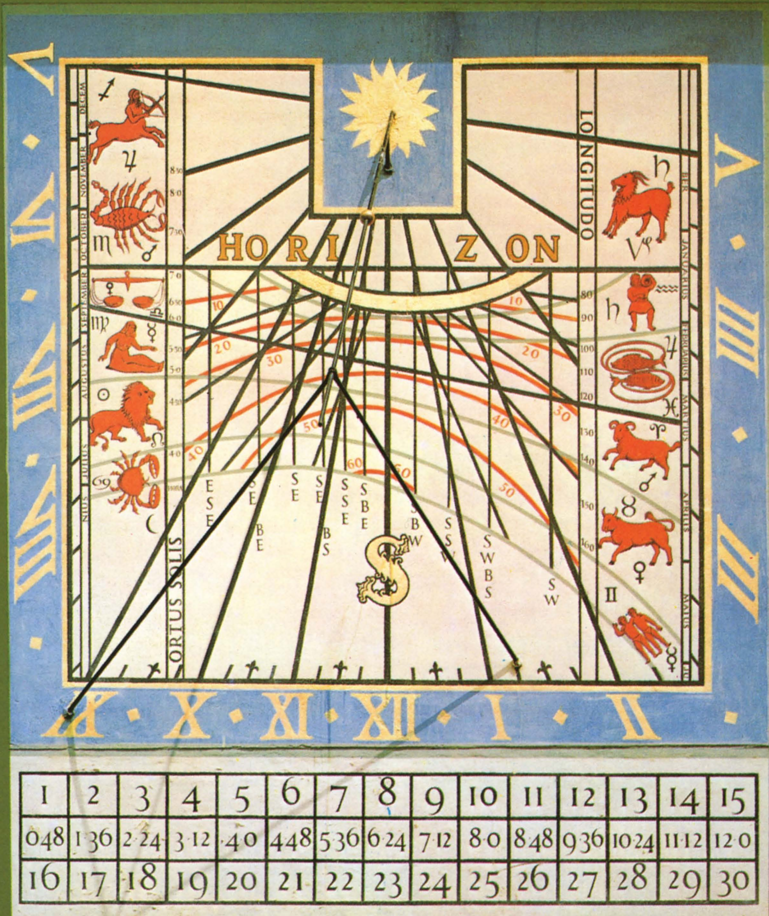
(e) **Marking of months**

It has not been possible to determine whether the months have been marked according to the old Julian or the present Gregorian Calendar. There is thus an additional potential discrepancy of 11 days in any reading to determine the date.

[Caesar's Julian Calendar served well but its year was 0·0078 days longer that the 365·2422 days taken by the earth to circle the sun. The accumulative error had become 10 days when Pope Gregory XIII solved the problem of lost days by decreeing that 4 October 1582 should be followed by 15 October for that year and that there should be no leap year in century years unless divisible by 400—e.g. the year 2000. This Gregorian Calendar was not adopted in the British Isles until 1752 by which time the date had to be advanced 11 days on the date given by the Julian Calendar still then in use.]

Back cover:

The Dial as it appears on the north wall of Old Court, Queens' College, Cambridge.



HORIZON
LONGITUDO
ORTUS SOLIS
S
XI X XI XII I II
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0·48 1·36 2·24 3·12 4·0 4·48 5·36 6·24 7·12 8·0 8·48 9·36 10·24 11·12 12·0
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30