QUEENS' COLLEGE DIAL

A short description of the Sun-dial in Queens' College, Cambridge

By

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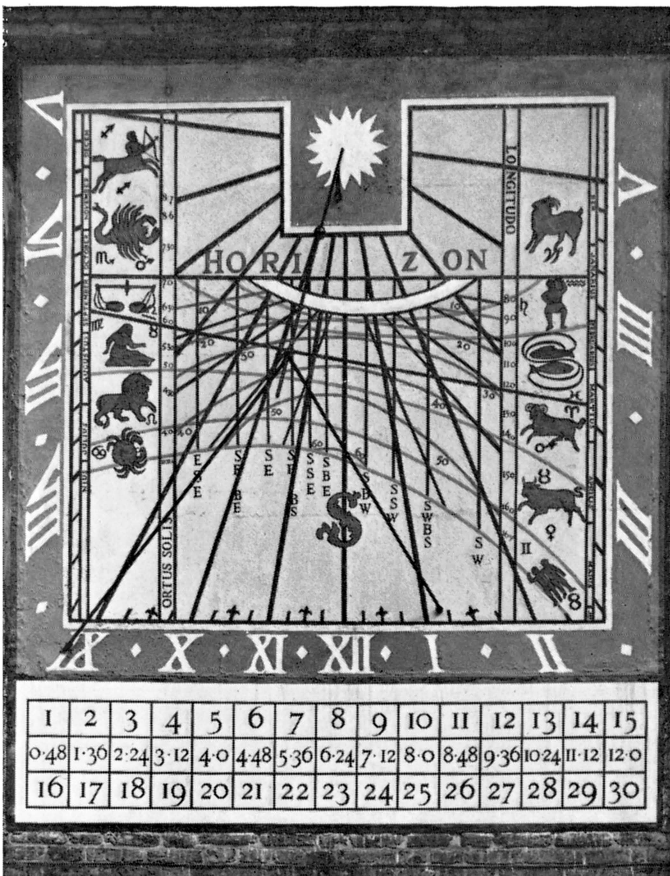

HORIZON
LONGITUDO
ORTUS SOLIS
X XI XII I II
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0·48 1·36 2·24 3·12 4·0 4·48 5·36 6·24 7·12 8·0 8·48 9·36 10·24 11·12 12·0
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

QUEENS' COLLEGE DIAL

The dial in the Old Court of Queens' College, Cambridge, is world famous. It is one of the finest examples of sun-dial art in this country, and is one of the few moon-dials in existence. The following description of the dial includes a brief account of its history, and an explanation of how it can be used to tell the time by day and by night and to determine many other astronomical quantities.

CONSTRUCTION AND HISTORY

At least five sun-dials have existed in the College at various times. The first to be put up in Old Court was erected in 1642. The Bursar's accounts of that year include the following entries:

"For stone and worke about ye 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".

This dial was in the same position in the court as the present one, for it is shown there in the detailed print of the College by Loggan in 1685. The first item in the above accounts refers to the sinking of a number of large blocks of stone into the brick wall to form a surface on which the dial could be painted.

An eighteenth century manuscript account of the College by William Cole, a fellow of King's College, refers to the painting of the present dial:

> "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."

This new dial was probably no more than an elaboration of the earlier one, using the same stone blocks and *style* (the metal rod that sticks out from the wall). It is often referred to as *Newton's dial*, though, as Cole's account suggests, it was not painted till after Sir Isaac Newton's death in 1727, so there is no evidence that he was concerned in any way with it.

In the eighteenth and nineteenth centuries, the dial would chiefly be used for checking the time of the clock above it. Sundials were commonly used for this purpose; even as late as the beginning of the twentieth century they were used for checking railway train times in France.

The dial has been repainted several times. Since the beginning of the century this has been done twice, in 1911 and in 1948. In 1948 the stonework on the lower part was faced with cement, the original design being carefully preserved by tracing.

The small ball on the style is a unique feature of the dial, and makes possible many of the observations described in the next section. In 1911 it was there (in the wrong position!) but subsequently it fell off, and the present ball, made of wood, dates from 1948.

HOW TO READ THE DIAL

(a) The Time by Day

When the sun is shining, the shadow of the style will cross the outer blue border of the dial in which the hours are indicated by golden Roman numerals. These numerals refer to markings on a scale just inside the blue border, and this is further subdivided into quarter hours. By estimating the position of the shadow between these subdivisions, the time may be estimated within a few minutes (although certain errors are inevitable due to the fact that a number of the quarter hour divisions are not accurately placed).

The time, read from the dial, will rarely be the same as that shown by the clock above. This is not entirely due to inaccuracies of the dial (or of the clock!) but because the dial indicates *apparent solar time*, and the clock shows *Greenwich mean time* (or, of course, *British summer time*). Apparent solar time is natural time in that noon occurs when the sun is due south. Owing to the sun's varying motion, this makes every day a different length. Greenwich mean time is man's invention, and one of great convenience since it makes every day of exactly the same length, an obvious necessity for a civilisation that depends more on mechanical timekeepers than on the sun for its time determination.

The difference between apparent time and G. M. T. is known as the *equation of time* and is usually denoted by *E*. It is tabulated below, correct to the nearest minute. In order to get G. M. T. it is to be added to apparent time if preceded

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

by + and subtracted from apparent time if preceded by —. For example, if on August 17 the shadow on the scale indicates 1.43, then since E is +4 minutes, the correct G. M. T. is 1.47 pm, and the clock above, which will be showing summer time, will read 2.47 p.m.

From the table it will be seen that E is zero on only four days in the year, namely April 15, June 14, September 1 and December 25. On these four days the dial will give G. M. T. directly.

(b) The Time by Moonlight

Any sun-dial can be used for telling the time by moonlight if we know the relative positions of the sun and moon in the sky. The angular difference between the sun and the moon is called the *moon's hour angle* and is measured in hours and minutes (and not in degrees—for this purpose 1 hour is 15°).

Then

(apparent time) = (time on dial indicated by moon's shadow) + (moon's hour angle)

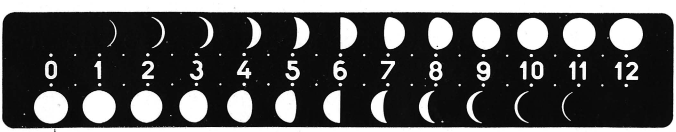
and from the apparent time the G. M. T. can be determined using the equation of time as described in (a).

The main difficulty, apart from the practical one of finding a night when the moon is strong enough to cast a readable shadow, is that of determining the moon's hour angle. One way of doing this is by using the table of figures that appears below the dial, and it is the existence of this table that substantiates the dial's claim to be a moon-dial.

The table is compiled on the assumption that the lunar period, from one new moon to the next, is exactly 30 days. If this were so, it would only be necessary to look up the moon's age in days in the first or third row of the table, and read off its hour angle in hours and minutes from the second row. Since the lunar period varies considerably in length, it is better to reckon from the nearest quarter moon (as given in a diary) working on the assumption that the first quarter, full moon and last quarter occur when the moon is $7\frac{1}{2}$, 15 and $22\frac{1}{2}$ days old respectively. For greater accuracy allow also for fractions of a day: 24 minutes for half a day, 12 minutes for a quarter, and so on. After these calculations we have an approximation to the moon's hour angle and so the correct time can be found.

For example, on February 26th, 1948, at about 11 p.m. the moon was casting a shadow that gave the reading 9.35 on the outer scale. There was a full moon on Tuesday, 24th February at 5.16 p.m. so that the moon was about $15 + 2\frac{1}{4}$ days old. Its hour angle when 17 days old (from the table) was 1.36, and allowing 12 minutes for the quarter day, the moon's hour angle at the time of observation was 1.48. The equation of time on February 26th is +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. This may not seem very accurate, but if you arrive at the time correct within half an hour, you may be proud! The moon's motion is so irregular that no moon-dial can possibly be accurate, and is to be regarded as providing an exercise in mental arithmetic rather than being an instrument of any practical value.

The diagram below (kindly supplied by Mr. Egger of Zürich) shows the appearance of the moon at different hour angles, and so provides an alternative method of determining this quantity. Near a quarter moon, this method is simple and accurate, but when the moon is full (and it is usually at that time that the shadow is strong enough to be read) the first method should be employed, otherwise the inaccuracies may amount to several hours!



(c) The Azimuth or Bearing of the Sun

On the face of the dial are a set of vertical black lines marked with letters at their lower ends. The letters refer to points of the compass, E. S. E. meaning east-south-east, S. E. B. S. meaning south-east by south, and so on. If the shadow of the small ball falls on one of these lines, then the direction or bearing of the sun can be read off immediately, and bearings between the various compass points can be estimated.

(d) The Altitude of the Sun

The altitude of the sun is its height above the horizon expressed as an angle in degrees. This is indicated by the position of the ball's shadow relative to the red curves (hyperbolae) painted on the dial, so that if the shadow lies on the curve marked 40, the sun is 40° above the horizon.

The curves give the altitude correct to 10° and intermediate altitudes may be estimated.

(e) The Sign of the Zodiac in which the Sun lies

As is well known, certain groups of stars are called constellations, to which the ancients gave the names of mythical creatures and heroes. Despite the fact that to modern eyes they bear very little resemblance to the objects they are supposed to represent, the names are still used by astronomers.

If it were possible to see the stars by day, the sun's position amongst them would be seen to be continually altering, and in the course of a year it would have made a complete circuit of the heavens along a path known as the *ecliptic*. In ancient times the ecliptic passed through twelve constellations, namely Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius and Pisces, starting on March 21st (the vernal equinox) at the *first point of Aries* and changing from one constellation to the next about the 21st of each month. These twelve constellations were known as the *zodiacal constellations*.

Owing to an effect known as *precession of the equinoxes* the position of the ecliptic is continually changing, with the result that the months and constellations are now completely out of step, and it will not be until about 20,000 A.D. that they will coincide again. But the names linger on, and we still conventionally divide the sun's path into twelve parts, known by the same twelve names. These are the *signs of the zodiac* and now that the astronomical significance has disappeared, their chief use seems to be in casting horoscopes!

The English forms of the names of the twelve signs can be easily remembered by the following rhyme, which gives them in their correct 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.

It is of interest to determine the sign of the zodiac in which the sun is lying, and this can be accomplished easily by observing the position of the shadow of the ball relative to the green curves (hyperbolae). The straight black line running between the pictures of the Scales and Virgin on the left and between the Fishes and Ram on the right also belongs to this system of curves. From December 21st to June 21st, 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.

(f) The Date

The date may be determined as in (e) by observing the position of the ball's shadow relative to the green curves. Glance to the right or left as far as the columns in which the names of the months are written vertically in Latin. By estimating the position between the green lines, the date may be determined within a few days.

The names of two months, JU-NIUS and DECEM-BER, have been split and occur in two parts, one on each side of the dial.

(g) The Time of Sunrise

Just inside the column of drawings representing the signs of the zodiac on the left side of the dial is a column marked ORTUS SOLIS. Using the green curves as a guide [as in (e) and (f)] the time of sunrise can be read in this column. The time of sunset can be determined by subtracting the time of sunrise in hours and minutes from twelve hours. Since the dial gives apparent time, in order to get the G. M. T. of sunrise and sunset it is necessary to apply the correction for the equation of time as in (a).

(h) The Right Ascension of the Sun

If, on the other hand, we use the column just inside the drawings on the right side of the dial marked LONGITUDO we can deduce the longitude or *right ascension* of the sun, that is the angle, expressed in hours and minutes, that the sun is westward of the position it occupies at the vernal equinox. The designer of the dial has mistakenly measured the angle from the position of the autumnal equinox, so in order to obtain the correct right ascension it is necessary to make the following corrections:

December 21 *to March* 21*:* Add 12 hours to the reading.
March 21 *to June* 21*:* Subtract 12 hours from the reading.
June 21 *to December* 21*:* Subtract the reading from 24 hours.

EXAMPLE

In order to illustrate the method of reading the dial we shall suppose that 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 then cross the border at the 1.30 marking. The full reading of the dial is as follows, the letters referring to the paragraphs above:

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

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

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

(f) The date is approximately May 6.

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

(g) 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.

(h) The right ascension of the sun is 15.00 — 12.00 = 3.00.

CONCLUSION

There now remains only one set of lines on the dial to be mentioned: the black lines radiating from the point where the vertical line marked S meets the line marked HORIZON. So far, there has been no satisfactory explanation of the purpose of these. It is possible that they were intended to show the angular distance of the sun east or west of the meridian, but if this is so it is strange that the lines should be neither marked in degrees nor even lie in the correct positions! A more probable theory (due to Mr. Egger) is that they were intended to enable one to read off the *temporary hours* that were in use until the eighteenth century in which the day, from sunrise to sunset, is divided into twelve equal (and therefore varying) parts. For this purpose a system of curves would be required, though perhaps the designer of the dial regarded straight lines as a sufficiently close approximation.

Scattered amongst the signs of the zodiac on each side of the dial are nineteen symbols whose full significance has only recently been discovered. Astrologers, who believe in the influence of the stars and planets on human destinies, have always ascribed specific effects to each of the heavenly bodies. In addition, each sign of the zodiac was associated with the sun, moon, or a planet in accordance with their supposed influences. For example the sun and Leo, the Lion, are associated because they both have fiery natures. The full scheme is described in detail by Ebenezer Sibly in his book *The Celestial Science of Astrology* published in 1788, and is reproduced below:

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 ♓,

Here the symbols associated with each planet and sign of the zodiac are the traditional ones used by astrologers from time immemorial. It seems likely that originally all 24 symbols were painted on the dial, two by each of the zodiacal drawings. If so, five must have been lost at various times during repainting, due to the artist's ignorance of their significance. Of the remaining nineteen, that we see to-day, twelve are the zodiacal symbols and four are planetary symbols (♂ in Scorpio and Aries, ♀ in Taurus and ♄ in Aquarius) fitting in exactly with the above scheme. There are also two symbols 8, which are presumably in error for ☿, the Mercury symbol, and finally one of the symbols ♐ by Sagittarius may be a faulty version of ♃ for Jupiter. When the dial is repainted again, it is hoped that all 24 symbols will be put in their correct positions.

If these remarks have helped to explain the mysteries of the dial, they will have fulfilled their purpose. To appreciate the ingenuity of the designer, why not try to read the dial in all its detail on a sunny day ? The pleasure derived will amply repay the trouble.

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