A Sure Reckoning:

Sundials of the 17th and 18th Centuries

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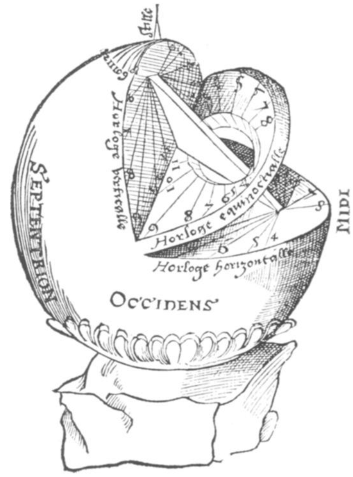
"Certa Ratio 1772" (a Sure Reckoning), the motto of a sundial on the south porch of the Kirk Deighton church in Yorkshire, suggests a serious use of the sundial in an age when the rapid development of clock- and watchmaking would seem to have made telling of time by the sun obsolete. On the contrary, advances in clockmaking during the seventeenth and eighteenth centuries actually spurred interest in sundials, the instruments for setting and regulating the clock. European efforts throughout these two centuries to perfect the sundial are recorded by a small but choice collection in the Metropolitan Museum, the gift of Mrs. Stephen D. Tucker. This collection not only shows the improvement in accuracy during two centuries, but also demonstrates some of the diverse solutions to the problem of "dialing," the technical name for the construction of sundials.

The uncertainty of timekeeping in the early part of the seventeenth century is well illustrated during the fourth act of Middleton's *Women Beware Women:*

BIANCA. How goes your watches, ladies? What's o'clock now?
FIRST LADY. By mine, full nine.
SECOND LADY. By mine, a quarter past.
FIRST LADY. I set mine by St. Mark's.
SECOND LADY. St. Anthony's they say goes truer. . . .
BIANCA. I'll end this strife straight: I set mine by the sun;
I love to set by the best; One shall not then be troubled to set often.

The working principle of any dial is that a pointer, called a style or a gnomon, casts a shadow on a calibrated surface. A horizontal garden sundial (Frontispiece), a product of mid-eighteenth-century England, serves to introduce the complexities involved in dialing. It also demonstrates, in its engraved and pierced decorations and in its precise construction, the high quality of the anonymous craftsmanship of the period. If this dial is fastened to a horizontal surface anywhere on the latitude circle of 52 degrees north, in England north of London, and is fixed so that the right angle at the base of the triangular style points due north, the shadow cast by the longest side of the style will indicate the time of day. The calibration of this dial is based on the orientation of the sun to the earth during the course of the day. The procedure that works for setting this sundial will not necessarily work for another dial (see Technical Aside, p. 158).

Among the earliest sundials in the collection is an ivory diptych dial (Figure 8) made by Paul Reinman, or Reinmann (worked 1575-1609), one of the best and most prolific of all Nuremberg craftsmen. During the second half of the sixteenth century, Nuremberg became the most important center for craftsmen who specialized in the making of sundials as well as other scientific instruments. The dial bears Reinman's mark (an open crown), his signature, and the date 1602. It is a good example of a portable Nuremberg dial that could be oriented to the north by means of a compass recessed into the base, a characteristic that accounts for the inclusion of most of the city's sundial makers in the guild of compass makers. Although the charming scenes of courtly life on the vertical leaf and the various lines that divide the dials are engraved, the decorative borders, the numbers, and the letters are stamped and tinted red or black.



1. A diagram opposite page 7 of Jean Bullant's Recueil d'Horlogiographie (Paris, Jean Bridier, 1561) shows how the plates of a horizontal, an equinoctial or equatorial, and a vertical sundial are positioned in relation to the earth's axis (stille). Woodcut, 6½ x 7½ inches. Harris Brisbane Dick Fund, 28.46.2

The history of portable dials in the seventeenth and early eighteenth centuries is the history of attempts to achieve ever greater accuracy. The sundial makers of Germany, England, and France invented or developed instruments with distinctive national characteristics. In Germany, refinement in dialing passed in the second half of the seventeenth century to the guilds of compass makers and clockmakers of Augsburg. An octagonal portable sun- and moondial of about 1700 (Figure 10) is probably the work of the Augsburg master Johann Martin (1642-1721). Although the dial was formerly attributed to Martin's younger contemporary, Nikolaus III Rugendas, the recent publication of a signed Martin dial in a private collection in Innsbruck, Austria, shows the engraved hour rings and inscriptions of the two to be almost identical.

Martin's step-brother, Johann Willebrand, came to Augsburg in 1682. In 1703 he set up his own shop, producing, until his death in 1726, some of Augsburg's best dials. A water-gilt copper dial with its silver fittings (Figure 11) is a fine example of the special type of portable equatorial, or equinoctial, dial invented in Augsburg and known to have been made as early as about 1700 by Martin and by Nikolaus III Rugendas. The engraved circle of the months and the zodiac on the plate of the Willebrand dial together with the discreet but lovely designs on the hour ring, the level, and the reverse (Figure 12) make it one of the finest in the collection.

A beautiful dial of brass and silver, signed at the edge of the compass by Ludewig of Dresden (Figure 13), also belongs to the first quarter of the eighteenth century. Few of Ludewig's instruments survive, but the pleasing proportions of this one, the relation

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of the lines of the minute divisions in the hour ring to one another, the careful scaling of numbers and letters in the deceptively casual list of city latitudes around the edge of Ludewig's compass have rarely been equaled. Like Willebrand's, Ludewig's dial has the advantage of being usable in all latitudes from 10 to 90 degrees – that is any place on the earth except a small band around the equator – and its compass is adjustable for local variations in the magnetic declination. The reverse (Figure 14) is an elaborate perpetual calendar.

The problem of dividing sundial time into one-minute intervals was ingeniously solved in 1671 by Michael Bergauer, an Augsburg master of Austrian origin. Two elegant dials in the Tucker collection (Figures 15-17) are based on Bergauer's solution. The two graphically demonstrate the different aesthetic approaches to dialmaking of the Continental and English schools in the eighteenth century. The larger dial, with its finely engraved and pierced foliate scroll designs on the equatorial plate and chased silver minute dial, is one of at least five surviving minute dials signed and dated by Claude Dunod at Düsseldorf between 1711 and 1716. A Burgundian, Dunod spent most of his working life in Germany where in 1672 he learned to make the instrument from Bergauer. The smaller dial reflects its English origins in the austerity of its structure and the precision of its hand-engraved graduations, relying on pleasing proportions rather than decorative motifs to achieve a strictly functional, but nonetheless genuine, beauty. Thomas Wright (about 1686-1748), who signed this dial as instrument maker to the king (Figure 16), was one of the best craftsmen of his time, and was appointed instrument maker to the Prince of Wales, afterward George II, not later than 1718. The Museum's dial must have been made after George's accession to the throne in 1726.

The same aesthetic characteristics distinguish an English universal ring dial (Figure 18, left) signed by William Collier, who worked in London between 1707 and 1730. The universal ring dial was an invention of about 1600 by the English mathematician William Oughtred (1575-1660), and was first made by the Englishman Elias Allen in the 1620s. Although an older invention than the minute dial, the universal ring is quite accurate and has the advantage of not needing a compass for its orientation. It depends instead on the place of the sun in the ecliptic during the course of the year (see Technical Aside).

Another Englishman, Michael Butterfield, who worked in Paris between 1678 and 1727, is believed to have been the inventor of a class of portable dial that bears his name, and it became the standard French model. These are small horizontal dials with a recessed compass, engraved with three or four circles or chapters of hour lines for several latitudes. They have folding styles that adjust to the correct angle of latitude, indicated by the characteristic little bird beak. (This class of sundial is represented by three French dials in the collection.) The type is clearly illustrated in the third edition of the most popular treatise on scientific instruments of the eighteenth century, Nicolas Bion's *Instruments de Mathématiques* (Figure 19, center). The prevalence of this design is seen on a beautifully engraved brass and silver instrument for making sundials (Figure 20) on which the multiple hour rings and small silver bird reappear. Bion explained that the use of this instrument avoids the necessity of having to calculate the positions of the hour lines mathematically.

The sundials discussed so far are highly sophisticated and finely finished instruments. The collection also contains two dials made for common use. Both depend on the sun's position in the ecliptic and are classified as altitude dials (see Technical Aside). Like all altitude dials, they do not need to be oriented to the north, but must be adjusted, however roughly, for the time of the year. A small local ring dial (Figure 22, right) of brass with punched calibrations employs a ray of light cast on the interior surface of the ring on which the hours have been marked (see the diagram in Figure 19, right) in much the same fashion as the universal ring dial. The dial is English and bears the punched initials T.W., for an unidentified master who is thought to have been working about 1730.

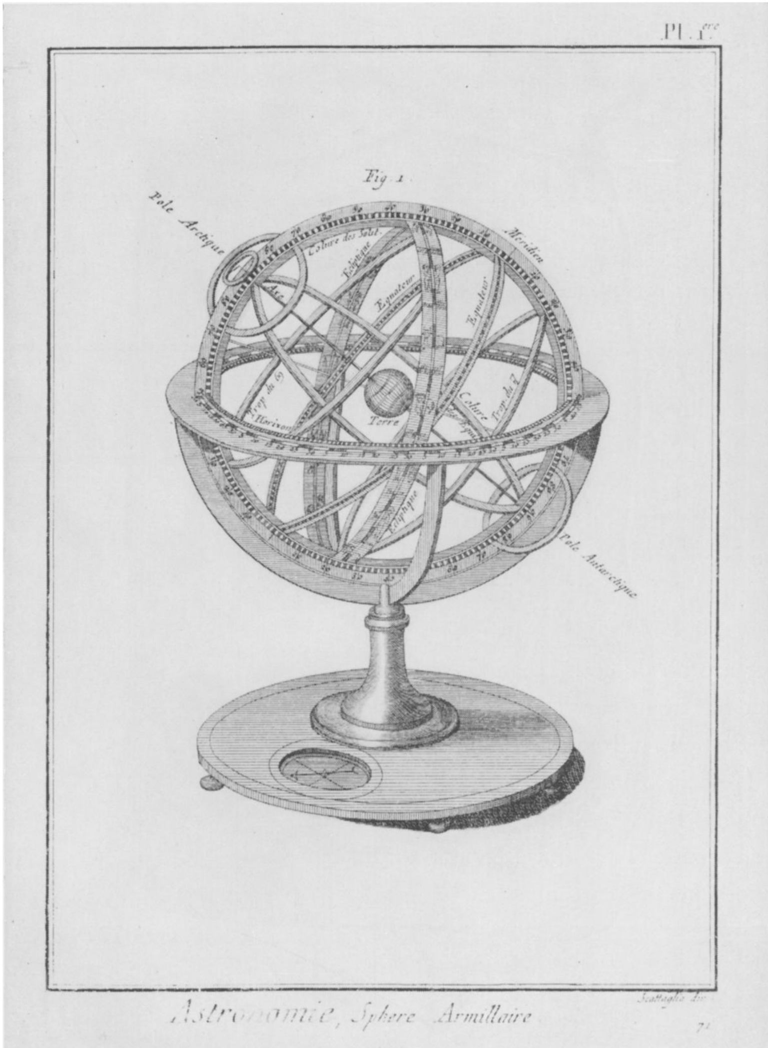
A fruitwood pillar or cylinder dial (Figure 22, left) is an ingeniously compact version of a type that goes back to Roman times. The months are marked off by the vertical lines and the hours by the diagonally curved lines that reflect the changes in the sun's position in the zodiac. A flattened diagram of a cylinder dial's calibrations appears in Figure 21. When the dial is suspended from its ring and the pointer, or gnomon, is erected over the line of the proper month, the tip of its shadow will indicate the time. Although this dial was made to be used in latitude 50½ degrees, the lack of decoration and signature makes it impossible to suggest its country of origin or even a satisfactory date for it. Dials of this type are known, however, to have been used in France until the early twentieth century, long after sophisticated sundials were more or less relegated to the status of toys.

Although David Beringer first made his five-sided dial in the eighteenth century, the cube dial in Figure 23 is a product of the Nuremberg Beringer workshop of the early nineteenth century. The whimsical character of the dial is perhaps symptomatic of the decline of the sundial.

In principle, the cube dial and the cylinder are no different than their illustrious ancestors made by Nicolas Kratzer, astronomer to King Henry VIII, which occupy a position of honor between the figures of The French Ambassadors, painted by Hans Holbein the Younger in 1533 (Figure 2). In Holbein's time they were the dignified symbols of the cultural attainments of the Lord of Polisy and the Bishop of Lavour and the pride of a scholar like Kratzer. Three centuries later and after extraordinary improvements they were reduced to everyday objects or playthings.

2. *Detail from The French Ambassadors at the English Court, by Hans Holbein the Younger. Oil and tempera on wood. Signed and dated 1533. National Gallery, London. Reproduced by courtesy of the Trustees*

The "Doctrine of the Sphere," or a Technical Aside



3. Design for an armillary sphere engraved by Pietro Scattaglia for a Venetian edition of the Encyclopédie méthodique: Mathématiques, by Denis Diderot and Jean le Rond d'Alembert, new ed. (Padua, 1787), III, p. 71. 9⅝ x 6⅞ inches. Private collection, New York. Photo: Taylor & Dull

The style and plate of a sundial are positioned in such a way that it is possible to predict mathematically the position of the shadow on the plate at any time. Dialing (the construction of sundials), therefore, was considered a branch of mathematics. An early manual on the subject, Sebastian Münster's *Horologiographia*, illustrated by Hans Holbein the Younger, was published in 1533, and a profusion of books appeared during the next two centuries giving constructions for various types of sundials. These books often presupposed a rather extensive mathematical background, as one of the English practitioners of dialing, Charles Leadbetter, complained in the preface to his *Mechanick Dialling*, new ed. (London, 1769):

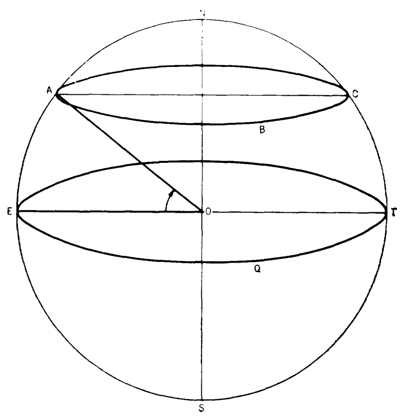
> Seeing the business of Dialling Mechanically considered, is of itself a Thing so natural and easy, one would wonder, after so much learned Bustle as the Mathematicians have made about it, that they should have more perplexed and obscured than promoted the Knowledge of that useful and entertaining Art amongst the Generality of Mankind.
>
> The different Ways, in which these Gentlemen have hitherto chose the World should see that useful Subject handled, would certainly have been right and proper, and liable to no Exception, if all Men were Mathematicians: But how few are such? And therefore their having treated of Dialling in a Geometrical, Instrumental or Arithmetical Method, I am sure cannot possibly be of any Use or Signification to such as know nothing at all of those Sciences, or the Doctrine of the Sphere.

Although the plotting of dials requires more mathematical knowledge than Leadbetter allows, some insight into the problems can be gained by a brief consideration of the relationship between the sun and the earth.

Historically there have been two major models for visualizing the relationship of the sun and the earth. The current conception puts the sun in the center of our solar system, imbedded in one of the galaxies of an immense universe. The earth travels in a nearly elliptical orbit about the sun in a little more than 364 days, while simultaneously revolving on its own north-south axis approximately every 24 hours. The older Ptolemaic system postulates a stationary earth at the center of the whole universe. All objects in the sky are called stars, but a distinction is made between the fixed stars, which keep a uniform relationship to one another over long periods of time, and the wandering stars, or planets, including the sun, which do not.

For an understanding of the working of the Museum's dials, a slightly modified version of the Ptolemaic system – the model still employed during the seventeenth and eighteenth centuries in dialing books – giving the relationship between the earth, the fixed stars, and the sun will be used. Consider the earth as a sphere at the center of a much larger sphere to which the fixed stars are attached. The sun travels in an earth-centered orbit between the earth and the fixed stars once every year. In contrast to the motionless earth of the Ptolemaic system, the earth is assumed to rotate once every twenty-four hours on its north-south axis, while the fixed stars are stationary. An eighteenth-century engraving of an armillary sphere (Figure 3) illustrates the system. The outer sphere to which the fixed stars are attached is not fully drawn, but is bounded by various circles, such as the equator, ecliptic, meridian, and the horizon. The axis of the earth *(Terre)* is extended to form a diameter *(Axe)* of the outer or celestial sphere; *Pole Arctique* being the continuation of the north extension and *Pole Antarctique* of the south extension. Positions on the earth are given in terms of latitude and longitude (Figures 4, 5) and those on the celestial sphere, by projecting the latitude and longitude circles from the center of the earth onto the larger sphere (Figure 6).

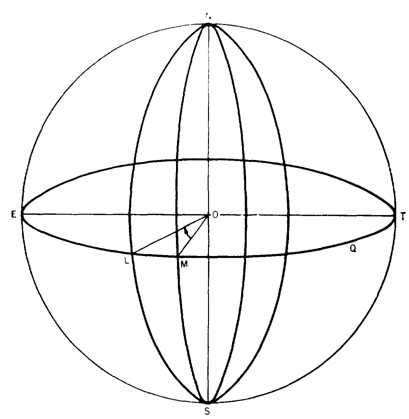
The sun is not indicated on the armillary sphere, but its orbit is projected on the celestial sphere as the great circle called the ecliptic or zodiac. The ecliptic cuts the celestial equator at an angle of approximately 23½ degrees, and at the northernmost point of its travels cuts the Tropic of Cancer (♋) – latitude 23½ degrees north – and at its southernmost point, the Tropic of Capricorn (♑) – latitude 23½ degrees south. The corresponding latitude circles on earth (Tropic of Cancer and Tropic of Capricorn) are so named because their projections on the celestial sphere are the two circles that bound the ecliptic (see Figure 6).



4. *Every place on the earth's surface can be located by two coordinates, latitude and longitude. The coordinate of latitude of a point is determined by the circle that passes through the point and is parallel to the equator. If EQT is the equatorial circle, A the point of latitude to be determined, ABC the latitude circle and O the center of the earth, the coordinate of latitude is given by the angle EOA stated in degrees and with the indication north. If the point is in the northern hemisphere the latitude has a value between 0 and 90 degrees north, and in the southern hemisphere, 0 to 90 degrees south.*

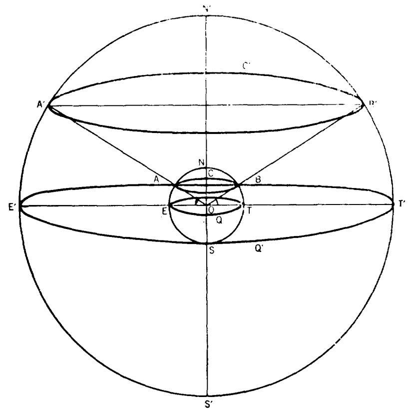
The ecliptic circle was divided by the ancients into twelve equally spaced segments, and in each the stars were grouped into the twelve constellations called the zodiac. The sun's position on any given day of the year was located by its position in the zodiac, rather than by its latitude and longitude.

At any instant the shadow on the sundial depends on two main factors, the position of the sundial on the earth, and the relative position of the style and the calibrated surface of the dial. An intuitive grasp of these relationships may be gained from a fanciful construction illustrated in a treatise on dialing by the Frenchman Jean Bullant, better known for his Renaissance architectural projects (Figure 1).



5. *The coordinate of longitude of point L is determined by the angle made by a fixed great circle (a circle on the sphere which has the same center as the sphere) passing through the north and south poles and Greenwich, England, and the great circle passing through the north and south poles and the point. Angle MOL is the angle of longitude of the point L if NMS is the great circle through Greenwich. In the eighteenth century, latitude and longitude were thought of as measurements on the surface of the sphere and not measurements from the center of the earth.*

6. *ESTBNA represents the sphere of the earth, E'S'T'B'N'A' the celestial sphere, ABC a circle of latitude on the earth. A'B'C' is the projected latitude circle on the celestial sphere. O is the center of the earth and angle E'OA' is the same as angle EOA. The coordinates of latitude of both circles are, therefore, the same.*



The relationship is best illustrated by the garden sundial (Frontispiece). The horizontal placement and northern orientation of this dial insures that at the instant of midday when the sun is at its zenith or directly overhead, the sun, the style, and the axis of the earth will be in one plane, so that no shadow is cast by the style at twelve o'clock. At any point on the given latitude circle, this alignment of style, sun, and axis occurs when the sun is at its zenith. The acute angle that the hypotenuse (the side opposite the right angle) of the triangular style makes with the base of the triangle is equal to the angle of latitude, insuring that the hypotenuse is parallel to the earth's axis (Figure 7). Hence, although this particular dial can be used in any longitude, it can be used in only one latitude.

With the dial correctly positioned, the shadow of the style's hypotenuse correctly indicates the hour of the day. In some dials, for example the altitude dials in this collection, there is a third factor, the sun's position in the ecliptic, which must also be measured by the dial.

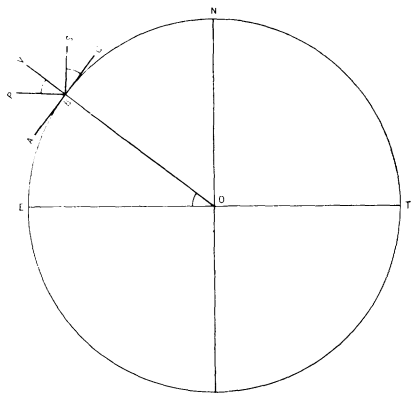
REFERENCES

The material concerning the German sundial makers appears in Ernst Zinner's *Astronomische Instrumente des 11. bis 18. Jahrhunderts* (Munich, 1956) and Maximilian Bobinger's *Alt-Augsburger Kompassmacher* (Augsburg, 1966). The portable dial signed by Johann Martin appears on p. 269 of the latter work.

The English makers are discussed by R. T. Gunther in *Early Science in Oxford*, 2 vols., (Oxford, 1923), and E. G. R. Taylor in two volumes *The Mathematical Practitioners of Tudor and Stuart England* (Cambridge, 1954) and *The Mathematical Practitioners of Hanoverian England* (Cambridge, 1966). *Les Instruments scientifiques aux XVII^e^ et XVIII^e^ siècles*, by Maurice Daumas (Paris, 1953), provided the information about Michael Butterfield and Nicolas Bion (pp. 107-110).

For the technology and classification of sundials, see R. Newton Mayall and Margaret Mayall, *Sundials: How to Know, Use, and Make Them* (Boston, 1938); K. Higgins, "The Classification of Sundials," *Annals of Science*, IX, no 4, 1953, pp. 342-358; Henri Michel, *Les Cadrans solaires Max Elskamp* (Liège, 1966); Derek J. Price's chapters (22 and 23) in Vol. III, *A History of Technology*, ed. by Charles Singer (Oxford, 1957). For an exhaustive treatment of the mathematical aspects of dialing see Joseph Drecker's *Theorie der Sonnenuhren*, I, part E (Berlin, 1925) of *Die Geschichte der Zeitmessung und der Uhren*, ed. by Ernst von Bassermann-Jordan.

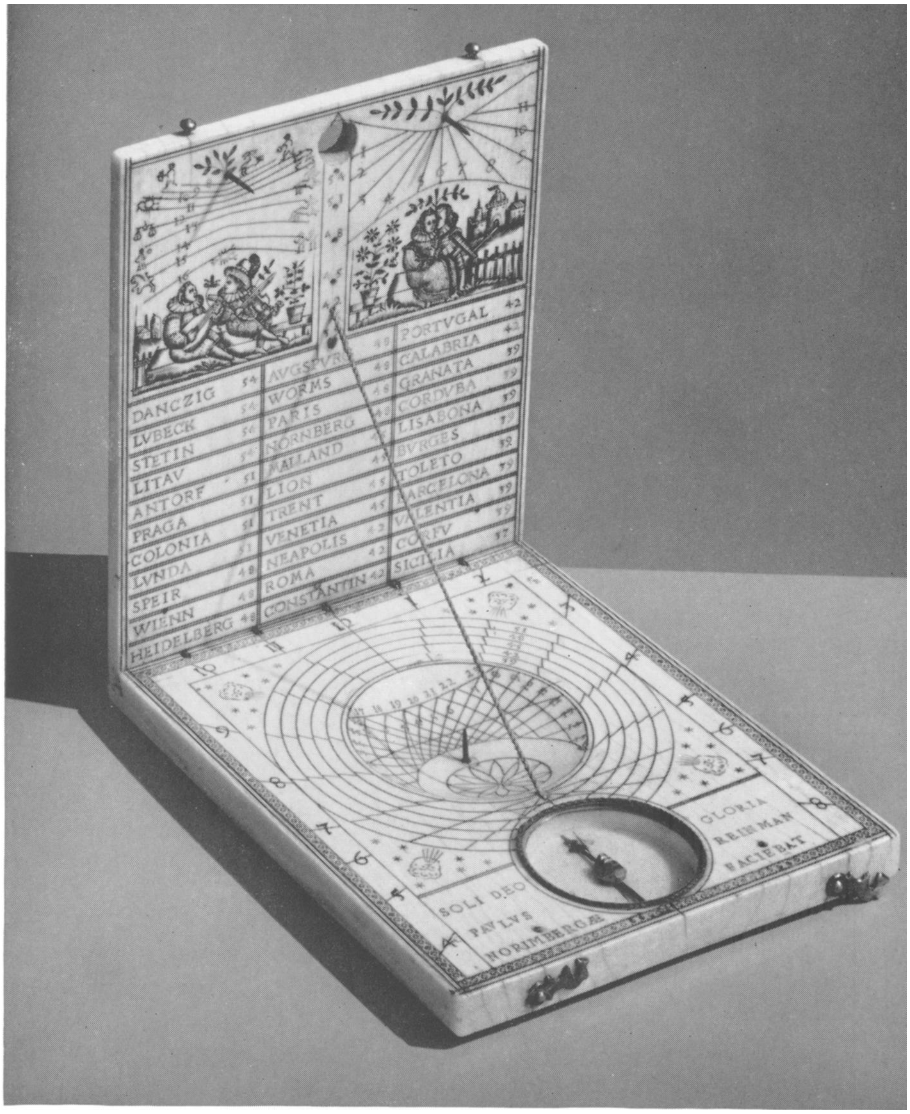
7. *The diagram illustrates the use of a horizontal and an equatorial sundial on the earth's surface at point B. N represents the north pole. Angle EOB is the angle that measures the latitude. BC is the plate of a horizontal sundial, and BS, the style. If angle CBS, the angle made by the style and the plate, is equal to the angle of latitude, BS is parallel to ON, the axis of the earth. The ring on an equatorial dial represented by BP is parallel to the earth's equator ET, when angle PBV is equal to the angle of latitude. The latitude on an equatorial dial is measured from the vertical to the horizontal, as can be seen in Figure 13.*



8. This portable ivory sundial by Paul Reinman can be used from Danzig to the island of Corfu, as the latitude table on the vertical leaf indicates. The basic dial found on the horizontal leaf of the diptych works on the same principle as the garden sundial (Frontispiece), but may be used in any one of six different latitudes. If the string that serves as the style is inserted in one of the six numbered holes, the angle it makes with the horizontal is the angle of latitude, and the time may be read from one of the six rings on the horizontal

surface. That the geometrical construction of the hour lines varies for each latitude is clearly demonstrated by the irregular pattern of the lines on each of the circles. At best, the shadow indicates the hour; finer divisions of the hour must be guessed at.

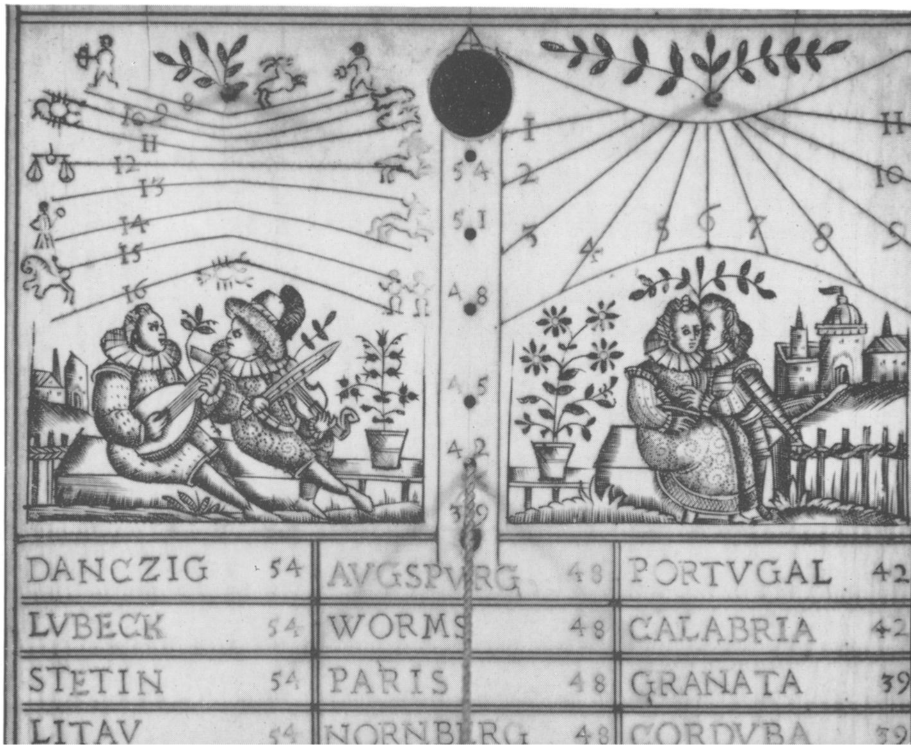
The Reinman diptych, like most dials of the period, is distinguished by the multiplicity of its functions. The concave surface at the center of the horizontal leaf is another sundial. Here the shadow cast by the tip of the fixed vertical pin, or gnomon, falls on a line that indicates the hour in two separate systems for recording the passage of twenty-four hours. One, known as the Babylonian hours, begins at sunrise (middle and right side of the bowl), and the other, known as the Italian hours, begins at sunset (left side and top of bowl). In this illustration the horizontal dial reads a few minutes after 10:00 A.M., and the concave dial shows that it is six hours since sunrise on the Babylonian scale and fourteen since sunset on the previous day on the Italian scale. German (Nuremberg), 1602. 4½ x 3½ inches. Acc. no. 03.21.24

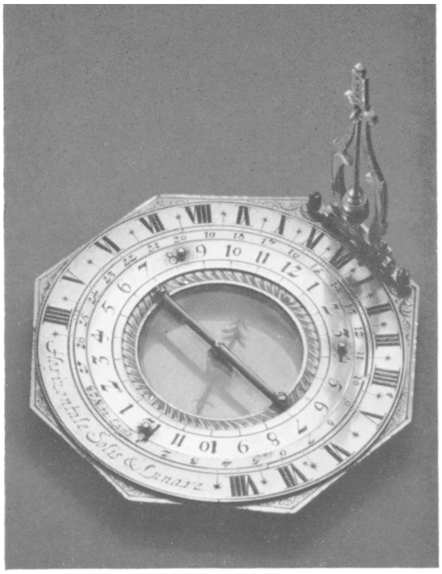


9. Detail of the vertical leaf, showing additional functions. The dial and gnomon on the left side indicate the number of hours of daylight in a given day of the year. The one on the right divides the daylight hours into twelve equal parts that vary in length according to the time of the year. These hours are called the temporary, or Jewish, hours.

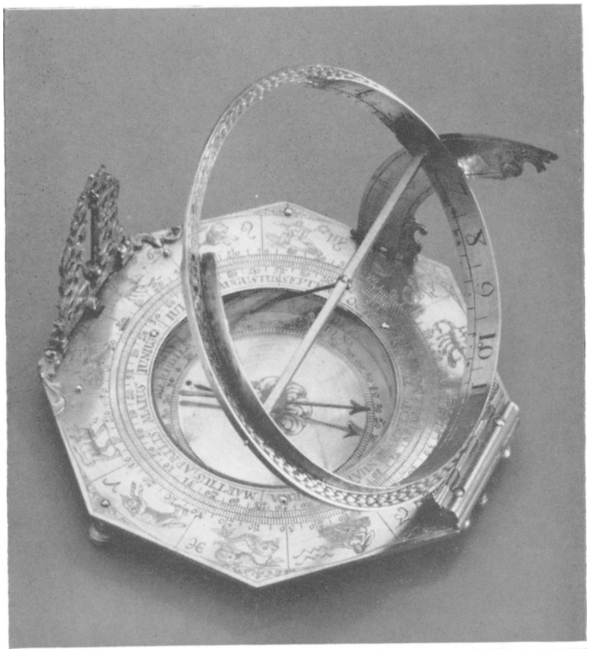
The shadow of the gnomon of the left dial indicates the position of the sun in the ecliptic. The number of daylight hours depends on this position and varies from eight to sixteen hours, as indicated on the dial. The designs around the dial's edge represent the signs of the zodiac. From the right side of the gnomon: Capricorn, Aquarius, Pisces, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, and Sagittarius.

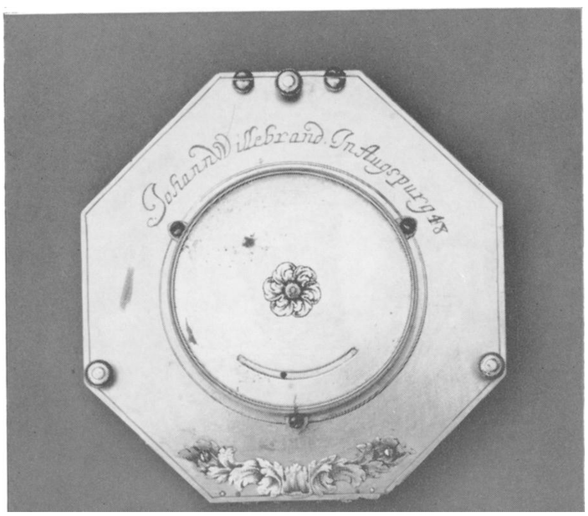
The top of the instrument (not illustrated) is a windrose to be used by navigators for identifying the direction of the prevailing winds. On the bottom of the diptych is an epact, a device used to calculate the date of Easter.





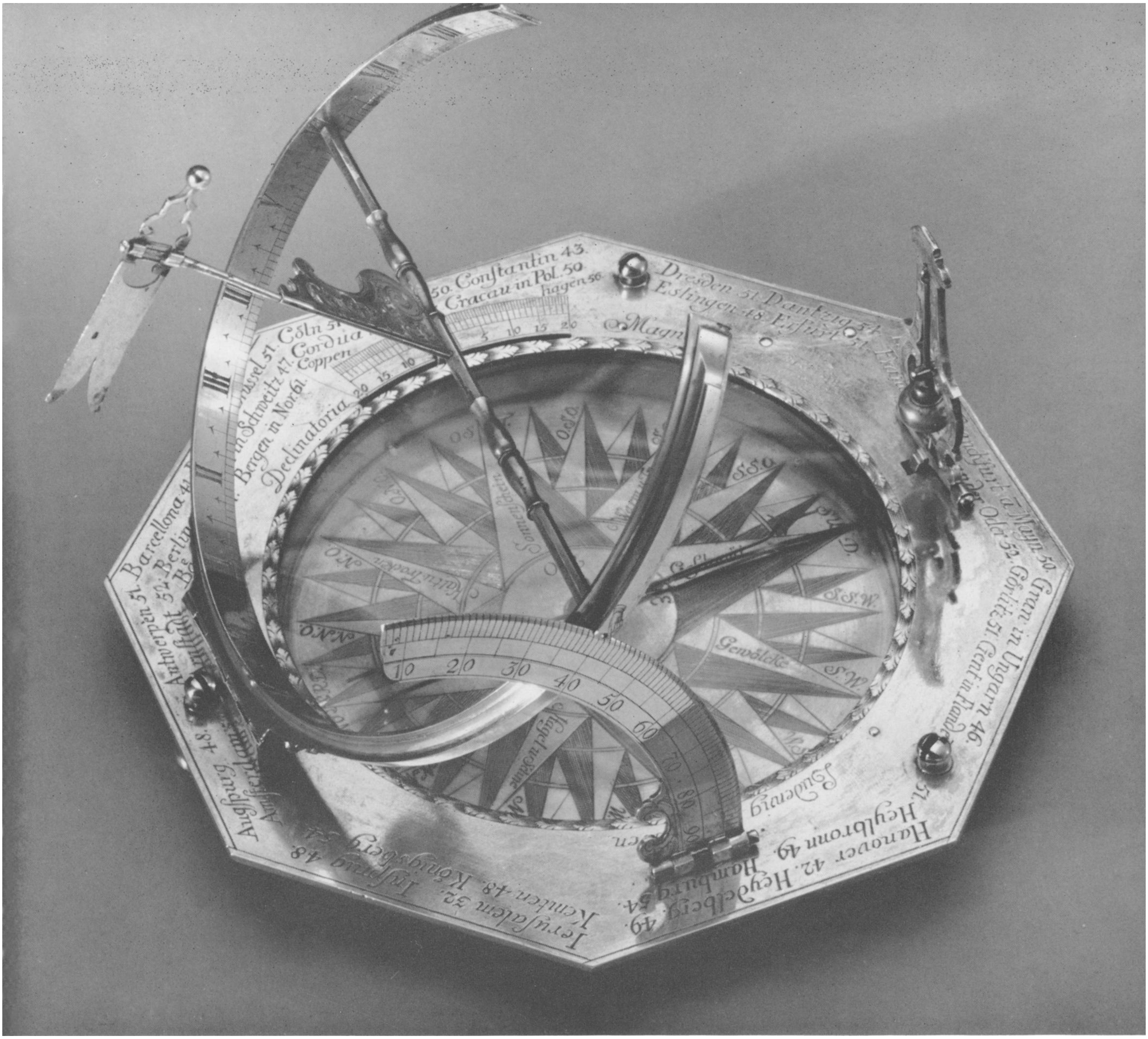
10. Portable sundial and moondial probably made by Johann Martin. The sundial, basically a horizontal one (see Technical Aside), is oriented to the north by a central, recessed compass, which, like the folding level with a plumb, is characteristic of Augsburg portable dials. In this dial the level serves the additional purpose of anchoring the string style, now missing. The style, like the one on the Reinman dial (Figure 8), was adjustable for only a few latitudes, and those are not very far apart. The outermost ring of numbers, giving the hours of the day, is divided with precision, although still not to a period of less than half an hour. No provision was made for the change in calibration of the hour lines required when the dial is used in more than one latitude. Martin's dial retains the seventeenth-century tendency to combine several functions in one instrument, for as its inscription indicates it is also a moondial. When the innermost ring is revolved into the position governed by the age of the moon (calibrated on the middle dial), it registers the hours by moonlight. The moondial in this illustration is set for use on December 1, 1967. German (Augsburg), about 1700. 2 x 2⅝ x 2½ inches. Acc. no. 03.21.61



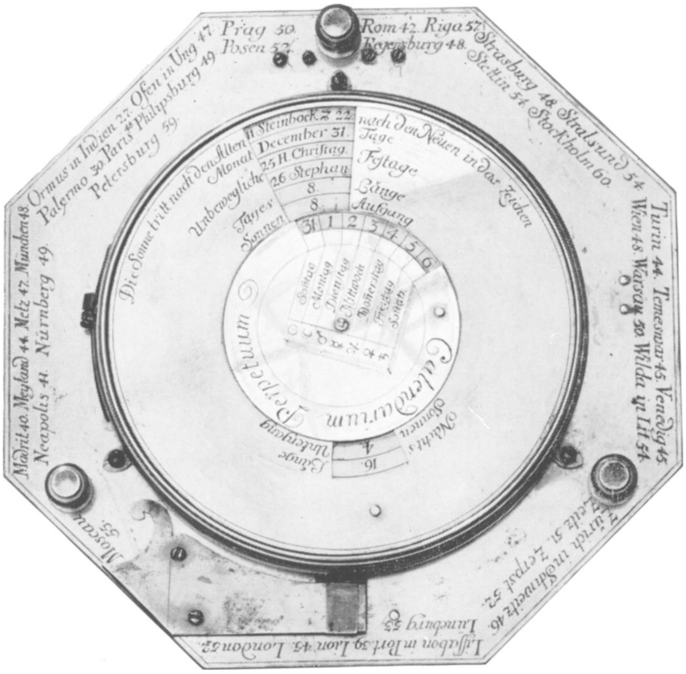


11, 12. Portable equatorial, or equinoctial, sundial of the type invented in Augsburg. In these dials, the dial plate of the horizontal sundial is replaced by a hinged ring that when positioned for the correct latitude and oriented to the north is parallel to the earth's equator (see Technical Aside and Figure 7). Hence the name equatorial sundial. The pointer, or gnomon, is attached perpendicularly to the hour ring so that it is automatically parallel to the earth's axis whenever the instrument is correctly positioned. The gnomon projects either above or below the ring according to the sun's place on its ecliptic, above or below the equator, so that its shadow can always be read on the interior of the hour ring. The ring's advantage is that the hour lines can easily be marked off, using equal divisions of the circle (15 degrees per hour), and that it is adjustable for use in any latitude by means of a graduated quarter circle or quadrant. The silver hour ring, level, and quarter circle fold flat when the dial is not in use.

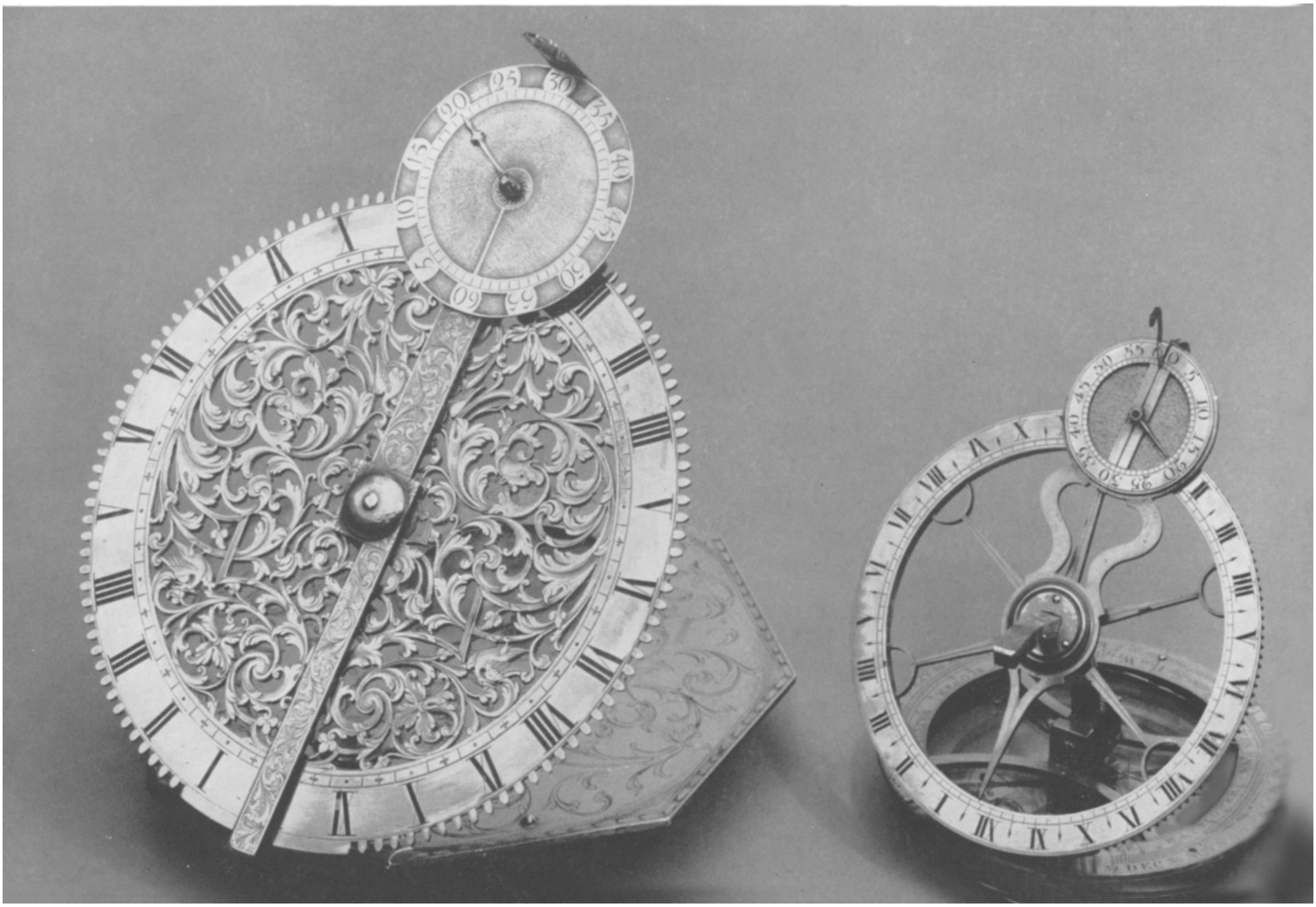
The reverse shows Willebrand's signature. The engraved spring of silvered brass at the bottom of the plate serves to support the level. The slot and pinhole device is used to adjust the compass for local variations in the magnetic field. Made by Johann Willebrand, German (Augsburg), first quarter of the XVIII century. Size of compass plate 3¾ x 3¹⁄₁₆ inches. Acc. no. 03.21.43

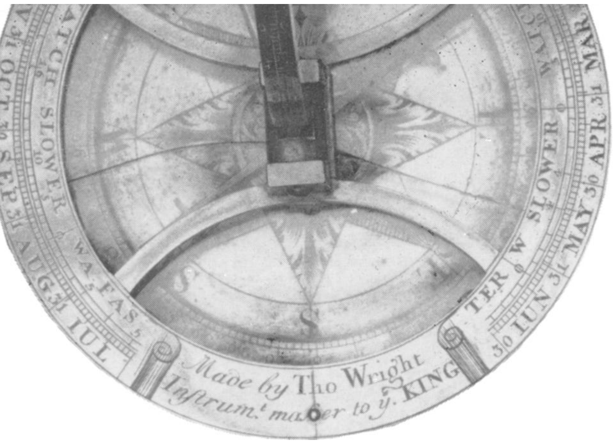


13. Portable equatorial sundial signed "Ludewig, Dresden." Brass with silver fittings. Like the Willebrand dial, it serves to illustrate German refinements in dial calibration, here scaled to five-minute intervals on the hour ring and to one degree of latitude (indicated by the tiny pointing finger on the molding of the silver hour ring). In this illustration, the hour ring is set for use during the summer months at latitude 42 degrees north. With the flag-shaped wind gauge at the end of the gnomon, the compass also serves as a windrose. German (Dresden), about 1725. Diameter of compass plate 5⅛ inches. Acc. no. 03.21.22



14. Reverse of the dial in Figure 13. The central circle is a perpetual calendar showing the day of the week. The sign of the zodiac (Capricorn), the month of the year (December), the number of days in the month (31), the most important festivals of the month (Christmas, St. Stephen's Day), the length of the day and of the night, and the hours of sunrise and sunset are all shown through slots cut to reveal the revolving circle of the calendar. Around the edge of the plate various city latitudes are inscribed.



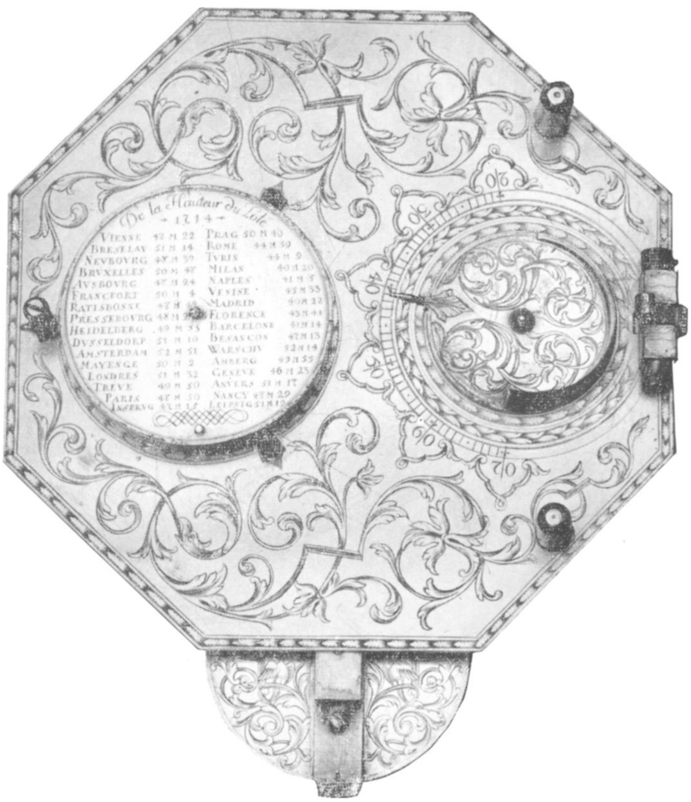


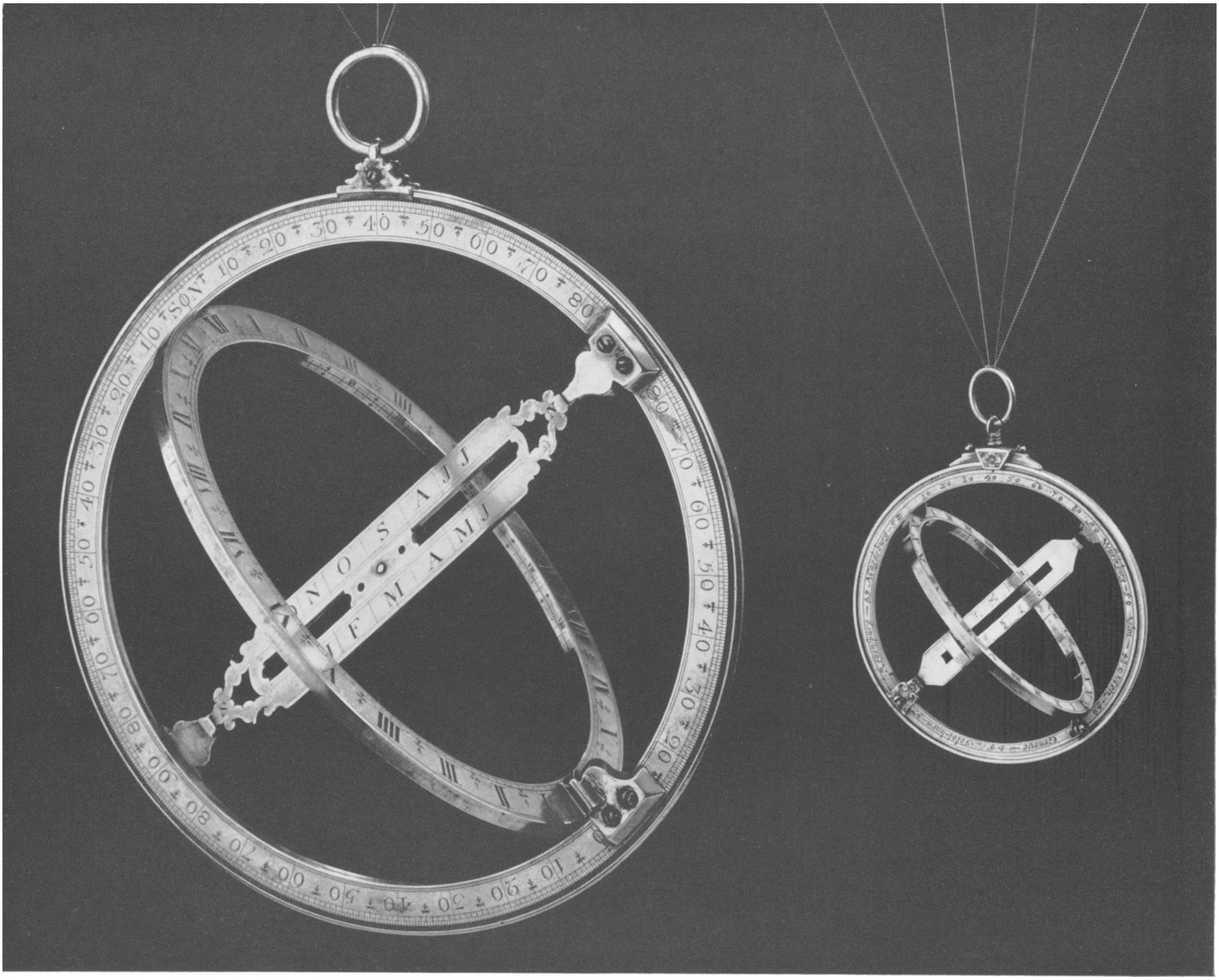
15-17. Two portable dials with minute wheels (opposite). Both are basically equatorial dials, oriented so that their hour plates are parallel to the equatorial plane. Because the style of the larger dial is missing, the principle of Bergauer's invention is better understood on the instrument on the right. A small wheel divided into sixty minutes is geared to the larger circle of hours. The minute wheel is moved along the circumference of the hour wheel until the shadow of the style attached to the minute wheel falls directly on the diameter engraved on it. At this moment the hand on the small dial points to the minute, and the pointer on the larger ring indicates the hour.

Both dials in the illustration opposite register the time 12:20 P.M. The dial on the left is by Claude Dunod. German (Düsseldorf), 1714. Diameter of compass plate 5½ inches. Acc. no. 03.21.37. The dial on the right is by Thomas Wright. English (London), 1726-1748. Diameter of compass plate 3¼ inches. Acc. no. 03.21.52

The detail of the compass plate (above) on the smaller dial shows Wright's signature. The one-minute calibration of these dials accentuated the difference between sundial time and clock time. A clock records an arbitrary twenty-four-hour day. But the sundial's day, due to one rotation of the earth, is measured from the sun's zenith of one day to the sun's zenith of the next. The period may be more or less than twenty-four hours, because of the sun's slight motion along the ecliptic during the course of a day. Clock time is called mean time, and sundial time, solar time. The relation between the two is represented by the scale marked "watch slower, watch faster" on the compass plate of the dial (the relationship is called the equation of time), indicating that the minute dial was used in the second quarter of the eighteenth century for the regulation of pocket watches.

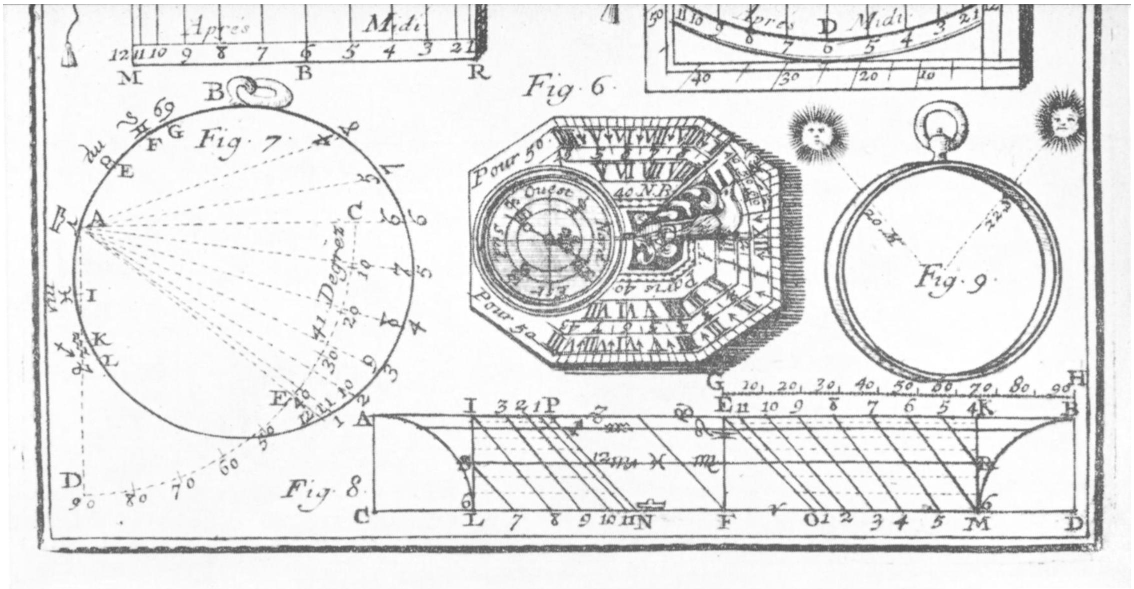
The reverse of the Dunod dial (right) shows the ingenious circular device with an inclined flange used for positioning the ring of hours at the correct latitude. The plate is of engraved brass, the chart of city latitudes of silver, and the latitude setting device of silvered brass.





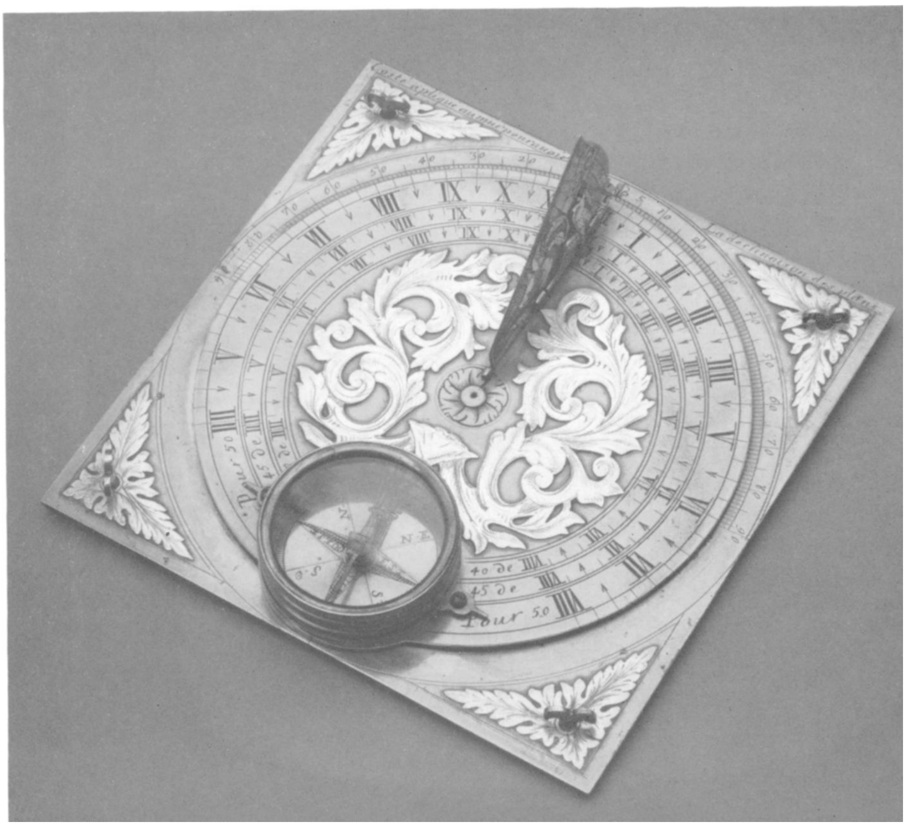
18. The larger universal ring dial of brass is set as illustrated here for use on March 30 or September 20 at latitude 40 degrees north. The outer circle is graduated to show the latitudes, and the inner circle fixed perpendicularly to it shows the hour lines. The months of the year are marked on the rotating flat plate on a diameter of the outer circle. The flat plate is equipped with a sliding index pierced by two pinholes. One pinhole is set opposite the appropriate month of the year, after which the suspension ring, attached to a clip that slides along the outer edge of the latitude circle, is fixed for the appropriate latitude. Then the whole instrument and the flat plate are rotated until a ray of sunlight passes through the pinhole and strikes the inside edge of the hour ring, giving the correct hour. When the light strikes the hour ring the instrument becomes a small model of an armillary sphere (Figure 3), the latitude circle being the meridian, the hour circle, the equator, and the diameter plate, the polar axis. On this dial, Collier calibrated the latitudes for the entire northern and southern hemisphere. The smaller universal ring dial, which, because of the character of its engraving and the location of the majority of the city latitudes, is probably of German origin, is graduated for use in only one hemisphere.

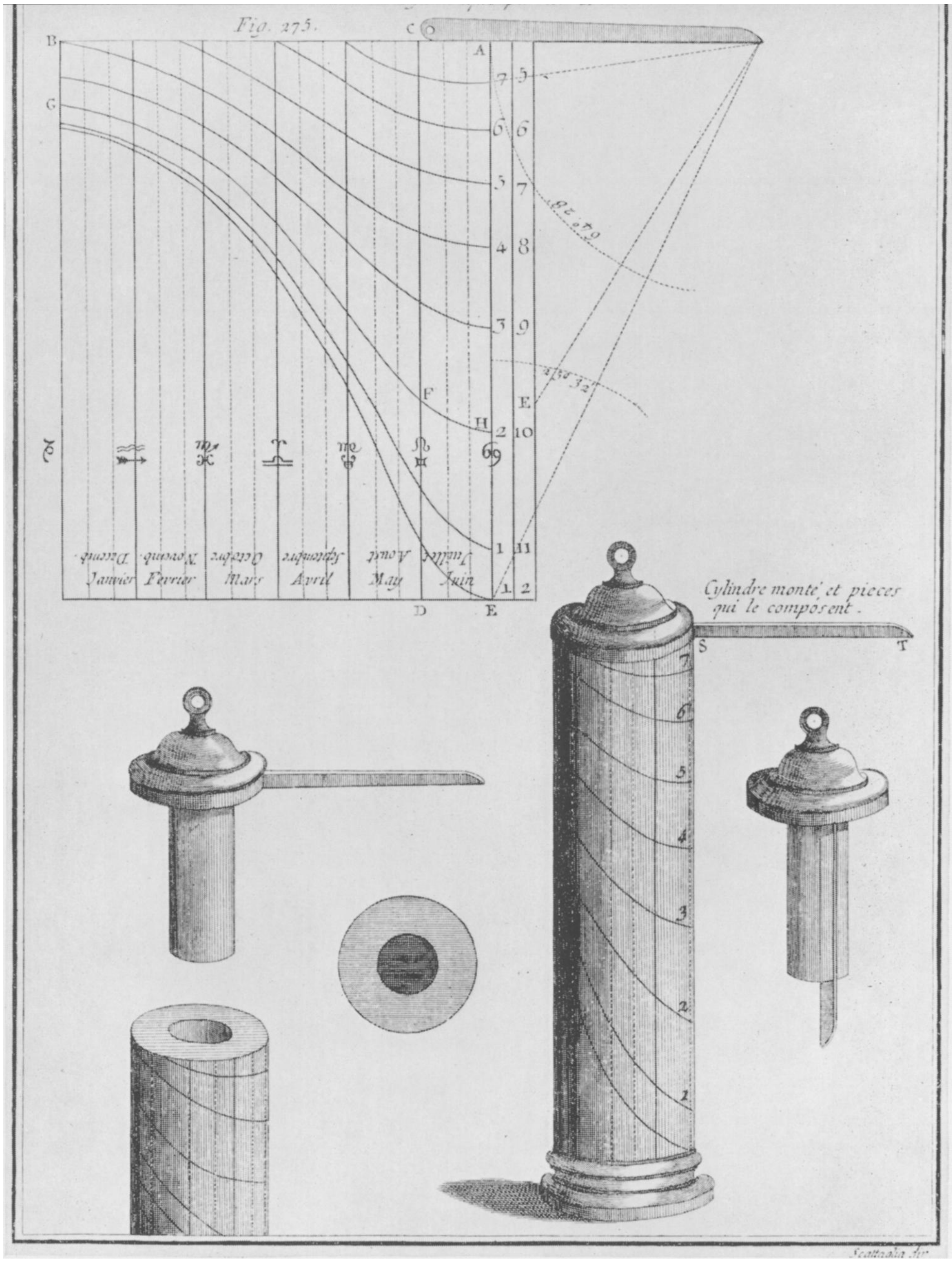
The larger ring is signed "Will. Collier. Londini, Fecit." English, about 1707-1730. Diameter 8½ inches. Acc. no. 03.21.50. The smaller dial, of gilded brass, as illustrated is set for use in mid-December at latitude 41 degrees north. Probably German, first half of the XVIII century. Diameter 2⅝ inches. Acc. no. 03.21.20



19. Design for a portable horizontal sundial known as a Butterfield dial (Figure 6 in the diagram) and three diagrams showing the principle and calibration of a local ring dial. Detail of plate 31 from the third edition of Nicolas Bion's *Traité de la Construction et des Principaux Usages des Instruments de Mathématique* (Paris, Michel Brunet, 1725). Bion was instrument maker to Louis XIV. Dimensions of this detail 5 x 7¼ inches. Bequest of W. Gedney Beatty, 41.100.8

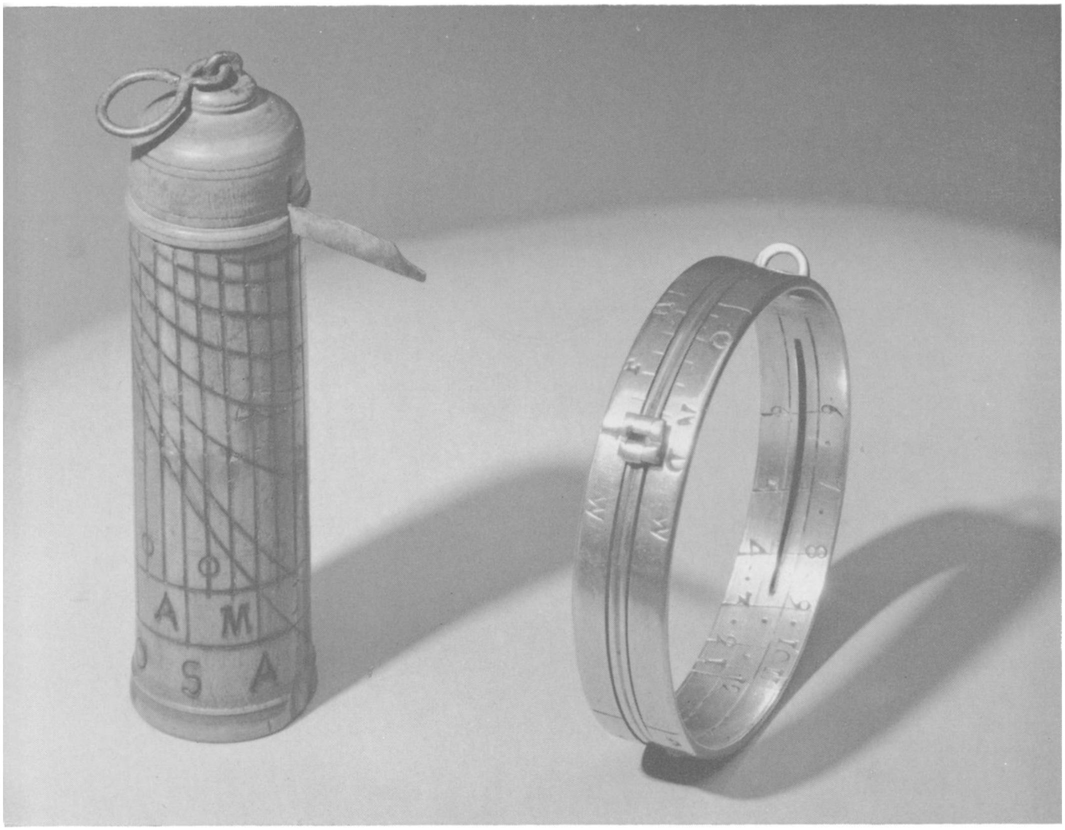
20. Brass and silver instrument used for making sundials. The style may be adjusted for use from latitude 40 to 50 degrees. French, late XVII – early XVIII century. 5¼ inches square. Acc. no. 03.21.17





21. Diagrams showing the construction of a cylinder dial. The angle formed by a line dropped from the tip of the gnomon to the twelve o'clock line of the longest day (top section) governs the latitude of the instrument's use. Diderot and d'Alembert, *Encyclopédie méthodique: Mathématiques*, III, p. 116. Engraving, 9⅝ x 6⅞ inches. Photo: Taylor & Dull

22. The local ring dial, or altitude ring dial (on the right), is set for use in mid-December. The changes in the sun's position in the ecliptic throughout the year are partly compensated for by the collar on the exterior. This contains a pinhole, and slides along two slots in the ring, one for the winter months and one for the summer. But the accuracy of the dial remains rather poor, and it can be used in one latitude only. English, probably about 1730. Diameter 2⅛ inches. Acc. no. 03.21.23. The pillar dial or cylinder was made for use on the latitude circle of 50½ degrees only, or on a line running through Cornwall, south of Brussels, Cologne, and Dresden, and east to Poland. European, XVIII or XIX century. Height 3 inches. Acc. no. 03.21.31



23. Portable wooden cube dial with paper facing, consisting of four vertical sundials and one horizontal dial. The multiplicity of dials increases the accuracy of the instrument. All are oriented by the compass on the base and adjusted for latitude by means of a hinge on the supporting post. German (Nuremberg), early XIX century. Height 7⅛ inches. Acc. no. 03.21.8