

## The Planar and the Spherical Sundials of the Archaeological Museum of Athens

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### Abstract

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*The two ancient marble sundials described in this work are of planar and spherical type; they are kept in the National Archaeological Museum of Athens with index numbers 13365 and 13366 respectively. Their gnomons have been lost. From elaborately measurements of its geometrical dimensions and further calculations, the sundials are classified into subtypes of planar and spherical sundials respectively.*

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### 1. Planar Sundials

The surface of the dial of planar sundials is flat and according to their orientation they belong to one of the following four subtypes:

- horizontal dials (the dial face lies parallel to the horizon)
- prime vertical dials (the dial face lies parallel to the prime vertical plane)
- meridian dials (the dial face lies parallel to the meridian plane) and
- deviating dials (the dial face does not lie parallel to the prime vertical or the meridian)

The flat dial surface consists of the hour lines, the summer solstice curve, the winter solstice curve and the curve of equinoxes. The shape of the grid line depends on the subtype of the planar sundial. The gnomon of the sundials is fixed outside the dial face and its shadow indicates the daily hours.

In the subtype of prime vertical dials are also included the vertical dials of southern orientation. Their dial face is of semicircle shape and is divided into 12 parts by 11 hour lines starting from a central gnomon hole. The two carved horizontal lines, equal to the diameter of the semicircle, define the sunrise and the sunset. It should be mention that till now gnomons of this type of sundials have not been found; probably gnomons were initially fixed perpendicular to the vertical dial (Gibbs, 1976).

### 2. Spherical Sundials

The surface of the dial of spherical sundials is spherical and according to the shape of their grid lines and the position of the gnomon point, the spherical sundials belong to one of the following six subtypes:

- a) hemispherical dials with central gnomon point

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- b) hemispherical sundials with noncentral gnomon point
- c) roofed spherical dials
- d) cut spherical dials with central gnomon point
- e) quarter spherical dials with central gnomon point and
- f) the spherical globe.

The spherical dial surface consists of: the hour lines, the summer solstice curve, the winter solstice curve and the curve of equinoxes. The shape of the grid line depends on the subtype of the spherical sundial. The gnomon of the sundials is fixed: in the center of the spherical dial face, within the spherical dial face but in the centre or on the spherical surface as in the roofed dials (Gibbs, 1976). The shadow of the gnomon indicates the daily hours.

### **3. The sundial of the Archaeological Museum of Athens with index no. 13365**

The ancient Greek sundial of the Archaeological Museum of Athens with index catalog no. 13365 is a planar one. It dates from late antiquity (Kraus, 1991); the place where it was found is unknown. It is made of marble; its shape is semicircular; its weight 4.3 kg. Its height along the meridian line is 22.0 cm; its width 31.0 cm; its depth is 3.0 cm.

The dial's surface and the gnomon hole in the central point of the dial's surface are preserved in good condition. The length of 11 hour lines and the other two on both sides of the gnomon hole measures 26.0 cm; value that coincides to the length of the diameter of the semicircle. In the external edge of the dial, a curve which defines the curve of the summer solstice is clearly obvious. Another less obvious curve is carved closely to the gnomon hole; it defines the curve of the winter solstice.

The lengths of the hour lines from left to right, are given in Table I, measured from the hole of the gnomon to the summer and winter solstice curves. The lengths of the successive arcs formed on the curves of the summer and winter solstices from the intersections of the hour lines with them are also given in this table.

<b>Table I: Lengths of the hour lines and lengths of arcs on the curves of the sundial no. 13365</b>					
Number of hour line (left-to-right)	From the hole of the gnomon to the winter solstice curve (cm)	From the hole of the gnomon to the summer solstice curve (cm)	Between the hour lines:	Lengths of arcs on the winter solstice curve (cm)	Lengths of arcs on the summer solstice curve (cm)
1st	4.4	14.4	Edge – 1st	1.5	4.2
2nd	4.5	15.8	1st – 2nd	1.3	4.3
3rd	4.6	17.2	2nd – 3rd	2.1	4.2
4th	4.7	17.7	3rd – 4th	2.1	4.3
5th	4.7	18.5	4th – 5th	2.1	4.2
6th*	4.7	18.8	5th – 6th	2.1	4.6
7th	4.6	18.7	6th – 7th	2.2	5.1
8th	4.5	18.1	7th – 8th	2.1	4.8
9th	4.3	16.8	8th – 9th	2.1	4.2
10th	4.3	16.0	9th – 10th	2.1	4.2
11th	4.3	14.5	10th – 11th	2.3	4.2
			11th–12th	2.2	4.5

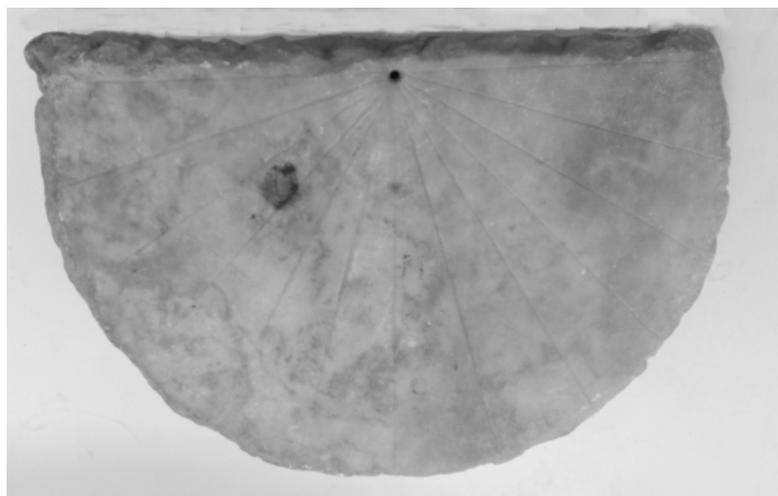
\* The sixth hour line corresponds to the meridian hour line

The gnomon of the sundial is not preserved. In the place of the lost gnomon there is a circular hole; its diameter is 0.6 cm and its depth 1.2 cm. Along the meridian hour line and at a distance of 5.0 cm from the hole of the gnomon, there is a smaller hole; its depth is 0.4 cm. Between the 2<sup>nd</sup> and the 3<sup>rd</sup> hour line there is a characteristic black-colored spot.

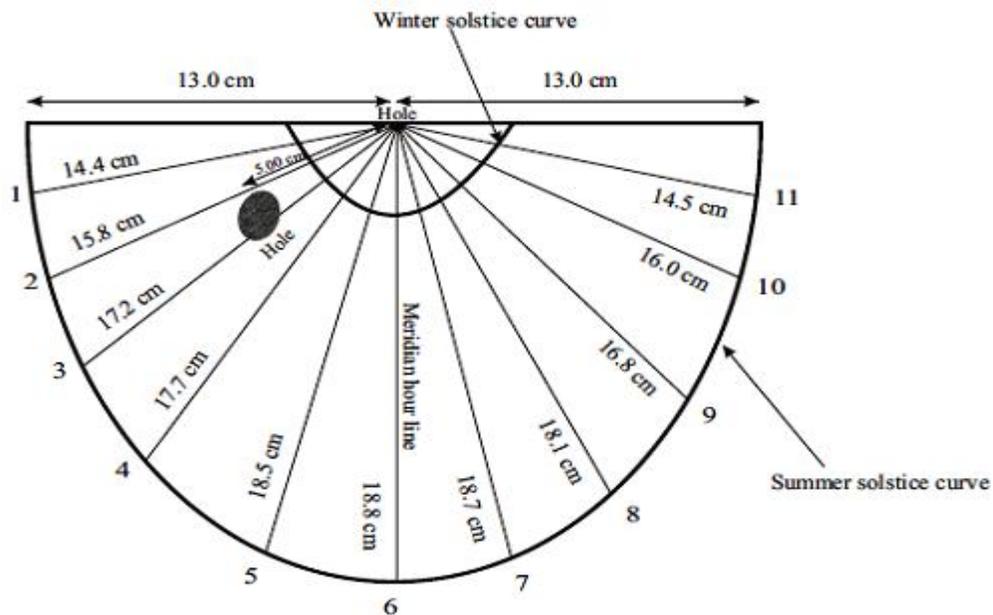
Based on a circle with radius 9.0 cm from the hole of the dial, the angles formed between the hour lines are calculated and the lengths of the successive arcs formed on this curve from the intersections of the hour lines with it are measured and are given in Table II.

<b>Table II: Angles between the hour lines</b>			
Between the hour lines:	Lengths of arcs on the semicircle curve with radius 9.0 cm (cm)	Angles between successive hour lines (rad)	Angles between the successive hour lines (degrees)
Edge – 1 <sup>st</sup>	2.6	0.29	16.55
1 <sup>st</sup> – 2 <sup>nd</sup>	2.4	0.27	15.28
2 <sup>nd</sup> – 3 <sup>rd</sup>	2.3	0.26	14.64
3 <sup>rd</sup> – 4 <sup>th</sup>	2.2	0.24	14.01
4 <sup>th</sup> – 5 <sup>th</sup>	2.2	0.24	14.01
5 <sup>th</sup> – 6 <sup>th</sup>	2.2	0.24	14.01
6 <sup>th</sup> – 7 <sup>th</sup>	2.4	0.27	15.28
7 <sup>th</sup> – 8 <sup>th</sup>	2.4	0.27	15.28
8 <sup>th</sup> – 9 <sup>th</sup>	2.4	0.27	15.28
9 <sup>th</sup> – 10 <sup>th</sup>	2.4	0.27	15.28
10 <sup>th</sup> – 11 <sup>th</sup>	2.4	0.27	15.28
11 <sup>th</sup> – 12 <sup>th</sup>	2.5	0.28	15.92

The line grid of the dial is asymmetric on both sides of the meridian hour line. Thus, the angles formed among them are not symmetrically distributed on both sides of the meridian hour line. The total angle formed between the left-side-edge and the 12<sup>th</sup> hour line measured  $180^{\circ} 48'$ , which is theoretically expected because of the shape of the dial. Thus, the sundial is a south-facing vertical one, while its lost gnomon was probably extended perpendicularly from the vertical dial surface.



**Figure 1: The planar sundial of semicircular shape of the National Archaeological Museum of Athens (no. 13365).**



**Figure 2: Drawing of the line grid of the planar sundial of semicircular shape of the National Archaeological Museum of Athens (no. 13365).**

#### **4. The sundial of the Archaeological Museum of Athens with index no. 13366**

The ancient Greek sundial of the Archaeological Museum of Athens with index catalog no. 13366 is a quarter spherical one. It dates from Roman period (Kraus, 1991); the place where it was found is unknown. It is made of marble and incorporates a marble base. The whole construction weights 7.8 kg. Its height ranges from 20.0 cm to 23.0 cm; its depth till to 21.0 cm and its width is 17.0 cm.

The sundial's base bears a lion's foot with 4 toes. The dimension of the base are: height 10.0 cm; width 12.0 cm and depth 11.0 cm. Both dial and base are not preserved in good condition. Certain surface alterations there are on the 1<sup>st</sup> and the 4<sup>th</sup> toe from the left-hand toe to the right-hand one. The dial's surface is 3.0 cm thick. Its maximum width is 17.0 cm; its maximum height 13.0 cm and its depth 9.0 cm. On the dial's surface 6 carved hour lines and segments of two curves (the upper curve and the main curve) are clearly visible. It is quite probable that these curves define the winter solstice curve and the equinoxes curve.

Only two arcs are discernible in the upper line curve, due to certain surface alterations. The starting point of the 3<sup>rd</sup> hour line is the ending point of the left-hand-side arc whose length is 7.0 cm while the starting point of the right-hand-side arc whose length is 4.4 cm coincides with the starting point of the 5<sup>th</sup> hour line.

The lengths of the hour lines from left to right are listed in Table III, measured from the upper curve to the mail curve of the dial and from the main curve to the lowest edge of the dial.

Number of hour line (left-to-right)	From the upper curve to the main curve (cm)	From the main curve to the lowest edge of the dial (cm)	From the upper curve to the lowest edge of the dial (cm)
1 <sup>st</sup>	2.3	-	2.3
2 <sup>nd</sup>	(2.8 + 1.0)	1.9	6.8 (+0.3 thick of missing part)
3 <sup>rd</sup>	4.6	4.3	8.9
4 <sup>th</sup>	4.0	4.6	8.6
5 <sup>th</sup>	4.7	3.6	8.3
6 <sup>th</sup>	4.0	-	4.0

The lengths of the successive arcs formed on the upper curve and the main curve from the intersections of the hour lines with them are given in Table IV.

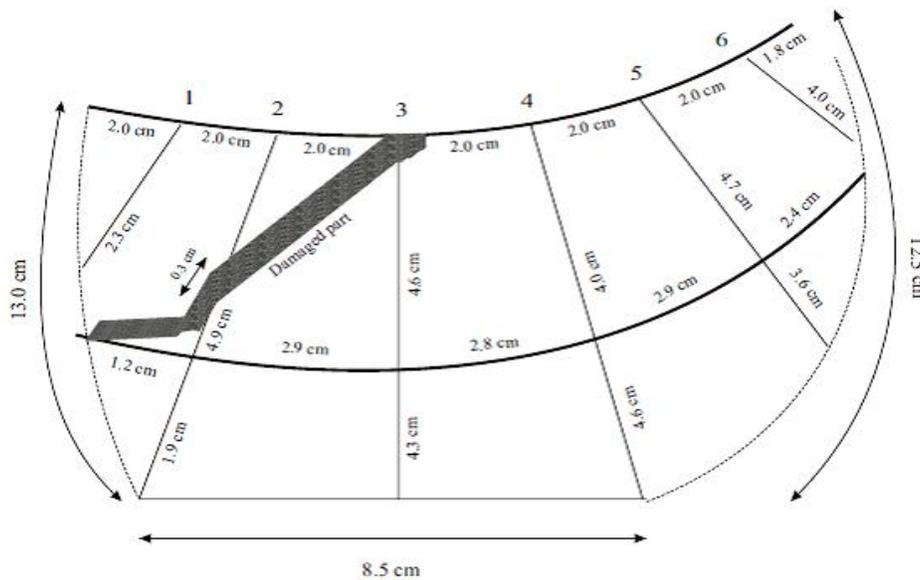
Between the hour lines:	Lengths of arcs on the upper curve (cm)	Lengths of arcs on the main curve (cm)
Edge – 1 <sup>st</sup>	2.0	broken
1 <sup>st</sup> – 2 <sup>nd</sup>	2.0	1.2
2 <sup>nd</sup> – 3 <sup>rd</sup>	2.0	2.9
3 <sup>rd</sup> – 4 <sup>th</sup>	2.0	2.8
4 <sup>th</sup> – 5 <sup>th</sup>	2.0	2.9
5 <sup>th</sup> – 6 <sup>th</sup>	2.0	2.4
6 <sup>th</sup> – 7 <sup>th</sup>	1.8	broken

There are visible alterations in the upper part of the sundial. A prominent one is a crack 0.3 cm thick at left upper edge of the dial; specifically distributes in the left side of the 2<sup>nd</sup> hour line and in the right side of the 3<sup>rd</sup> hour line. The crack extends to the back side of the construction at 9.0 cm depth. Moreover, the old index number (E377) of the sundial is obvious in the central part of the dial, written in black.

The sundial no. 13366 is not in a good condition and does not have a gnomon. The summer solstice curve does not exist; it probably coincides with the frontal curve part of the dial. The 4<sup>th</sup> hour line measuring from the left has not any serious alterations. Considering that this is the radius of the sphere the whole length of the arc on the upper curve is equal to 1/4 of the length of the great circle of the sphere with radius 8.6 cm. The length of the great circle of the sphere is 54.0 cm. According to Table IV the whole length of arcs on the upper curve is 13.8 cm; very close to the value 13.5 cm which is expected. Thus, the sundial is certainly of quarter spherical type.



**Figure 3: The quarter spherical sundial of the National Archaeological Museum of Athens (no. 13366).**



**Figure 4: Drawing of the line grid of the quarter spherical sundial of the National Archaeological Museum of Athens (no. 13366).**

### 5. Conclusions

The planar sundial with index no. 13365 is preserved in good condition; its gnomon does not exist. Although the dial is asymmetrically constructed with respect to the meridian hour line, the whole sundial's construction is quite accurate.

From the geometrical characteristics of the dial, the total angle formed between the most left-side-edge and the most right-side-edge measured  $180^{\circ} 48'$ , which is theoretically expected because of the semicircular shape of the dial. The sundial is a south-facing vertical one, while its lost gnomon was probably extended perpendicularly from the vertical dial surface.

The sundial with index no. 13366 is not preserved in good condition; its gnomon does not exist. Taking into account the present-day measured lengths of the hour lines and curves, it is clearly that the sundial is of quarter spherical type.

### ***Acknowledgments***

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