Chapter 20 (Oechslin: 2.2)

Klein's geographic clock in Prague (c1732-1737)

This chapter is a work in progress and is not yet finalized. See the details in the introduction. It can be read independently from the other chapters, but for the notations, the general introduction should be read first. Newer versions will be put online from time to time.

20.1 Introduction

The clock described here was completed probably around 1732-1737 by Jan Klein (1684-1762) (figure 20.2).[1]

Klein was born in Česká Kamenice, now in the Czech Republic.[2] After having been in a Jesuit school, he entered the order of the Jesuits in 1703. He studied and taught mathematics, astronomy and mechanics. In 1732, he became director of the mathematical museum in the Clementinum College and remained in this position until his death.

His biographer Pelcl also mentions that besides his astronomical and geographical clocks, Klein has constructed a large number of other works of art, in particular a moving sphere, an elliptic clock, a quadrant, etc. He also made automata, for instance an automatic harp, a drum, a moving tortoise, etc.

[1]This clock has been dated from 1753 by Böhm [2], but Engelmann [7] believes that it was made around 1732-1737, and that it is the clock which was copied for the Dresden geographical clock made in 1738. The same position was held by Grötzsch [9] and I have decided to follow Engelmann and Grötzsch, in particular because the Dresden clock has a simpler mechanism than the one from Prague. Oechslin also dated the clock to 1753 [14], and was apparently unaware of Engelmann's article. Pařízek [17] dates this clock around 1760.

[2]Biographical information on Klein is scarce. Almost all that we know comes from Pelcl's 1782 account [18, p. 137-141]. In 1751, Stepling didn't give any biographical details on Klein [23]. In his 1791 account, Strnadt borrows from Stepling and Pelcl [24]. Böhm [2] gives a very brief one-page biographical notice on Klein, which is mostly drawn from Pelcl [18]. See also Maurice [11, v.1, p. 267-268], Abeler [1], Michal [12] and Šíma [21, p. 84-85, 93-95, 113].

Plassmeyer claims that Klein has also made clocks for the Court of the Chinese emperor in Beijing, but I do not know what his sources are.[3]

Klein died in Prague in 1762.

20.2 Description of the clock

This clock is a geographical clock and belongs to a group of three similar clocks kept in the Clementinum in Prague. It is similar, but slightly more complex, than Klein's geographical clock kept in Dresden and which is dated from 1738 (Oechslin 2.1).[4] Like the clock in Dresden, this clock is inspired by Johann Baptist Homann (1663-1724)'s design of a geographical clock which was constructed in 1705 by Zacharias Landteck (1670-1740) [5, 15] (figure 20.1).

This clock was first described in detail by Böhm in 1863 [2, 3] and in 1910 by Engelmann [7].[5] It was again described by Oechslin in 1996,[6] but Oechslin did not have the opportunity to disassemble the clock and based his description only on that published by Böhm.

It is a table clock with two sides. One side shows the time on a 12-hour dial with additional openings for the day of the month, the sunrise and sunset. The other side shows a fixed the Northern hemisphere, but with a rotating transparent shell representing the part of the Earth which is not lit by the Sun. The Sun rotates around the Earth and there is a ring for the ecliptic.

The common arbor to both sides is arbor 1 which makes one turn in one hour. Measured from the time side, we have

$$\mathrm{V}_1^0 = -24 \tag{20.1}$$

$$\mathrm{P}_1^0 = -\frac{1}{24} = -1 \text{ h} \tag{20.2}$$

[3][19, p. 94]

[4]See Schardin [20, p. 21], Dolz [6, p. 112-113], Michal [12] and Plaßmeyer [19, p. 94-95]. Pelcl also describes Klein's three clocks in Prague, and mentions that a copy of the geographical clock in Prague had to be made for the King August of Poland and is now in Dresden [18, p. 137-141]. Maurice, incidentally, claims that Klein must have made a third geographical clock [11, v.1, p. 268], because Klein's portrait shows a geographical clock which differs both from the Prague and from the Dresden one.

[5]Engelmann slightly adapted Böhm's drawings, but I am not including them here.

[6][14, p. 38, 49-50]

Figure 20.1: Johann Baptist Homann's geographical clock (1705).

Figure 20.2: Left: Portrait of Jan Klein with his geographic clock from 1753/1754. (source: [2]) Right: portrait in Pelcl's biographical notice [18].

20.2.1 The time side of the clock

This side of the clock (figure 20.3) gets its input from arbor 1 which carries the minute hand. This motion is derived from the going work which is not described by Oechslin (see figure 20.4 for Böhm's drawing).

The motion of arbor 1 is certainly transferred to tube 10 which makes a turn in 12 hours, but the details are not given by Oechslin. We thus have

$$\mathrm{V}_{10}^{0} = -2 \tag{20.3}$$

$$\mathrm{P}_{10}^{0} = -\frac{1}{2} = -12 \text{ h} \tag{20.4}$$

The motion of tube 10 is first transferred to arbor 11 which makes a turn in a day:

$$\mathrm{V}_{11}^{0} = \mathrm{V}_{10}^{0} \times \left(-\frac{36}{72}\right) = 1 \tag{20.5}$$

This arbor carries a finger which moves a 31-teeth wheel by one position and this will serve to indicate the day of the month in the lower part of the 12-hour dial, just above the figure VI (figure 20.5). The lengths of the months do not seem to be accounted for.

The motion of arbor 11 is used to obtain the motion of arbor 14:

$$\mathrm{V}_{14}^{0} = \mathrm{V}_{11}^{0} \times \left(-\frac{1}{5}\right) \times \left(-\frac{1}{73}\right) = \mathrm{V}_{11}^{0} \times \frac{1}{365} = \frac{1}{365} \tag{20.6}$$

$$\mathrm{P}_{14}^{0} = 365 \text{ days} \tag{20.7}$$

This arbor carries a cam and this cam is used to move the hours of sunrise and sunset back and forth. These hours are written on a horizontal slider, with the hour of sunrise on the left and the hours of sunset on the right (see figure 20.5). The figures on the left part are given in opposite order as the figures on the right, so that when the sunrise is one hour later, the sunset is also given one hour earlier.

Die Klein'sche Geographische Uhr.
Stundenseite.

Figure 20.3: The front side of Klein's clock. (source: [2])

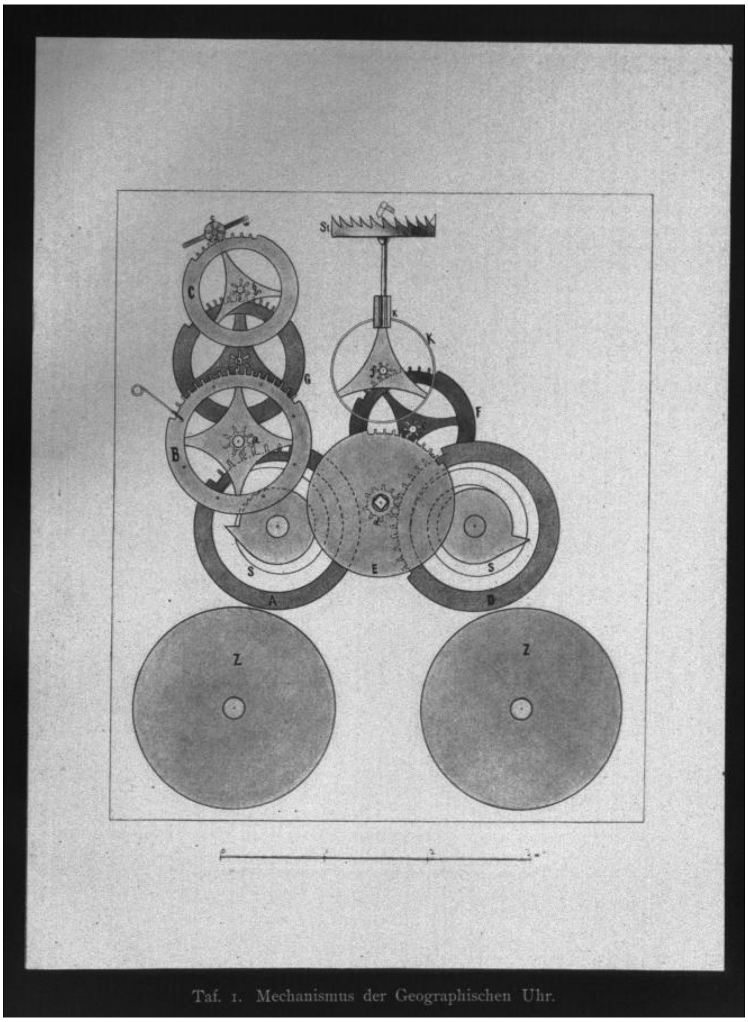

Figure 20.4: Details of the going and striking works of Klein's clock. (source: [2])

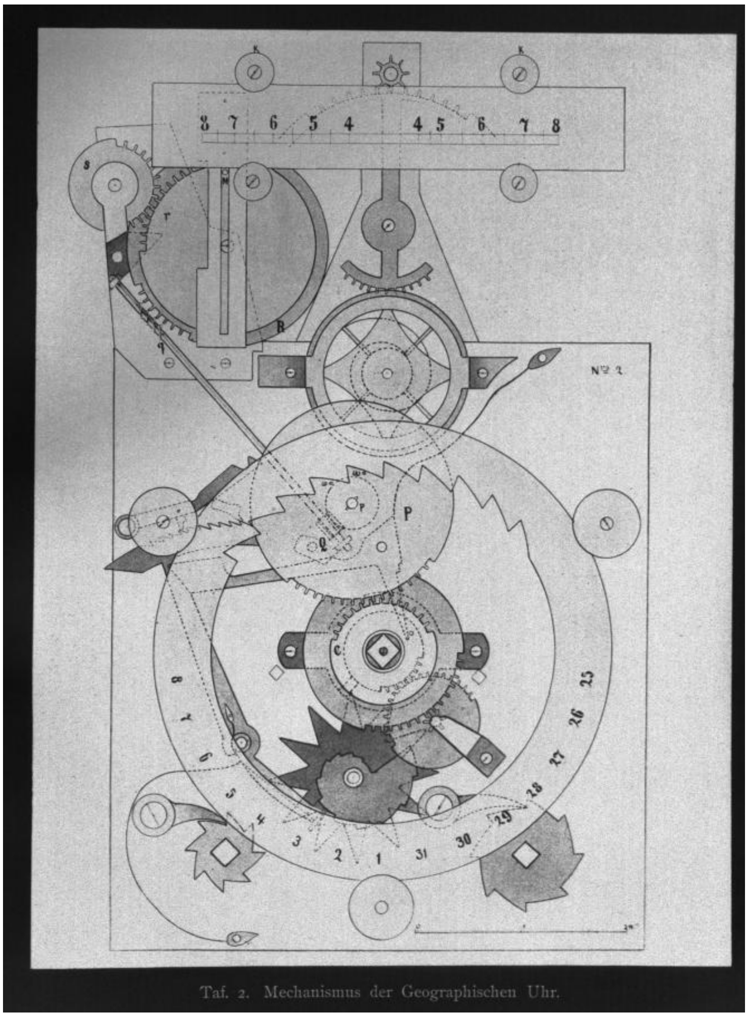

Figure 20.5: Details of the day of the month and sunrise/sunset mechanisms in Klein's clock. (source: [2])

20.2.2 The geographic side of the clock

The geographic side (figure 20.6) of the clock shows a fixed Northern hemisphere and a moving shell shows which part of the globe is lit, and which one is not, taking into account both the diurnal motion of the Sun, and the inclination of Earth's axis on the ecliptic.

The input motion of that side is also arbor 1 which makes one turn clockwise in one hour as seen from the other side:

$$\mathrm{V}_1^0 = -24 \tag{20.8}$$

$$\mathrm{P}_1^0 = -\frac{1}{24} = -1 \text{ h} \tag{20.9}$$

20.2.2.1 The rotating motion of the shell and the Sun

The arbor 1 carries a 3-pin pinion which meshes with a 72-teeth wheel on tube 2, which is on the central axis of the geographic side. The center of this side is therefore higher than the center of the opposite side which is at the level of arbor 1. Tube 2 has the velocity (measured from the geographic side)

$$\mathrm{V}_2^0 = \mathrm{V}_1^0 \times \frac{3}{72} = \mathrm{V}_1^0 \times \frac{1}{24} = -1 \tag{20.10}$$

This tube makes a turn clockwise in one day and carries the transparent shell representing the shadow. This shell is not a hemisphere, but must extend at least $90° + 23.5°$. The clockwise motion is the expected motion, because the apparent motion of the Sun is clockwise.

The shell is also mobile around an horizontal axis (in fact, horizontal on the drawing, but parallel to the dial), but this axis moves with frame 2. The Sun is at a fixed position on frame 2, at right angle with the horizontal axis of the shell, so that the Sun is always in the middle of the lit part of the Earth.

20.2.2.2 The motion of the ecliptic

The ecliptic is represented by a ring 9 located around the Earth, outside of the Sun (part of frame 2), but inside of the 24-hour dial (frame 6). This ring carries an internal 73-teeth wheel, which meshes with a 6-leaves pinion on frame 2 (figure 20.7). The arbor 8 of this pinion carries a 30-teeth wheel which meshes with another 6-leaves pinion on arbor 7, which is also part of the frame 2. Finally, this arbor 7 carries a 6-pointed star wheel which is advanced (meshes) by a finger on the 24-hour dial. In order to compute the motion of the ecliptic, it is best to consider first the motions relative to frame 2. We have

$$\mathrm{V}_9^2 = \mathrm{V}_6^2 \times \frac{1}{6} \times \left(-\frac{6}{30}\right) \times \frac{6}{73} = \mathrm{V}_6^2 \times \left(-\frac{1}{365}\right) = \mathrm{V}_2^0 \times \frac{1}{365} \tag{20.11}$$

Figure 20.6: The geographic side of Klein's clock. (source: [2])

and

$$\mathrm{V}_9^0 = \mathrm{V}_9^2 + \mathrm{V}_2^0 = \mathrm{V}_2^0 \times \left(\frac{1}{365} + 1\right) = \mathrm{V}_2^0 \times \frac{366}{365} = -\frac{366}{365} \tag{20.12}$$

$$\mathrm{P}_9^0 = -\frac{365}{366} = -23 \text{ h } 56 \text{ m } 3.9344\ldots \text{ s} \tag{20.13}$$

The ecliptic ring, or the zodiac, makes a turn clockwise in a sidereal day. This is the expected motion.

20.2.2.3 The oscillating motion of the shell

The shell has a back and forth motion between the two solstices. In Winter, the shell covers the North pole, but in Summer the North pole is lit by the Sun. This is done by having a cam make a turn in one year with respect to the frame 2 (figure 20.7).[7] This motion is introduced within this frame by a finger located on the frame 6 of the 24-hour dial. When frame 2 rotates, a 5-pointed star on arbor 4 meets this finger and rotates the arbor. This motion is then transferred to the vertical arbor 5 which carries the cam. We have

$$\mathrm{V}_5^2 = \mathrm{V}_6^2 \times \left(-\frac{1}{5}\right) \times \left(-\frac{1}{73}\right) = \mathrm{V}_6^2 \times \frac{1}{365} = -\mathrm{V}_2^6 \times \frac{1}{365} \tag{20.14}$$

$$= -\mathrm{V}_2^0 \times \frac{1}{365} = \frac{1}{365} \tag{20.15}$$

$$\mathrm{P}_5^2 = 365 \text{ days} \tag{20.16}$$

The cam acts on a lever which is connected to the shell and causes its oscillation.

In the 1738 clock kept in Dresden (Oechslin 2.1), the motions of the ecliptic and of the shell are obtained by the same gears, which seems a simpler solution than the one used here.

[7] See also [14, p. 148-149] on this construction.

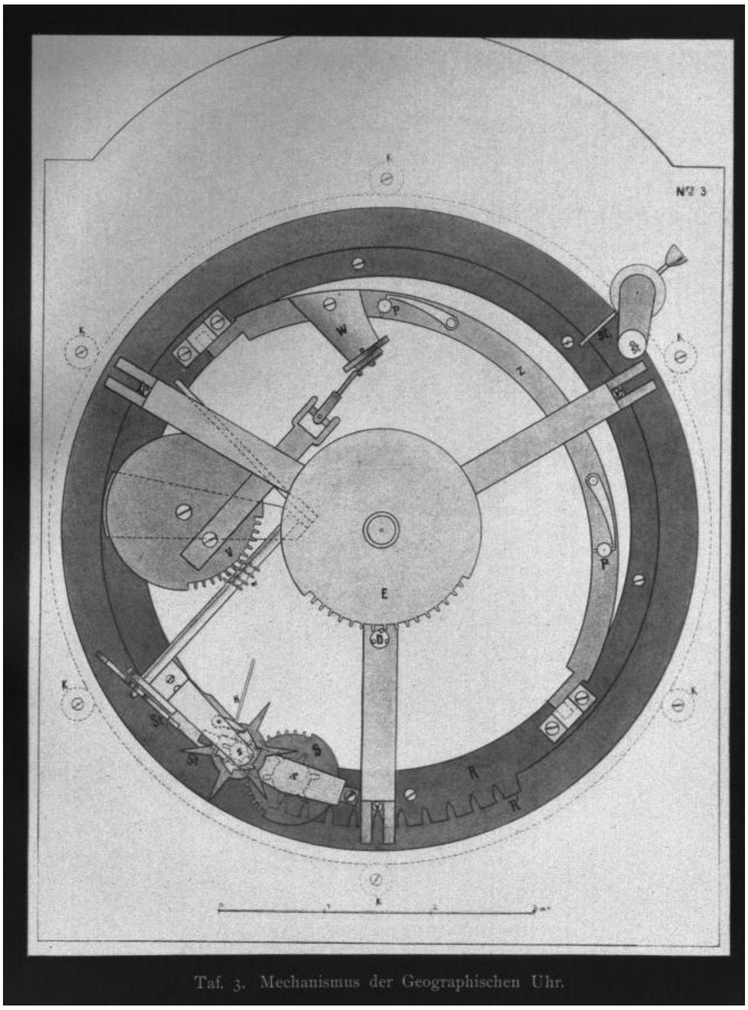

Figure 20.7: Details of the mechanism of the globe in Klein's clock. At the bottom, we can see the internal 73-teeth wheel (R') and the 6-pointed star wheel St. Towards the left, there is the 73-teeth wheel V which carries the cam. This wheel is moved by a worm. The wheel at the center is the 72-teeth wheel E which is part of tube 2. Under it, we can see the 3-pin pinion D making a turn in an hour. (source: [2])

20.3 References

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