

The Same “Hour” Is Half as Long Again in Summer

— At the latitude of Edo a daytime hour lasts **144.2036** minutes at the summer solstice and **95.7964** at the winter solstice, a ratio of **1.505312** — the clocks were not inaccurate; the definition of the unit was different —

[Paper 414]

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— *From thinking to syncing.* —

Abstract

The timekeeping of Edo-period Japan is called inaccurate. This paper shows that it was not inaccurate—that an hour varies by a factor of **1.505312** with the season is not an error but a definition. No new theorem or law is claimed. First, this is the core of the paper. At the latitude of Edo, **35.7** degrees, a daytime hour is **144.2036** minutes at the summer solstice and **95.7964** minutes at the winter solstice (Section 2). Second, the ratio is **1.505312**, and it agrees exactly with the independent expression $\text{day}/(24 - \text{day})$ (Section 2). Third, at the equinoxes the day is exactly **12.000000000** hours and the hour exactly **120.000000000** minutes (Section 2). Fourth, the summer daytime hour of **144.2036** minutes coincides exactly with the winter night-time hour (Section 3). Fifth, at the equator the ratio is exactly 1, and at latitude **60** degrees the solstice day stretches to **18.4898** hours (Section 3). Sixth, the separator is what is being divided into equal parts. Divide the sky and one time results; divide a pendulum and another does (Section 4).

Scope of this paper (scope note): No new theorem or law is claimed—the sunrise equation and the mechanism of seasonal hours are both standard. History is not discussed—the mechanism of Japanese clocks, the calendar reform and regional variation are not the subject. Neither system is called superior—equal hours are not called “progress”. It is a choice of what to divide. Refraction and the solar disc are not included—the computation is purely geometric, and real sunrise is about 7 minutes earlier. The effect on the ratio is small, but the length of the day itself moves. The equation of time is not included—the difference between apparent and mean solar time is not the subject. One latitude is used—35.7 degrees stands for Edo, and variation across Japan is not treated. Relation to earlier papers: Paper 412 showed that “nearest” is not defined until the distance is—here “an hour” is not defined until what is divided is fixed. Paper 300 showed that common root and distinct root can be decided—the seasonal hour and the equal hour are distinct roots by that criterion. Paper 403 showed that the order of temperature is not the order of hotness—here too, a scale with the same name does not point at the same quantity. Paper 411 showed that an invariant can be defined from the side of the transformation—here the unit of time is defined from the side of two events, sunrise and sunset. What is added is giving the length of the hour in minutes for three seasons, matching the ratio against an independent expression, using the exact 12 hours and 120 minutes at the equinoxes as a self-test, showing that the summer day and the winter night coincide exactly, and placing the equator and latitude 60 on either side of the boundary.

1. Notation and the Question

Setting: Under seasonal hours, sunrise to sunset is divided into 6 daytime hours and sunset to sunrise into 6 nighttime hours. The length of the day follows from the sunrise equation.

$$\cos \omega_0 = -\tan \varphi \tan \delta, \quad \text{day} = \frac{2\omega_0}{15} \text{ hours}$$

Take $\varphi = 35.7$ degrees (Edo) and obliquity $\delta = \pm 23.44$ degrees.

Observation 1.1

Under equal hours an hour is always the same. The day is cut into 24—the reference is the rotation of the Earth.

Observation 1.2

Under seasonal hours day and night are divided separately. The reference is sunrise and sunset—and the length of the day changes with the season.

Question: By how much.

2. An Hour Runs from 95.7964 to 144.2036 Minutes

Computation 2.1: Give the length of the day and of an hour for three seasons.

Season	Length of day	Daytime hour	Night-time hour
Summer solstice	14.4204 h	144.2036 min	95.7964 min
Equinox	12.0000 h	120.0000 min	120.0000 min
Winter solstice	9.5796 h	95.7964 min	144.2036 min

Observation 2.2

At the equinoxes the day is exactly 12.000000000 hours and the hour exactly 120.000000000 minutes. Because $\delta = 0$ gives $\cos \omega_0 = 0$ —these round numbers show that the computation is implemented correctly.

Observation 2.3

The summer daytime hour is 144.2036 minutes. More than 24 minutes longer than an equal hour—and it carries the same name.

Computation 2.4: Take the ratio of the summer to the winter daytime hour.

It is 1.505312. Since day and night sum to 24 hours, the same ratio is $\text{day}/(24 - \text{day})$ —and computing it that way gives the same value.

Observation 2.5

The summer hour exceeds 1.5 times the winter one. “Working one hour” differs by more than 50 per cent with the season—this is not an error. It is the value the definition prescribes.

3. Symmetry, and the Effect of Latitude

Observation 3.1

The summer and winter days sum to exactly 24.000000000 hours. Because δ and $-\delta$ are symmetric—another self-test of the computation.

Observation 3.2

The summer daytime hour and the winter night-time hour coincide exactly. Both are **144.2036** minutes—from the same symmetry.

Computation 3.3: Vary the latitude.

At the equator the summer-to-winter ratio is exactly 1. Since $\tan 0 = 0$ gives $\cos \omega_0 = 0$, the day is 12 hours all year—seasonal and equal hours coincide.

At latitude 60 degrees the solstice day stretches to **18.4898** hours. An hour becomes 184.9 minutes—the higher the latitude, the less usable the system.

Observation 3.4

So how well seasonal hours work is set by latitude. At the equator there is no difference; at the poles the day disappears altogether—Japan sits where the seasonal difference is felt and the system still holds.

4. The Separator

The separator: what is divided into equal parts.

Observation 4.1

Equal hours divide the rotation. The reference is the turning of a body—independent of season.

Observation 4.2

Seasonal hours divide the time there is light. The reference is sunrise and sunset—dependent on season.

Observation 4.3

These are distinct roots by the criterion of Paper 300. Both give a time of day, but what is being divided differs—an angle in one case, the daylight in the other.

Observation 4.4

And seasonal hours fitted the life better. When lighting was expensive, work was possible only while it was light—“divide the day into six” meant dividing the usable time into six.

Observation 4.5

That is why the clocks were hard to build. Japanese clocks needed their scales exchanged with the season—the mechanism was complicated not because the craft was primitive but because the definition demanded it.

Observation 4.6

To be honest—144.2036 minutes omits refraction and the solar disc. Real sunrise is about 7 minutes earlier than the geometric one, so the day is somewhat longer—the effect on the ratio 1.505312 is small, but the length of the day itself moves.

Observation 4.7

One last thing—calling the old time “inaccurate” takes equal hours as the instrument. From the other side, it is equal hours that drift away from sunrise—which is accurate depends on what one wants to measure.

5. Roll Call and Closing

1. Summer daytime hour **144.2036 min** (Computation 2.1): **24 min longer**.
2. Winter daytime hour **95.7964 min** (Computation 2.1): **24 min shorter**.
3. Ratio **1.505312** (Computation 2.4): **over 1.5**.
4. The independent expression agrees (Computation 2.4): **day/(24 – day)**.
5. Equinox day exactly **12.000000000 h** (Observation 2.2): **a self-test**.
6. Equinox hour exactly **120.000000000 min** (Observation 2.2): **equal hours agree**.
7. Solstice days sum to **24.000000000 h** (Observation 3.1): **symmetry**.
8. Summer day hour = winter night hour (Observation 3.2): **exactly**.
9. Ratio exactly **1 at the equator** (Computation 3.3): **the other side of the boundary**.
10. **18.4898 h at latitude 60** (Computation 3.3): **approaching breakdown**.

Closing: The timekeeping of Edo-period Japan is called inaccurate—but computing at the latitude of Edo, 35.7 degrees, the daytime hour is **144.2036** minutes at the summer solstice and **95.7964** minutes at the winter solstice, a ratio of **1.505312**. That is not an error but the value the definition prescribes. Since day and night sum to 24 hours the same ratio is $\text{day}/(24 - \text{day})$, and computing it that way gives the same number. At the equinoxes the day is exactly **12.000000000** hours and the hour exactly **120.000000000** minutes, and those round numbers show the computation is right. The symmetries come out exactly too—the summer and winter days sum to exactly **24.000000000** hours, and the summer daytime hour coincides exactly with the winter night-time hour. How well the system works is set by latitude: at the equator the ratio is exactly **1** and the two systems coincide, while at latitude 60 degrees the solstice day stretches to **18.4898** hours and an hour becomes 184.9 minutes. Japan sits where the seasonal difference is felt and the system still holds. One thing separates them—what is divided into equal parts. Equal hours divide the rotation, an angle, and so do not depend on the season; seasonal hours divide the daylight, and so do. They are distinct roots by the criterion of Paper 300, giving the same kind of answer from different divisions. And when lighting was expensive the seasonal system fitted the life better—“divide the day into six” meant dividing the usable time into six. Japanese clocks needed their scales exchanged with the season not because the craft was primitive but because the definition demanded it. To be honest—144.2036 minutes is a purely geometric value that omits refraction and the solar disc; real sunrise is about 7 minutes earlier and the day is somewhat longer. The effect on the ratio is small, but the length of the day itself moves. One last thing—calling the old time “inaccurate” takes equal hours as the instrument. From the other side it is equal hours that drift away from sunrise, and which is accurate depends on what one wants to measure.

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