Essl 290 2021

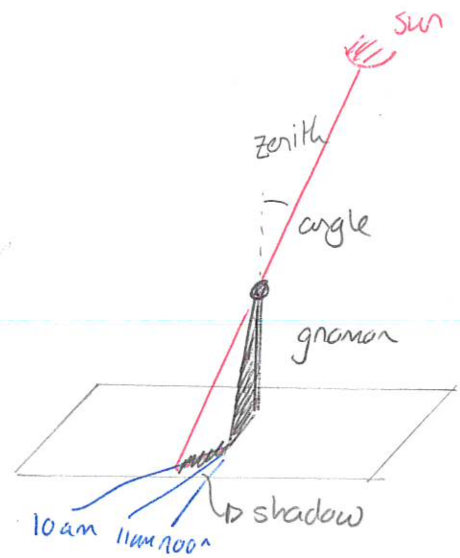
Lecture 7

Mon: HW 2 due 5pm

Weds: Read → Barnett Ch3
→ Mondschein pg 49-54

Local apparent solar time

We can keep time using the apparent motion of the sun either by:



1) measuring angle with respect to the zenith

2) projecting a shadow cast by a gnomon onto a surface. Usually the surface would be calibrate so that the hour can be read without any further calculation

Both of these will depend on:

1) ~~latitude of observer~~
2) day of the year.

One fundamental question is how accurate this is. Can we measure time to an accuracy of
- one hour?
- half hour?
- quarter hour?
- 5 minutes
- 1 minute.

We do an exercise to check.

1 Tracking Sun's motion

It would be difficult to track the Sun's motion by trying to look at the Sun. A more convenient way would be to track the position of a shadow created by the Sun. We can see how well this works for the duration of a portion of a class meeting.

a) Observe the shadow cast by a fixed object onto a sheet of graph paper. Can you see it move?

No

b) Mark the location of a part of the shadow at one instant and record the time at that instant.

2:45pm

c) Record the time when this part of the shadow has moved by one major (thicker) gridline. Determine how much time it takes the shadow to travel one major gridline.

About 6 minutes

d) The instructor will now have you use the moving shadow to tell time. The instructor will tell you to record the *position and time* of the shadow at one moment and then just the position at a later moment. Determine the time (without using a watch or your phone) at this later instant.

start 2:58pm } moves 2 small blocks $= \frac{2}{5} \times 6\,min = 2.4\,min$ 3:00pm

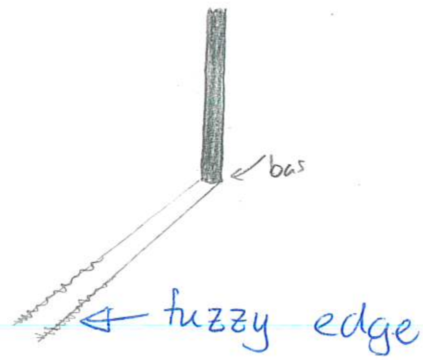
e) Could you use this method of timekeeping to measure time with an accuracy of 1 minutes. How about 30 seconds?

Probably 1 minute ~ approx one small block

30seconds ~ less than one small block. → unlikely

The example illustrates that the accuracy of this shadow tracing for timekeeping might be limited. We might notice that the edges of the shadow are not well defined, especially as they are cast further away from the base of the gnomon.

Locating this fuzzy edge will limit the accuracy of the method.

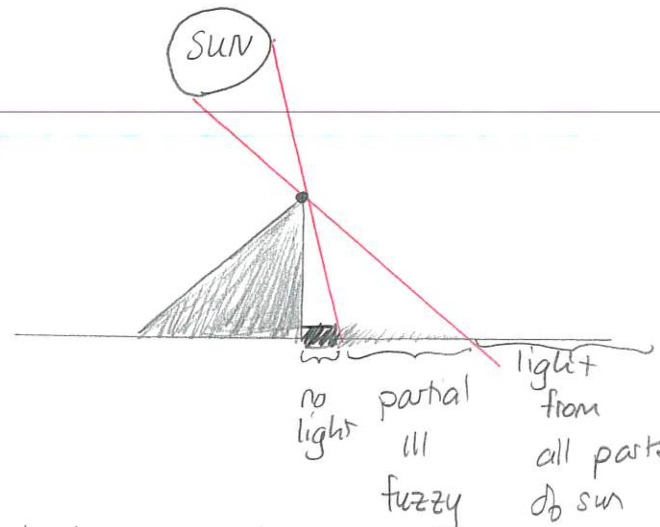


Q The edge is less fuzzy closer to the base. Would this improve accuracy? What would limit the accuracy of the cleaner edge.

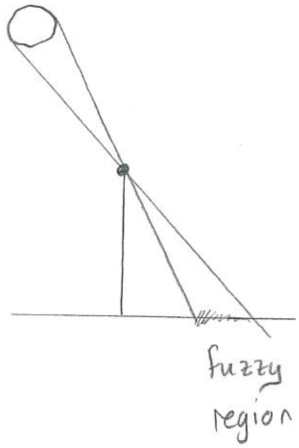
Q What is the fundamental reason for the fuzzy shadow edge?

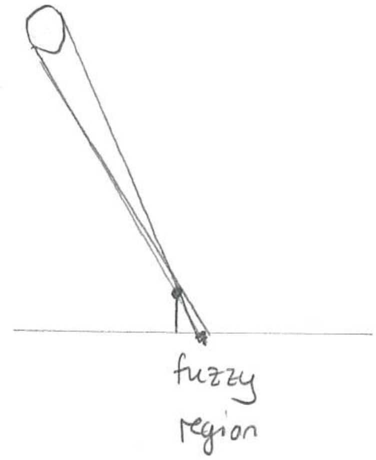
The reason that the edge is fuzzy is because the sun has non-zero width. The taller the gnomon the more accentuated the fuzzy region.

The angular width of the sun is approximately 0.50° and we know that 1° ≈ 4min. Thus we expect a resolution of about 1→2min in timing accuracy.



We could try to use the base of the shadow, as this will be clearer.





Here the fuzzy region will be smaller for a lower gnomon. However, the distance moved by the shadow will be smaller during a fixed interval and harder to measure accurately.

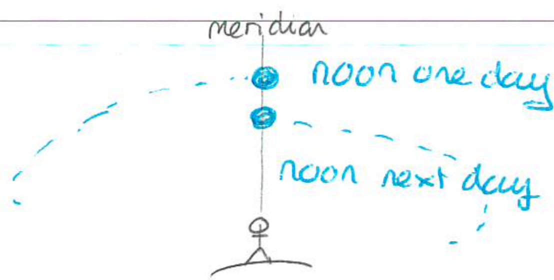
Accuracy issues with Earth's motion

There are two issues associated with Earth's motion:

1) Earth orbits in a slightly elliptical path and speeds up + slows down during this motion. So on some days of the year the Sun appears to move faster than others

2) Earth's axis is tilted so the Sun appears to move up + down along the meridian.

Near solstice

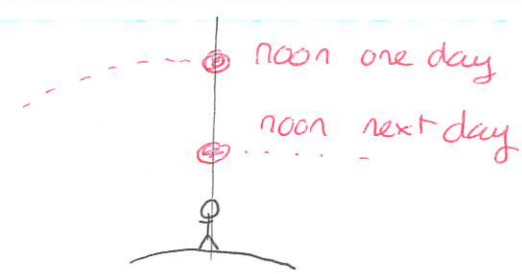


Apparent vertical drop shorter

⇒ shorter orbit path

⇒ less time noon to noon

Near equinox



Apparent vertical drop longer

⇒ longer orbit path

⇒ more time noon to noon

Thus:

> The true time from noon to the next noon varies during the year.

This was known to ancient Greeks. These were reconciled using the <u>equation of time</u>

<u>Demo</u>: Wikipedia eqn of time

This then gave the notion of <u>mean solar time</u> – this is the time given via a fictitious Sun that moves at a steady rate through all days. Various formulas were developed in order to extract this from the position of Sun on various days.