Weds: Read Barnett Ch 10

Balance Spring

The pendulum as a regulator dramatically improved clock accuracy. However, there are some limitations:

* the pendulum needs to swing vertically and the clock must be held in a position such that the pendulum is vertical.
* the pendulum will be disrupted if it is moved or rocked. It needs a stable surface
  → clocks cannot be moved and maintain operation
* the pendulum needs to be somewhat large. The smaller the pendulum, the smaller the period. This could cause greater inaccuracies in the clock
  → cannot be minaturized easily

The key break was to replace the pendulum with an oscillating spring/mass system.

Demo: Oscillating spring/mass

The particular arrangement that was used involved a fine coiled spring attached to a rotating wheel that provided to oscillating mass

Demo: YouTube balance Spring clock (Wooden) – note the balance spring is driving the clock as well

Demo: Law Balance Spring clock - seems to be weight driven

Landes Such balance spring clocks appear to have been first developed around
135-137 1675 either by Huygens or Hooke

~~Demo: 18th ... British Museum search~~

Demo: Frick Museum - Balance Spring Clock 17th century museum
- Youtube video
- Arland clock

The advantages of using a balance spring clock are:

* clock does not need to be oriented vertically (gravity does not matter for the mechanism)
* clock can be miniaturized
* clock is relatively stable when disturbed

Improved escapements

The original anchor escapement provided some recoil during the motion. One of the effects of this recoil is that the clock train reverses briefly

Demo: YTube Trowbridge Anchor Escapement - observe recoil

- also NWACC video Ch10

The recoil could be averted by slightly altering the configuration of the pallets and crown wheel teeth. This resulted in the deadbeat escapement, which was invented around 1675 by Richard Towneley.

Demo: Kuo Circular deadbeat escapement

Such deadbeat escapements have significant advantages in accuracy over recoil escapements but require greater manufacturing precision.

- see NWACC video Ch11

Using Clocks to Determine Location

During the 17th and 18th century the primary driving force for increased accuracy was... ??

Q: An anchor escapement pendulum clock from the late 17th century would provide an accuracy of 15s per day.
Recall that this would result in a loss of 12hr over a period of 2880 days.
A loss of one hour would take ~ 240 days. Imagine that you had such a clock.

1) How would such inaccuracy affect your life? Much, not much?

2) How would you check the accuracy? What would you have to do to deal with the inaccuracy?

3) Would you pay say 10 times or 100 times as much for a clock which only lost 1s per day?
Who might have to pay for ~~stay~~ such clocks?

By the late 1600s / early 1700s conventional clocks had sufficient accuracy for ordinary everyday purpose.

The demand for clocks of increased accuracy came from:

1) anyone interested in navigation on the open ocean.
2) astronomers
3) other scientists ??

We consider the prospect of determining location on Earth's surface.

Latitude and longitude

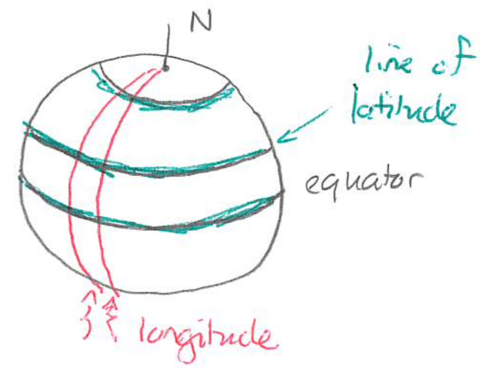
Since Earth's surface is approximately spherical one useful system of co-ordinates uses two angles to describe any single point

Demo: Smithsonian video

We can create a grid consisting of two types of line:

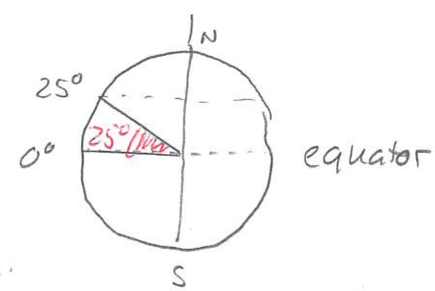
1) line of latitude ≡ circle in planes parallel to the equator

2) line of longitude ≡ semicircles passing through North and South poles

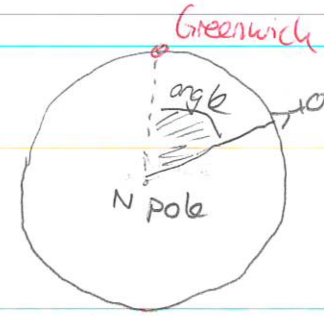


There is a system of degree measures for representing these lines:

1) for lines of latitude, the equator is 0° and for others we use the illustrated angle to determine latitude angle with an indication of north or south of the equator. There are a total of 180° in this system.



2) for lines of longitude the line passing through Greenwich is 0° and we use the angle as measured, east or west of Greenwich. There are a total of 360°



Every location on Earth has a unique set of two numbers:

latitude = ?? longitude = ??

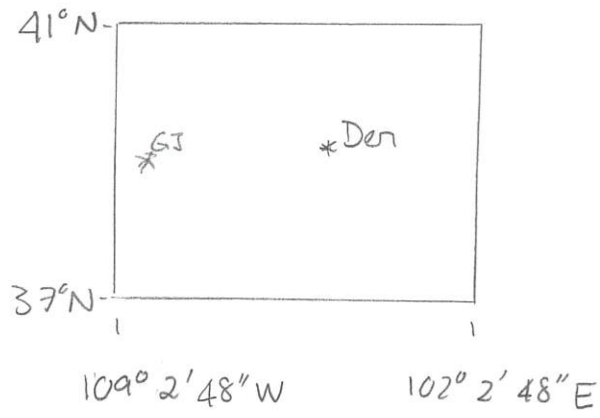
Demo: Maps of World - zoom in to GJ → 39.09°N 108.57°W

To get an idea of the extent of the latitude and longitude numbers consider the state of Colorado

The range of latitudes is about

4° S → N

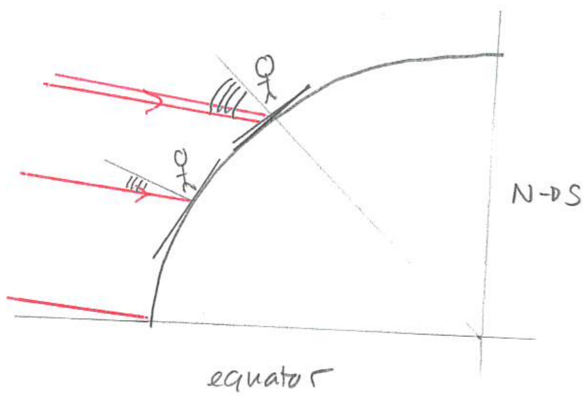
7° E → W



If we can determine the longitudes and latitudes of a location we can pinpoint that location and its direction + distance relative to others on Earth.

Determining latitude

Latitude can be determined by using the apparent position of Sun at noon. The diagram illustrates why this might work. We can see that along the same line of longitude the angle between the Zenith and Sun's direction depends on the latitude. Thus we could do:



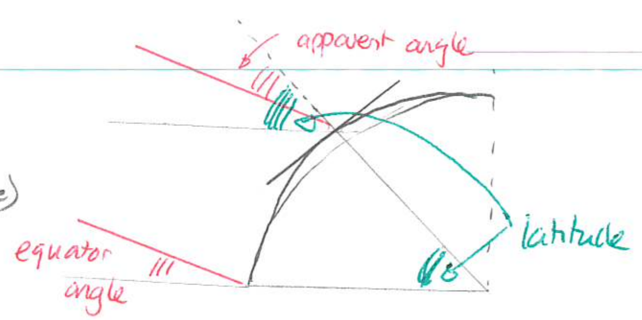
1) Note the day of the year and we can establish the angle of Sun above the equator on that day by calculation
   - zero at equinox
   - 23° N at summer solstice

2) determine the angle between Sun + zenith at noon – this might involve calculation from an angle between sun + horizon

3) simple angular geometry gives latitude

   in the diagram (in summer N hemisphere)

   latitude = apparent angle + equator angle



For example at the equinox the Sun's apparent angle at Grand Junction is 39° S of the zenith. The Sun is directly over the equator and so the calculation gives a latitude of 39° N.

So we see:

Latitude can be determined from observations of Sun's position relative to the local zenith and done at local noon. This requires knowing the day of the year and some simple geometry.