Essl 290

Lecture 27

Note 26 skipped

Weds: Mordsch ~~1127~~ 117 - 125
Barnett. 108 - 113

## Navigation and Longitude Finding

By the 1500s and into the 1600s European ships explored and traversed most of the world's oceans. When travelling E-W it become important to have some idea of longitude. A particular example was that of the ships of the Dutch East India Company traversing the Indian Ocean. Rather than sailing close to Africa and India before reaching Indonesia, it was advantageous to sail across the southern Indian Ocean and veer north just west of Australia. This was the Brouwer route pioneered in 1611

Demo: Show Duyfken

Various company ships were wrecked off the coast and adjacent islands of Western Australia: Batavia (1629), Vergulde Draeck (1656), Zuytdorp (1712), Zeewijk (1727). The last at least was almost surely the result of a longitude error.

Other examples of longitude location issues were:

1) Admiral Clowdisley Shovell sailing a British Naval Fleet from Gibralter to England. The fleet sunk after hitting the Scilly Islands (1707) ~2000 lost

Wikipedia: Scilly Naval Disaster

2) Commodore George Anson sailing around Cape Horn and attempting to find the Juan Fernandez Islands (1741) ~80 lost.

# Developement of methods to find the longitude

The financial and strategic national interests of various monarchies and countries motivated incentives for finding reliable methods to determine longitude at sea. Particular early incentives were:

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1) King Phillip II of Spain (1567)
2) King Phillip III of Spain (1598) - included a prize and "seed" investments.
3) States General of Holland (1590s) - intended to award this to Galileo for a method involving Jupiter's moons but he was unable to accept.

There were two basic methods advocated:

1) celestial methods - lunar eclipse timing (already disussed)
   - observing eclipses of Jupiter's Moons - proposed by Galileo.

The method of using eclipses of Jupiter's Moons had the following

* advantages - eclipses occurred frequently (every few days)
  - motion relatively easier than Moon
* disadvantages - eclipses would have to be predicted years in advance with an accuracy of ~ 1 min
  - observations required a telescope to view the Moons and this would be difficult on a moving ship.

2) <u>chronometer methods</u> – the ship would carry a clock synchronized to the time in the port of departure. The clock time could be observed at local noon and the difference used to determine the longitude difference. A precise clock that could do this is called a <u>chronometer</u>.

The trouble with this were:

a) the best pendulum clocks in the late 1600s were accurate to 15 s per day. At the equator this would translate to a distance inaccuracy via:

$1°$ longitude $\Rightarrow$ 4 min ($1°$ ↓ 69 mi)

$\Rightarrow$ 1 min diff $\sim \frac{69\,mi}{4} = 17\,mi$

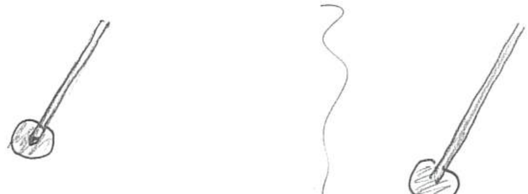
⇓

15 s diff $\sim \frac{17\,mi}{4} \approx 4\,mi$

So an error of 4 mi per day could accumulate.

b) on a ship the rocking motion would further disturb the pendulum oscillation.

c) a pendulum has the problem that it will expand or contract as temperature increases.



lower temp
$\Rightarrow$ shorter length
$\Rightarrow$ shorter period

higher temp
$\Rightarrow$ longer length
$\Rightarrow$ longer period.

d) friction - as more moving parts were added, there were more opportunities for friction and reduction in timing effectiveness.

Balance spring clocks could help with the problem of turbulent environment but suffered the other problems just as badly as pendulum clocks.

## 1 Scilly Islands

The Scilly Islands, the site of the British naval disaster of 1707, stretch out over about 10 miles in the East-West direction. If one approaches this by sea, one would want to know one's position to within 10 miles. At the latitude of the Scilly Islands, about 50° N, one degree of longitude corresponds to 44.5miles.

Suppose that one traveled from New York to Britain by sea in the 18$^{th}$ century and that the voyage took six weeks. We want to find out how much time the ship clock can lose per day so that one will still be able to pass by the Scilly islands safely.

a) First, how accurately would we need to know longitude if one wanted to know one's position to within 10 miles at the latitude of the Scilly Islands?

$1^\circ \leadsto 44.5\text{mi}$

$1\text{mi} \leadsto \frac{1^\circ}{44.5} \Rightarrow 10\text{mi} \leadsto \frac{10^\circ}{44.5} = 0.22^\circ$

b) How much time could the clock lose so that one would still know one's position with the necessary accuracy?

$1^\circ \leadsto 4\text{min}$

$0.22^\circ \leadsto 0.22 \times 4\text{min} = 0.90\text{min} = 54\text{s}$

It can lose 54s over $6 \times 7\text{days} = 42\text{days}$

$\Rightarrow$ It can lose $\frac{54\text{s}}{42} = 1.3\text{s}$ per day

c) How much time could the clock lose per day?

## 2 Pendulum Accuracy

A pendulum that is made of brass and has length 1.0000 m will have a period of 2.0061 s. If the temperature of the rod increases by 20° F the length of the rod will increase to 1.0002 m and the period will increase to 2.0063 s. This seems minute. Explain how such a small difference can result in a timing difference bad enough to cause a ship to collide with an island or a reef.

In England there were two initiatives to solve this:

1) the establishment of the Greenwich Observatory by Royal Charter in 1674-1675

- the purpose of this was to catalog stars accurately so that they could be used to determine longitude accurately via celestial methods

- this necessarily involved accurate timing and Greenwich had the most accurate clocks from early in its history.

2) the Longitude Act of 1714 in Great Britain

- this was inspired by the Scilly islands disaster.
- it established various rewards up to £20 000 (roughly $10 million today) for finding longitude accurately.