

# **The Problem of Longitude**

**(from "The World of Mathematics" by James R. Newman, 1956)**

**(Article by Lloyd A. Brown)**

**May 4th, 1493, Pope Alexander issued the Bull of Demarcation to settle the dispute between Spain and Portugal**

**A line 100 leagues West of the Azores (but no one knew where the line fell)**

**Practically a meaningless line**

**Ships were lost because they did not know where they were**

**Spain offered a perpetual pension of 6000 ducats plus a life pension of 2000 ducats and an additional sum of 1000 ducats for the "discoverer of Longitude"**

**This attracted every crank and inventor to research the "East and West navigation"**

**Portugal, Venice, and Holland also posted rewards**

**In 1636 Galileo suggested using the moons of Jupiter as an accurate time reference**

# Possible Solutions

It was not obvious that the solution was to carry an accurate clock

At sea the only thing to observe were the stars

but they revolve around the earth so do not distinguish different longitudes

## Possibilities

Magnetic variation

suggested by Columbus, Cabot, Magellan, Tasman

Jupiter's satellites

Motion of the Moon

Ocean depth

Accurate Time

$15^\circ = 1 \text{ hour}$

Latitude is easy - look at the pole star (or any celestial object)

# **Clock mechanisms**

**Ancient water clocks**

**Christian Huygens, 1656, pendulum clock**

**Louis XIV founded the Académie Royale des Sciences**

**proposed the prime meridian through the observatory in Paris**

**measured the diameter of the Earth**

**1668 Giovanni Domenico Cassini measured the longitude of many cities using the satellites of Jupiter**

**1682-3 determined longitude of places in the New World**

# **London Parliament Prize**

**London Parliament in 1714 offered a prize of**

**£10,000 for any device that determined longitude within 1°**

**£15,000 for any device that determined longitude within 40'**

**£20,000 for any device that determined longitude within 30' (2 minutes of time)**

**The Board of Longitude was to examine submissions**

**50 years no one claimed the prize**

**The problem with clocks was that many environmental factors affected the rate**

**pendulum clocks were erratic at sea**

**also depended on the gravitational gradient**

**Hooke proposed using springs**

# **John Harrison (1693-1776)**

**John Harrison investigated the physical laws of clocks**

**Noted most problems caused by the expansion of metals with temperature**

**Built a pendulum clock with alternating steel and brass rods**

**Worked on clock escapements that did not need oiling**

**Inferior oil was the cause of many clock problems**

**George Graham, England's leading horologist loaned him money to build his first "longitude" clock finished in 1735 (H1)**

**Board of Longitude gave him £500 for future work**

**Continued to build H2 but was not satisfied with it - never tested at sea**

**Proposed H3 - a superior design**

**Board of Longitude gave him another £500 for additional work**

**Before sea trials of H3 Harrison started work on H4 and H5 which were "pocket" sized**

**H4 was 5 inches in diameter**

**Harrison requested a sea trial of H4**

**"Nine days out from Portsmouth the ship's longitude, by dead reckoning, was 13° 50' west of Greenwich, but according to Number Four and William Harrison it was 15° 19' W. Captain Diggs naturally favored his dead reckoning calculations, but Harrison stoutly maintained that Number Four was right and that if Madeira were properly marked on the chart they would sight it the next day. Although Diggs offered to bet Harrison five to one that he was wrong, he held his course, and the following morning at 6 A.M. the lookout sighted Porto Santo, the northeastern island of the Madeira group, dead ahead."**

**Number Four had a total error after five months' voyage was only one minute 53 seconds or an error of longitude of 28 1/2 minutes**

**Harrison claimed the £20,000 prize as he had met all of the requirements.**

**Finally His Majesty King George the Third, after an audience with Harrison, said, "By God, Harrison, I'll see you righted"**

**The King examined Harrison's clock and petitioned the House of Commons to grant the prize**

**Finally (after more wrangling) the Board of Longitude capitulated and awarded Harrison the prize**