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John Harrison and the Longitude problem

The Harrison timekeepers are on permanent display in Flamsteed House at the Royal Observatory, Greenwich. [Take our interactive virtual tour of Flamsteed House.](#)

The Longitude problem

Whereas, in order to the finding out of the longitude of places for perfecting navigation and astronomy, we have resolved to build a small observatory within Our Park at Greenwich...

Charles II

For every 15° that one travels eastward, the local time moves one hour ahead. Similarly, travelling West, the local time moves back one hour for every 15° of longitude.

Therefore, if we know the local times at two points on Earth, we can use the difference between them to calculate how far apart those places are in longitude, east or west.

This idea was very important to sailors and navigators in the 17th century. They could measure the local time, wherever they were, by observing the Sun, but navigation required that they also know the time at some reference point, e.g. Greenwich, in order to calculate their longitude. Although accurate pendulum clocks existed in the 17th century, the motions of a ship and changes in humidity and



The Royal Observatory, Greenwich

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temperature would prevent such a clock from keeping accurate time at sea.

King Charles II founded the Royal Observatory in 1675 to solve the problem of finding longitude at sea. If an accurate catalogue of the positions of the stars could be made, and the position of the Moon then measured accurately relative to the stars, the Moon's motion could be used as a natural clock to calculate Greenwich Time. Sailors at sea could measure the Moon's position relative to bright stars and use tables of the Moon's position, compiled at the Royal Observatory, to calculate the time at Greenwich. This means of finding Longitude was known as the 'Lunar Distance Method'.

In 1714, the British Government offered, by Act of Parliament, £20,000 for a solution which could provide longitude to within half-a-degree (2 minutes of time). The methods would be tested on a ship, sailing

...over the ocean, from Great Britain to any such Port in the West Indies as those Commissioners Choose... without losing their Longitude beyond the limits before mentioned

and should prove to be

...tried and found Practicable and Useful at Sea.

A body known as the Board of Longitude was set up to administer and judge the longitude prize. They received more than a few weird and wonderful suggestions. Like squaring the circle or inventing a perpetual motion machine, the phrase 'finding the longitude' became a sort of catchphrase for the pursuits of fools and lunatics. Many people believed that the problem simply could not be solved.

John Harrison (1693-1776)

The longitude problem was eventually solved by a working class joiner from Lincolnshire with little formal education. John Harrison took on the scientific and academic establishment of his time and won the longitude prize through extraordinary mechanical insight, talent and

determination.

Harrison was born in Foulby, near Wakefield, in Yorkshire in 1693 but his family moved to Barrow, in Lincolnshire, when he was quite young. His father was a carpenter and John followed in the family trade. He built his first longcase clock in 1713, at the age of 20. The mechanism was made entirely from wood, which was not a curious choice of material for a joiner. Three of Harrison's early wooden clocks have survived; the first (1713) is in London, at the Worshipful Company of Clockmakers' Collection in Guildhall; the second (1715), is in the Science Museum; the third (1717) is at Nostell Priory in Yorkshire.



John Harrison

Repro ID PU2851

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He married his first wife, Elizabeth, in 1718. She died just eight years later and he remarried within six months, to another Elizabeth.

During the latter part of his early career, he worked with his younger brother James. Their first major project was a revolutionary turret clock for the stables at Brocklesby Park, seat of the Pelham family. The clock was revolutionary because it required no lubrication. 18th century clock oils were uniformly poor and one of the major causes of failure in clocks of the period. Rather than concentrating on improvements to the oil, Harrison designed a clock which didn't need it. It was radical thinking of this sort that would be important later on, when he tackled the problem of designing a marine timekeeper.

During the mid-1720s, John and James designed a series of remarkable precision longcase clocks, to see how far they could push the capabilities of the design. By inventing a pendulum rod made of alternate wires of brass and steel, Harrison eliminated the problem of the pendulum's effective length increasing in warmer weather, slowing the clock. As a result, Harrison's regulators from this period achieved an accuracy of one second in a month, a performance far exceeding the best London clocks of the day.

To solve the longitude problem, Harrison would have to devise a portable clock which kept time to the same accuracy as these precision regulators...

H1 (1730-1735)

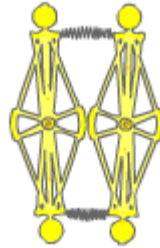


Harrison's Marine Chronometer number 1

Repro ID D6783_1

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Constructed between 1730 and 1735, H1 is essentially a portable version of Harrison's precision wooden clocks. It is spring-driven and only runs for one day (the wooden clocks run for eight days). The moving parts are controlled and counterbalanced by springs so that, unlike a pendulum clock, H1 is



independent of the direction of gravity.

The animation (© NMM) illustrates how the linked balance mechanism works. It ensures that any change in motion which affects one of the balances is compensated for by the same effect on the other balance.

H1 was brought to London in 1735 and displayed to the scientific community. Harrison was besieged by requests from both scientists and socialites to see the timekeeper.

In 1736, Harrison and his timekeeper travelled to Lisbon aboard the ship *Centurion* to test the clock, and returned on the *Orford*. H1 performed well in the trial, keeping time accurately enough for Harrison to correct a misreading of the *Orford's* longitude on the return voyage. However, Harrison did not ask for a second trial but, instead, requested financial assistance from the Board of Longitude to make a second marine timekeeper.

H2 & H3 (1737-1759)



Harrison's Marine Chronometer number 2 (H2)

Repro ID D6784_1

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H3 incorporated two inventions of Harrison's; a bimetallic strip, to compensate the balance spring for the effects of changes in temperature, and the caged roller bearing, the ultimate version of his anti-friction devices. Both of these inventions are used in a variety of machines nowadays.

Despite these innovations, work on H3 seemed to lead nowhere and its ultimate role was to convince Harrison that the solution to the longitude problem lay in an entirely different design.

Larger and heavier than H1, H2 is of fundamentally the same design as H1.

Harrison began work on H2 in 1737 but in 1740 realised its design was wrong. The bar balances did not always counter the motion of a ship, a deficiency that could be corrected if the balances were circular. Harrison requested more money from the Board to work on a third timekeeper...

Harrison worked on his third timekeeper from 1740 to 1759. After 19 years of labour, it failed to reach the accuracy required by the Board of Longitude.

H4 (1755-1759)

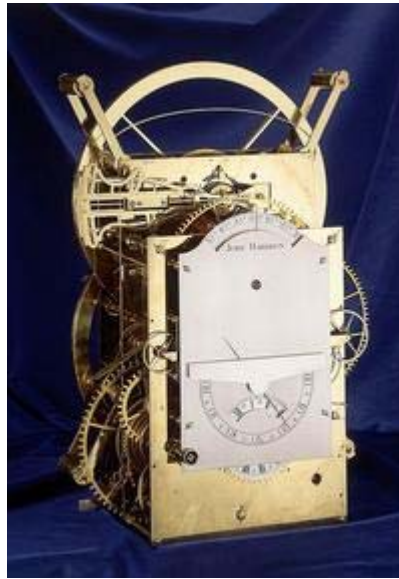


Harrison's marine timekeeper H4

Repro ID D0789-1

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In



Harrison's Marine Chronometer number 3 (H3)

Repro ID D6785_3

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1753, Harrison commissioned London watchmaker John Jefferys to make him a watch following Harrison's own designs. The watch was intended for Harrison's own personal use - to help with his astronomical observing and clock testing. No one in the 1750s thought of the pocket watch as a serious timekeeper. However, Harrison discovered with his new watch that if certain improvements were made, it had the potential to be an excellent timekeeper.

In 1755, as well as asking for continued support for the construction of H3, he asked the Board of Longitude for support

... to make two watches, one of such size as may be worn in the pocket & the other bigger... having good reason to think from the performance of one already executed... that such small machines may be render'd capable of being of great service with respect to the Longitude at Sea...

H4 is completely different from the other three timekeepers. Just 13 cm in diameter and weighing 1.45 kg, it looks like a very large pocket watch. Harrison's son William set sail for the West Indies, with H4, aboard the ship *Deptford* on 18 November 1761. They arrived in Jamaica on 19 January 1762, where the watch was found to be only 5.1 seconds slow! It was a remarkable achievement but it would be some time before the Board of Longitude was sufficiently satisfied to award Harrison the prize.

A second trial of H4 was arranged and William departed for Barbados aboard the *Tartar* on 28 March 1764. As with the first trial, William used H4 to predict the ship's arrival at Madeira with extraordinary accuracy. The watch's error was computed to be 39.2 seconds over a voyage of 47 days, three times better than required to win the £20,000 longitude prize. The Board of Longitude, however, implied that the watch was a fluke and would not be satisfied unless others of the same kind could be made and tested. Harrison would be paid £10,000 as soon as he disclosed his secrets and handed over his mechanisms to the Astronomer Royal, with the remaining £10,000 being paid when other timekeepers of the same type, accurate enough to find longitude to within 30 miles, were made.

Winning the Longitude Prize

Although the performance of H4 during its second sea trial was three times better than the two minutes accuracy required to win the longitude prize, the Board of Longitude remained unconvinced. They stated that half of the prize money would be paid once Harrison had disclosed the workings of H4 to a specially-appointed committee. They also implied that H4's accuracy was a fluke and that copies of the watch should be made and tested. Finally, all four of Harrison's timekeepers should be handed over to the Board once he had received the £10,000.

At first, Harrison refused to accept any of these proposals, but the Board was equally adamant. After several weeks, both John and William agreed to disclose the inner workings of H4.

In August 1765, a panel of six experts gathered at Harrison's house in London and examined the watch. One week later, they were satisfied that the disclosure was complete and had signed a certificate to this effect. The Board then insisted that the four timekeepers should be handed over to them, and asked Harrison to recommend someone who could copy H4. Reluctantly, he recommended Larcum Kendall, a leading watchmaker

who had probably contributed to the construction of H4, and finally received the first half of the longitude prize.

In order to qualify for the second half of the prize, Harrison had to make at least two more watches and have them tested. The Board of Longitude insisted that he make these copies of H4 himself, but took the original away for testing at the Royal Observatory. Nevil Maskelyne, who had been appointed Astronomer Royal in 1765, remained unconvinced that a watch could be more reliable than the lunar distance method for finding Greenwich Time.

John Harrison (now in his seventies) and William worked on a fifth timekeeper (H5), while Kendall made good progress on his copy of H4. Kendall's watch, now known as K1, was completed in 1769 and inspected in early 1770 by the same panel that had examined H4. William Harrison was also present and admitted that the copy was exceptional. The Board of Longitude was asked to consider H5 and K1 as the two copies of H4, but told John and William, in no uncertain terms, that both copies of H4 should be made by the Harrisons.



K1 Marine Chronometer(Kendall's copy of Harrison's H4)
Repro ID D9661
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John, now 79 years old, made an appeal to the highest authority in Britain. On 31 January 1772, an approach was made to King George III, via a letter to his private astronomer at Richmond, Dr Stephen Demainbray. William was summoned for an interview with the King himself, at which the King is said to have remarked

... these people have been cruelly wronged... ,

and

By God, Harrison, I will see you righted!

H5 was put on trial by the King himself in 1772, and performed superbly. The Board of Longitude, however, refused to recognise the results of this trial, so John and William petitioned Parliament. They were finally awarded £8750 by Act of Parliament in June 1773. Perhaps more importantly, John Harrison was finally recognised as having solved the longitude problem.

In the meantime, Captain Cook had set out on his second voyage of discovery with K1, Kendall's copy of H4. He returned in July 1775, after a voyage of three years, which ranged from the Tropics to the Antarctic. The daily rate of K1 never exceeded 8 seconds (corresponding to a distance of 2 nautical miles at the equator) during the entire voyage and Cook referred to the watch as

...our faithful guide through all the vicissitudes of climates.

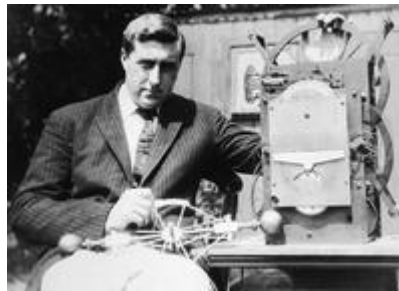
It is not known for certain whether Harrison knew of this success, but Cook's voyage proved beyond doubt that longitude could be measured from a watch.

John Harrison died almost one year after Cook's return, on 24 March 1776, in his house at Red Lion Square, London. It was his 83rd birthday.

Rupert Gould

Rupert Thomas Gould's father (the composer, William Monk Gould) had intended his son for a life as a Navy Officer and a promising start under Beatty and Jellicoe had augured well, but a severe nervous breakdown at the outbreak of the First World War ended Rupert's career in active service.

In 1916 he was transferred to work in the Hydrographic Office of the Navy, where his talents with pen and ink were highly valued, and in 1919 he was promoted to the rank of Lieutenant-Commander (retired).



Lietenant Commander R.T. Gould with H3 and one
of the balances of H2

Repro ID B7777

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However, fine as his illustration was, he was much more than just an artist/draughtsman. Gifted with a photographic memory, R.T. Gould has been described as a veritable Renaissance Man. During the trauma of his first breakdown, for the first six months of which he was unable to speak, his interests turned to the occult. He had always been interested in scientifically unexplained occurrences ('The X Files' would have fascinated him) and he was the first to write a series of factual books on such matters, in the late 1920s. He was, for example, the first to systematically investigate the case of the Loch Ness monster, which he concluded did exist, and he published his results (*The Loch Ness Monster and Others*) in 1934.

One of his most notable passions was Antiquarian Horology; at the top of the long list of the talents and interests which Gould possessed was a profound learning in the history of time measurement. In 1923 he wrote the definitive work on the Marine Chronometer (*The Marine Chronometer, its History and Development*), a work so thoroughly researched and beautifully written that it still has no equal today; the book is particularly valued for its fine and careful pen-and-ink illustrations of mechanisms, drawn by the author. Gould's skills were also practical. In 1920, during his research for his book, he discovered the great timekeepers by Harrison - the most important timekeepers ever constructed - neglected in the Royal Observatory's stores. He gained permission to restore them to their former glory, a project that was to occupy him for much of the rest of his life and which was to alienate him from his wife and family; he was separated from his wife in a high profile case, heard at the Royal Courts of Justice in 1927.

In spite of two further severe nervous breakdowns, one in 1925 and another at the outbreak of the Second World War, Gould managed to cram many other interests and activities into his short life. He was a dedicated tennis player and his knowledge of the history and rules of the game led him to umpire on centre court at Wimbledon on many occasions during the 1930s. His interest in all things mechanical included a fascination for studying and collecting typewriters and he wrote the first history of the instrument. Throughout the 1930s and 1940s he delighted children across the country with his educational broadcasts on BBC Radio's 'Childrens' Hour' as 'The Stargazer', and in the mid 1940s he joined that select group of eccentrics who broadcast as 'The Brains Trust'. The most famous of the Brains Trust panellists, Professor Joad, was Gould's bete noir and regular sparring partner on the air waves. Gould died in 1948 at just 57 years old. The previous year the British Horological Institute had awarded him the BHI gold medal, its highest honour for contributions to horology.

© Jonathan Betts (A biography of Gould is in preparation)

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Home of the Prime Meridian of the World

Longitude 0° 0' 0", Latitude 51° 28' 38"

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