Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time Study Guide

Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time by Dava Sobel

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Plot Summary

Longitude is the story of English clockmaker John Harrison and how he figured out how to track longitude, or the east-west position of ships. The problem of longitude was long regarded as unsolvable. At sea, there were no landmarks by which one's east-west position could be tracked. Since ships were in motion, the position of the sun would also not suffice. Calculations by moon were impracticable and could only be used at night. All the clocks that existed were too unreliable, often keeping time at very different rates depending on temperature.

Without longitudinal calculations, many ships became lost. During long voyages, calculating one's distance became nearly impossible to gauge with serious accuracy. Discovering the "secret of the longitude" was therefore a great goal for any ship's captain and for any country with business, military or commercial, on the high seas. The British legislature set up a Board of Longitude which had the authority to offer an award to anyone who could solve the problem. The book is about John Harrison's long, bedeviled question to built an incredibly accurate time-piece that could resist the vagaries of the sea.

There are two major conflicts in this book. The first is between John Harrison's ability and his perfectionism. Harrison builds four clocks before he is satisfied enough to believe he deserves the full prize of the Board of Longitude. He spends several decades of his life constructing these clocks. The second conflict is between Harrison and his arch rival, Royal Astronomer Nevil Maskelyne. Maskelyne, like most astronomers, aimed to discover a lunar solution to the longitude problem. He had what one might term an astronomer's bias, which holds that the only solution worthy of the longitude problem could be solved by someone with the elite education of an astronomer, not a country watchmaker. This causes him to be extremely hostile to Harrison claiming the prize, fighting him until Harrison's death. The book ends by drawing out the influence of Harrison's contribution, showing that it leads to dramatic improvements for sailors around the world.

The major theme of the book is the extraordinary and surprising sources of excellence. Harrison is an uneducated, idiosyncratic English countryman, yet he solved a problem that even Isaac Newton had not. It is also the story of the pettiness of the jealous, particularly embodied in the bitter Nevil Maskelyne. Many are threatened by the greatness of others, particularly if that greatness threatens one's status. This leads to the standard historical phenomenon of hostility to persons of great creativity and inventiveness.

Chapter 1: Imaginary Lines

Chapter 1: Imaginary Lines Summary and Analysis

Chapter 1 begins by explaining the history of the longitude problems. It turns out that assigning latitude - or the east to west running lines on maps - is not terribly complicated. Ptolemy was one of the first latitude mapmakers. But the author notes that longitude is not fixed by the laws of nature, as latitude is. Instead it must be stipulated in a form that is practical for the use of sailors. Longitude can typically be calculated as a function of speed and distance. But at sea, there are no landmarks to distinguish these two variables. A ship may travel far and fast or slowly and only a short-distance. Without landmarks it is difficult to tell. And if a ship is thrown off course perhaps during a storm, then the captain cannot find the ship's location without some method of calculating longitude. The result of this inability often led to the deaths of entire crews of sailors. John Harrison, an English Clockmaker, devoted himself to solving this problem. Newton thought that constructing an accurate enough clock to calculate longitude might be impossible, and Harrison set out to prove him wrong. This chapter serves as an introduction to the book's main character, John Harrison and the age-old problem he aimed to solve - the problem of longitude. It also sets up the major conflict of the book - Harrison, a simple watchmaker vs. the elite members of the Royal Academy of Astronomers. The astronomers believed that only a solution that required their expertise could be used to solve the problem of longitude. As such, they were offended at the very idea that man without their refined education could do what they could not. This leads one astronomer in particular, Nevil Maskelyne, to stand in Harrison's way.

Chapter 2: The Sea Before Time

Chapter 2: The Sea Before Time Summary and Analysis

The story begins with the tale of Admiral Sir Clowdisley's unfortunate crash due to a longitudinal miscalculation. The crash destroyed his ship, the Association, and killed nearly all his crew. This is only one example of the uselessness of the typical mode of calculating longitude - "dead reckoning" - or the use of a brief time/distance calculation via the use of a sea-borne log. It was highly inaccurate, particularly on long voyages. Not only did the problem of longitude have human consequences; it also had economic ones. Seagoing trade was particularly difficult without a measure of longitude. So nation-states had an interest in finding a solution. As a result of Sir Clowdisley's misfortune, the British legislature passed the Longitude Act of 1714, promising twenty-thousand pounds to whoever could solve the problem. This chapter sets up the urgency of solving the problem of the longitude and specifies how the Board of Longitude, one of the major sources of characters in the book, was founded and acquired its power. It also explains that the main prize in the book - twenty-thousand pounds, the equivalent of millions of dollars today, would go to anyone who could solve the problem of the longitude.

Chapter 3: Adrift in a Clockwork Universe

Chapter 3: Adrift in a Clockwork Universe Summary and Analysis

This chapter concerns the possibility of a lunar solution to the problem of the longitude. Stars moves with regularity over time and so hold the potential of serving as a "celestial" clock. In 1514, German astronomer Johannes Werner used the motion of the moon in such a way. But the "lunar distance" method required detailed knowledge of the motion of stars, which no one had. A century later, Galileo thought he could use the motion of Jupiter's moons as a clock, but the plan was too complex. Fifty years later, Cassini produced a better map but his plan faced a similar problem - it was excessively complicated. In future decades, particularly in France and England, people looked for a solution with the earth's moon, particularly a young man named John Flamsteed. Flamsteed spent most of his life mapping the stars in part so the maps could be used to determine longitude. The original purpose of the Royal Observatory was to aid individuals like Flamsteed in figuring out longitude. Flamsteed died in 1725, and his maps were published posthumously. The purpose of Chapter 3 is to explain the long history of looking for a celestial solution to the problem of longitude. Harrison offers a distinctly "earthly" solution to the problem, but the prestige of deducing a celestial method was highly sought by astronomers for decades. This will partly explain the hostility Nevil Maskelyne has to Harrison's project.

Chapter 4: Time in a Bottle

Chapter 4: Time in a Bottle Summary and Analysis

The difficulty of designing a clock to measure longitude extended back to the 16th century. But clocks in that time were not accurate enough and could not weather temperature changes. In the 17th century, Galileo designed a pendulum clock, and its mechanisms were later used in many different clocks. Galileo's heir, Christiaan Huygens, was one of the first great "horologists" or clock makers. He built a pendulum clock and published an argument that the clock could establish longitude at sea. Huygens eventually meets a competitor scientist, Robert Hooke, and they both fight over the British patent for the coiled balance spring, which prevents waves from destabilizing a clock's timekeeping. Chapter 4 outlines the origins of the clock strategy for tracking longitude. Its history is not independent of elite interest, with great early scientists such as Huygens and Hooke pursuing the dream of a longitudinal clock. The chapter also outlines some of the first mechanical innovations to which Harrison would add.

Chapter 5: Powder of Sympathy

Chapter 5: Powder of Sympathy Summary and Analysis

Many crank solutions to the problem of the longitude were proposed. One crazy idea was to use wounded dogs to find longitude. A less insane solution involved the magnetic compass, but this method was too inaccurate. Two men, William Whiston and Hymphrey Ditton, proposed that cannon shots be used to time distances, but this solution was wholly unworkable. They hoped to use lights, but this would not work on longer voyages. While the Whiston-Ditton solutions failed, they excited enough of the shipmen in Britain to unite them in pressing for the longitude act. Chapter 5 tells the story of the frenzy to solve the longitude problem and how it led to the passage of the longitude act. The Longitude Act sets up the massive financial prize for solving the problem, the prize that Harrison and Maskelyne will fight over.

Chapter 6: The Prize

Chapter 6: The Prize Summary and Analysis

Chapter 6 focuses the primary goal of all the major characters in the book: win the prize by solving the problem of the Longitude. It introduces several early players - Thacket, Newton, Halley, Flamsteed and the Board of Longitude. Only Halley and the Board play a significant role in subsequent chapters. The committee for the Longitude Prize was formed in 1714 with the advice of Sir Isaac Newton and his friend and fellow astronomer Edmond Halley. Newton wrote that he was skeptical of a watch-based solution and thought the astronomical solutions were the way to go. The prize required the method to determine longitude within half a degree, but lesser amounts were offered for methods nearly as accurate. One half degree of longitude is thirty miles. The Longitude Act established the Board of Longitude, which had the authority to help financially poor investors to bring their ideas into reality. Many more crackpot schemes were proposed now that money was at stake. But Jeremy Thacket built a watch within a vacuum that could tell stable time, but lost accuracy due to temperature. His clock often lost six seconds a day, not accurate enough for the prize. Newton turned to Flamsteed's maps, and with Halley seized them from the Royal Observatory. Flamsteed reacted angrily, burning most of his maps. Newton came to believe that a Clock may be able to do the job.

Chapter 7: Cogmaker's Journal

Chapter 7: Cogmaker's Journal Summary and Analysis

We know little about John Harrison's life, but we do know that despite a lack of formal education, he learned to read, and he read everything he could. He was born March 24th, 1693, the oldest of five children. He learned crafts from his father and continued to read all he could. In particular, he studied a textbook on mechanics over and over again. He built his first pendulum clock before he was twenty and was not a watchmaker's apprentice. In fact, no known clockmaker lived anywhere near his town of north Lincolnshire at the time. Harrison married in 1718 and had a son Jon the next summer, but Elizabeth and John died within a few years. Harrison's second wife, Elizabeth and he were married in 1726 and were married fifty years. They had two children, a son named William and a daughter Elizabeth. We know nothing of Elizabeth, but William was Harrison's right hand man for all of his adult life until his father's death.

Harrison was truly incredible and built a variety of clocks around town that function to this day. He created a remarkable number of innovations in clock building in the process. He invented, for instance, a brass and steel pendulum that could aid in keeping time despite temperature changes. Harrison and his brother-in-law James were able to build a clock that lost never more than a second per month. We know that Harrison knew of the Longitude Prize by 1727 and set out to win it. He left with his new clock to London to make his case before the Board of Longitude. This chapter introduces us to our hero, John Harrison. Harrison is an ingenious, honest and determined clockmaker, who is out to solve one of the greatest problems in the history of nautical travel and in mechanics generally. He has no formal education, no high-class status, merely strength of will and incredible talent. We know his character and his goal. The plot of the book is set.

Chapter 8: The Grasshopper Goes to Sea

Chapter 8: The Grasshopper Goes to Sea Summary and Analysis

John Harrison arrives in London but the Board of Longitude cannot be located. Harrison goes to see Edmund Halley who now worked around the Royal Observatory. Halley knew that the Board wanted an astronomical solution but he heard Harrison anyway. Halley sent Harrison to George Graham, a well-known watchmaker. Graham, twenty years Harrison's senior, was so impressed by Harrison that he became Harrison's patron after one day. He gave Harrison a loan to built his first sea clock, the H-1. Harrison spends five years building it. The H-1 still exists today and weights seventy pounds, enclosed in a 4 x 4 x 4 foot cabinet. It worked spectacularly and passed tests on numerous occasions. Halley was converted, among others.

The chapter introduces all the characters of the board: Dr. Halley, Sir Charles of the Admiralty, Admiral Norris, two academics, the main astronomers from Cambridge and Oxford, Dr. Robert Smith and Dr. James Bradley. Sir Hans Sloane was also present and was president of the Royal Society. The two other board members were the Right Honorable Arthur Onslow, the speaker of the house of Commons, and Lord Monson, commissioner of Lands and Plantations.

Harrison exhibits an odd characteristic before the board. He could have easily passed the requirements with H-1 but spent his presentation complaining about H-1's errors. He asked for a small loan to build a second clock and the board agreed so long as Harrison agreed that the clock would be available for public use. In two years, he produced the H-2 but became dissatisfied with it before presenting it to the board. Because of this, he wanted to try again and H-2 was never at sea. Harrison would spend the next twenty years building the H-3, emerging only to collect small loans from the board. H-1 grew more famous overtime. This chapter builds up to the book's conflict. It illustrates Harrison's early successes and tells us a lot about his personality. He doesn't seem interested in winning the prize because of the money, but instead he wants to deserve the prize by using his intellect and talents to permanently solve the problem of the longitude. Our hero is better understood as having a heroic character, albeit with idiosyncrasies.

Chapter 9: Hands on Heaven's Clock

Chapter 9: Hands on Heaven's Clock Summary and Analysis

Chapter 9 introduces us to two astronomers, a Britishman John Hadley and an American Thomas Godfrey. They invent a method that can calculate lunar distance. This put a lunar solution within closer reach. Edmund Halley also took up a study of the moon's motions and made several successful predictions about celestial movements. His heir, James Bradley, continued his search. Bradley saw his mission as a Royal Astronomer as primarily aiding navigation. Bradley teamed up with a German mapmaker, Tobias Mayer to help compete for the longitude prize. Mayer drew influence from his correspondence with mathematician Leonhard Euler who is famous for reducing the motion of the planets to a few equations. The problem with the lunar method, however, is that it took a great deal of calculation. Anyone who could complete these calculations showed himself to be very intelligent.

It was for this reason the astronomers found Harrison's clock idea so outrageous. Harrison "offered the world a little ticking thing in a box" (99). Due to the astronomers' elitism, Harrison would face much adversity after he finished his greatest work, the H-4, in 1759. Chapter 9 sets up the political motivations of Harrison's enemies - the elite members of the Royal Academy of Astronomers. Not all of them opposed Harrison but many were threatened by his clocks. The solution to the problem was not "worthy" of Harrison. We learn in Chapter 9 the struggles that astronomers had gone through in developing a solution and they would not allow all their work to be shown unnecessary.

Chapter 10: The Diamond Timekeeper

Chapter 10: The Diamond Timekeeper Summary and Analysis

We do not know why Harrison took so long to build the H-3. It looks as if he did nothing but work on it. Harrison's son grew up as his father was building the H-3 and aided his father with these clocks until he was 45. The H-3 has 753 working parts and possessed numerous innovations that would balance against temperature and friction problems. H-3 weighs only sixty pounds and has a simpler core design. While Harrison is building the H-3, he comes in contact with John Jefferys, a freemason, who made Harrison a pocket watch built from Harrison's design. Jeffreys stays in contact with Harrison until the H-4 is finished.

H-4 is five inches in diameter and is absolutely beautiful, including diamond mechanisms and a silver case. We do not know how the watch was jeweled. H-4 continues to be able to function to this day, along with H-3, H-2 and H-1. But it does not run so as not to wear down its parts. Chapter 10 is the story of Harrison's greatest triumph - the H-4. It was a thing of beauty and more than capable of winning Harrison the Longitude prize. This is the high point of the book, with Harrison at the tip of his rise. From here there is only adversity and struggle. H-4 is his crown, and his enemies will attempt to wrest it from him.

Chapter 11: Trial by Fire and Water

Chapter 11: Trial by Fire and Water Summary and Analysis

We meet our villain - Nevil Maskelyne - "the seaman's astronomer" as he was known. The author suggests the Maskelyne acted not out of wickedness but of stubbornness. But Harrison despised him nonetheless, but not without justification. Maskelyne was a major proponent of the lunar distance method. He was obsessed with discovering a solution. He was about forty years younger than Harrison although apparently he always seemed old and uppity. He had an elite education and was among the members of the elite classes. He was also a companion of James Bradley.

In the meanwhile, H-3 and H-4 were set to be tested at sea by William, Harrison's son. But apparently Dr. Bradley deliberately delayed the trial for his own gain while Maskelyne was testing the lunar method. Bradley wanted to split the award with Mayer and wanted to stop Harrison. Eventually, however H-4 was tested and lost only five seconds after 81 days at sea. The captain was overjoyed. At this point, the prize should have gone to Harrison but the Board of Longitude called for re-evaluations, adding to the testing burden. Harrison receives only 1500 pounds until the testing is complete.

Maskelyne builds his reputation during this time by writing The British Mariner's Guide which helps captains to calculate longitude by lunar distance. Bradley dies but that does not soften the Board's attitude towards the Harrisons. The open slot is filled by Nathaniel Bliss, who becomes an enemy of the Harrisons. William embarks on another trip to the West Indies and encounters Maskelyne, who is sure of the superiority of his method. In this chapter, we see the beginnings of the conflict between the Royal Astronomers and Harrison, William and their allies. The point of the chapter is to reveal the intelligence and craftiness of Harrison's opponents and the bias of the Board towards an astronomical solution.

Chapter 12: A Tale of Two Portraits

Chapter 12: A Tale of Two Portraits Summary and Analysis

The H-4 was three times more accurate than the Longitude Act required. But the board only offered Harrison half the reward and offered it on the condition that Harrison hand over the plans for the H-4 to the public. If he wanted the full amount, he would have to produce two copies of H-4 to prove that duplication was possible. What was worse, Nathaniel Bliss died and Nevil Maskelyne took his place. Further, in 1765 the British Legislature passed on act that placed new restrictions specifically on Harrison.

Harrison was furious, but he eventually gave in and handed over his drawings. He dismantled the H-4 piece by piece before a board that included Maskelyne. After this, the Board demanded that Harrison hand over the H-4 to be used by the Navy. It was to be housed in the Royal Observatory where it would be tested every day for ten months by none other than Nevil Maskelyne. Harrison was even more enraged, but not as enraged as he became when Maskelyne came to his door with a warrant to seize all four H sea clocks. Harrison made only one request of Maskelyne - that he certify the clocks as all in working order when they were seized. Maskelyne signed an agreement where he notes that the clocks "appeared to be" in working order. In fact, while Maskelyne's workers were moving the H-1, they dropped it, apparently not by accident. The villain and his crew, the Board of Longitude, springs into action to prevent Harrison the fame and wealth of winning the Longitude prize. This chapter is where the major conflict of the book begins, with Maskelyne aiming to undermine and destroy Harrison's reputation and secure his place as a major contributor to a lunar distance method, claiming the glory and perhaps the award for himself. It is a tale of talent and hatred of that talent and of elitism. Maskelyne was clearly threatened by Harrison's accomplishment, thinking him too unsophisticated to be worthy of the prize.

Chapter 13: The Second Voyage of Captain James Cook

Chapter 13: The Second Voyage of Captain James Cook Summary and Analysis

Chapter 13 is the story of Harrison's ultimate vindication. He survives the attacks of the cruel Board of Longitude, and lives late into life completing a fifth clock. The fifth clock finally vindicates him as does the knock-off K-1 made by Kendall and used by Captain Cook. In this chapter we reach the climax of the book - the major conflict of the book is resolved - George III and Parliament help Harrison to vindicate his claims, although the Board of Longitude still refuses him the award. Harrison is ultimately satisfied and Maskelyne is largely thwarted.

The H-4 failed its ten month test at the Royal Observatory. Many argued that Maskelyne handled H-4 too roughly or that he deliberately distorted the trial. Maskelyne also developed a strange trial method for the clock. Previous voyages indicated that the watch was incredibly accurate. Maskelyne was ultimately forced to conclude that the lunar distance method had problems as well, however. In particular, it will not work when the moon lies on the other side of the world from the sun, about thirteen days a month. Nonetheless Maskelyne argued that H-4 was less accurate than the heavens. Of course, Harrison protested that H-4 was placed in direct sunlight, superheating the watch mechanisms under the glass. Maskelyne never answered the allegations. And even after Harrison was ignored, the Board refused to return H-4 to Harrison. The Board did, however, hire one of John Jeffrey's assistants, Larcum Kendall, to attempt to copy H-4. After two and a half years, Kendall finished K-1. Harrison was invited to help judge the K-1 and was enthusiastic about it. Although Captain Cook, on his second voyage around the world, selected K-1 and not H-4 to accompany him.

Somehow, despite Harrison's age, he completed an austere version of H-4, H-5. It took him five years to build and test. When he was finished, he was seventy-nine. King George III at the time took an interest in the H-4 trials and spoke with William Harrison about them. William recounted how cruelly Harrison had been treated and the King agreed. George III turned over H-5 to his private scientist, S. C. T. Demainbray for a six-week indoor trial. The H-5 lived up to expectations despite an initial run-in with some of the king's lost lodestones. H-5 was accurate to within one second of a day. Harrison then appealed to Parliament and was awarded the rest of the money, although it wasn't the prize itself, as it was awarded by Parliament and not the Board. Parliament then threw up even stricter standards for winning the prize. And the prize was never claimed. But Harrison was vindicated when Cook returned with great praise for the K-1.

Chapter 14: The Mass Production of Genius

Chapter 14: The Mass Production of Genius Summary and Analysis

John Harrison died on March 24th, 1776, at the age of 83. He became a martyr to clockmakers. After his death, clock-making boomed. Some claimed that Harrison's work allowed Britain to master the seas, holding that his clocks changed history. After Harrison's death, Kendall worked on K-2, attempting to reduce its price. But K-2 was shown to be fairly unimpressive. In 1774, Kendall built K-3 which did no better. Another clockmaker, Thomas Mudge, also built several good clocks, but ended up going head to head with Maskelyne until the 1790s. Later John Arnold made several hundred watches of high quality. He made so many through using cheaper labor to do the easier tasks, saving the hardest tasks for himself. In 1779, Arnold created a pocket watch which Maskelyne tested for over a year. It stayed accurate within three seconds the entire year. Both Arnold and Mudge built factories for mass production and lowered the price through competition. Thomas Earnshaw came along later, competing with Arnold and further reducing the price of the clock. It was Earnshaw who prepared the watch for the assembly line. Arnold and Earnshaw later fought a lengthy patent battle over a spring innovation. For whatever reason, Maskelyne liked Earnshaw and motivated the Board of Longitude to declare his clocks the better. The Board ultimately gave both Earnshaw and Arnold an award of three-thousand pounds. The number of these watches grew from one in 1737 to five thousands in 1815. The Longitude Act was repealed in 1828, disbanding the Board of Longitude. By the mid-nineteenth century, the reliability of Harrison's approach was beyond dispute. Harrison's successes extended beyond his death, only adding to the excellence of his accomplishments. Clockmaking boomed after his death and clocks became widely mass-produced, with thousands created by the mid-nineteenth century. The chapter also tells about the end of the Longitude Act and the Board of Longitude, rendered an anachronism by the incredible successes of Harrison's work. His shadow is cast over the entire rest of the Board of Longitude's history.

Chapter 15: In the Meridian Courtyard

Chapter 15: In the Meridian Courtyard Summary and Analysis

The chapter is the book's denouement, reflecting on the awe the author experiences viewing Harrison's clocks, most of which run to this day. Harrison's story is an extraordinary one and the author is clearly overwhelmed with admiration for a countryside clockmaker who changed the world. The last chapter occurs from the author's perspective at the present day in the Meridian House, where Nevil Maskelyne placed the prime meridian, the Greenwich meridian which marks the division of days all over the world. The chapter tells the story of the establishment of the meridian. Close by is Flamsteed House, where Harrison met Halley in 1730 and his journey began. The Flamsteed house holds H-1, H-2, and H-3 which work to this day. The author tells the story of Lieutenant Commander Rupert T. Gould of the Royal Navy, who restored the clocks and explained their workings clearly in a way that Harrison could not. They have H-4 as well but they do not run it; it is housed in a "see-through cave" with K-1.

Characters

John Harrison

We know little about John Harrison's life, but we do know that despite a a lack of formal education, he learned to read, and he read everything he could. He was born March 24th, 1693, the oldest of five children. He learned crafts from his father and continued to read all he could. In particular, he studied a textbook on mechanics over and over again. He built his first pendulum clock before he was twenty and that without a job as a watchmaker's apprentice. In fact, no known clockmaker lived anywhere near his town of north Lincolnshire at the time. Harrison married in 1718 and had a son, Jon, the next summer, but Elizabeth and John died within a few years. Harrison's second wife, Elizabeth and he were married in 1726 and were married fifty years. They had two children, a son named William and a daughter Elizabeth. We know nothing of Elizabeth, but William was Harrison's right hand man for all of his adult life until his father's death.

Harrison was truly incredible and built a variety of clocks around town that function to this day. He created a remarkable number of innovations in clock building in the process. He invented, for instance, a brass and steel pendulum that could aid in keeping time despite temperature changes. Harrison and his brother-in-law James were able to build a clock that lost never more than a second per month as a result of Harrison's ingenuity. We know that Harrison knew of the Longitude Prize by 1727 and set out to win it . He left with his new clock to London to make his case before the Board of Longitude.

Harrison's life is full of achievement, but he receives only sporadic and hard-fought recognition for those achievements. He builds five clocks of unparalleled sophistication over a thirty year period: H-1, H-2, H-3, H-4, and H-5. Each clock exists to this day, and the first three still run. But Harrison had to fight hard to receive recognition for his achievements from the astronomer-dominated Board of Longitude. His struggle against the elite astronomers, particularly Nevil Maskelyne, forms the major conflict of the book.

Nevil Maskelyne

Nevil Maskelyne was known as "the seaman's astronomer" and was famous decades after Harrison's death for his astronomical charts that he published for the use of seafarers. But Nevil Maskelyne plays another role in the book - as the man most determined to defeat Harrison and leave Harrison's achievements unrecognized. Maskelyne was a major proponent of the lunar distance method. He was obsessed with discovering a solution. He was about forty years younger than Harrison, although apparently he always seemed old and uppity. He had an elite education and was among the members of the elite class. He was also a companion of James Bradley.

H-3 and H-4 were set to be tested at sea by William, Harrison's son. But apparently Dr. Bradley deliberately delayed the trial for his own gain while Maskelyne was testing the lunar method. Bradley wanted to split the award with Mayer and stop Harrison. Eventually, however H-4 was tested and lost only five seconds after 81 days at sea. The captain was overjoyed. At this point, the prize should have gone to Harrison but the Board of Longitude called for re-evaluations, adding to the testing burden. Harrison receives only 1500 pounds until the testing is complete. Later in the book, Maskelyne is actually given the job of testing H-4 all by himself. To no one's surprise, H-4 failed Maskelyne's tests. Over and over again, Maskelyne acts craftily to thwart Harrison's success.

Maskelyne builds his reputation during this time by writing The British Mariner's Guide, which helps captains to calculate longitude by lunar distance. His guides and almanacs were a source of great renown for him.

William Harrison

John Harrison's son and right-hand man. William Harrison was not the clock-making genius his father was, but he did work hard to help his father build and test H-3, H-4, and H-5. He also often functioned as John Harrison's advocate before various groups with whom they hoped to ally themselves.

Admiral Sir Clowdisley

The British Admiral whose shipwreck motivated the passage of the 1714 Longitude Act, which created the Board of Longitude.

Galileo/Newton/Kepler/Cassini

Famous astronomers who play a large role in the pre-history of this book. They not only struggle and fail to solve the problem of Longitude (making Harrison's achievements all the more impressive), but they lay out the path towards a lunar distance method that was championed by later astronomers.

John Flamsteed

A British Royal Astronomer and world-famous star chart maker. He spent several decades charting the stars to aid seafarers. But when Halley and Newton decide to seize Flamsteed's maps for themselves, Flamsteed burns them all.

Christiaan Huygens/Robert Hooke

Huygens and Hooke were scientists in their own right but were also two of the first "horologists" or clock makers. They fought over an early patent on a clock spring coil.

William Whiston and Hymphrey Ditton

The creators of the absurd cannon distance method of pinpointing longitude. This method, despite its utter failures, whipped the seafaring community into a frenzy hoping to find a solution to the problem of Longitude.

Edmund Halley

A Royal Astronomer who was one of Harrison's early advocates and stays his ally throughout the book.

John Jeffreys

An expert clock-maker who helps Harrison build the H-4. builds a knock-off of Harrison's clock, known as the K-1. He builds the clock with Harrison's help in order to - in a roundabout way - win acclaim for Harrison's designs. Jeffrey's tries to make subsequent clocks for less cost, the K-2 and K-3, but they don't work very well.

Larcum Kendall

A student of Jeffreys who attempts to make smaller, yet accurate, versions of Harrison's clocks for manufacture. He builds a knock-off of Harrison's clock, known as the K-1. He builds the clock with Harrison's help in order to - in a roundabout way - win acclaim for Harrison's designs. He tries to make subsequent clocks for smaller cost, the K-2 and K-3, but they don't work very well.

The Board of Longitude

The original characters of the board consisted of Dr. Halley, Sir Charles of the Admiralty, Admiral Norris, two academics, the main astronomers from Cambridge and Oxford, Dr. Robert Smith and Dr. James Bradley. Sir Hans Sloane was also present and was president of the Royal Society. The two other board members were the Right Honorable Arthur Onslow, the speaker of the house of Commons, and Lord Monson, commissioner of Lands and Plantations. Eventually Nathaniel Bliss takes a seat on the Board and after his death he is replaced by Nevil Maskelyne. The Board acts to first help but then mostly thwart the work of John Harrison. They award him enough money to continue to work on clocks but every time he meets their requirements to earn the prize, they increase or change the requirements. Yet Harrison never gives up. After Harrison's

death, the British Parliament makes winning the prize so hard that it is never awarded, although the Board does award a variety of smaller prizes.

John Hadley and Thomas Godfrey

British and American astronomers who made some of the innovations which made a lunar distance method look attainable within a short time.

George Graham

George Graham was a master clockmaker that Halley sent Harrison to for the purpose of explaining his ideas. Graham was a big fan. He also provides Harrison with his first clock-making loan.

James Bradley

James Bradley was one of the Royal Astronomers and one of Maskelyne's partners in crime.

Captain James Cook

Captain Cook was an extraordinarily famous captain, the first to sail around the entire world. He figures into this story because the K-1 was the clock that helped make that trip possible.

Thomas Mudge

Thomas Mudge followed in Harrison's footsteps, building more clocks. He became Maskelyne's new nemesis after Harrison's death.

John Arnold/Thomas Earnshaw

Two clockmakers interested in figuring out how to make Harrison's clock designs cheaper so they could manufacture them for the public. They were successful to some extent and competed fiercely with one another, often fighting over patents.

Robert Gould

Lieutenant Commander Rupert T. Gould of the Royal Navy restored Harrison's clocks and explained their workings clearly in a book. He worked on the clocks primarily in the 1920s.

Objects/Places

H-1

Harrison's first sea clock. Harrison spends five years building it. The H-1 still exists today and weights seventy pounds, enclosed in a 4 x 4 x 4 foot cabinet. It worked spectacularly and passed tests on numerous occasions. Halley was converted, among others.

H-2

H-1 could have easily passed the Board of Longitude's requirements but Harrison spent his presentation before the Board complaining about H-1's errors. He asked for a small loan to build a second clock and the board agreed so long as Harrison agreed that the clock would be available for public use. In two years, he produced the H-2 but became dissatisfied with it before presenting it to the board. Because of this, he wanted to try again and H-2 was never used at sea.

H-3

After he gave up on H-2, Harrison would spend the next twenty years building the H-3, emerging only to collect small loans from the board. This clock was the most accurate yet. The H-3 has 753 working parts and possessed numerous innovations that would balance against temperature and friction problems. H-3 weighs only sixty pounds and has a simpler core design.

H-4

While Harrison is building the H-3, he comes in contact with John Jefferys, a freemason, who made Harrison a pocket watch built from Harrison's design. Jeffreys stays in contact with Harrison until the H-4 is finished. H-4 is five inches in diameter and is absolutely beautiful, including diamond mechanisms and a silver case. It is not not known how the watch was jeweled. H-4 continues to be able to function to this day, along with H-3, H-2 and H-1. But it is not run so as not to wear down its parts.

H-5

In Harrison's dotage, he completed an austere version of H-4, H-5. It took him five years to build and test. When he was finished, he was seventy-nine. King George III at the time took an interest in the H-4 trials and spoke with William Harrison about them. William recounted how cruelly his father had been treated and the King agreed. George III turned over H-5 to his private scientist, S. C. T. Demainbray for a six-week indoor

trial. The H-5 lived up to expectations despite an initial run-in with some of the king's lost lodestones. H-5 was accurate to within one second of a day.

K-1

Maskelyne argued to the Board of Longitude that H-4 was less accurate than the heavens. Of course, Harrison protested that H-4 was placed in direct sunlight, superheating the watch mechanisms under the glass. Maskelyne never answered the allegations. And even after Harrison was ignored, the Board refused to return H-4 to Harrison. The Board did, however, hire one of John Jeffrey's assistants, Larcum Kendall, to attempt to copy H-4. After two and a half years, Kendall finished K-1. Harrison was invited to help judge the K-1 and was enthusiastic about it. Captain Cook, on his second voyage around the world, selected K-1 and not H-4 to accompany him. When Cook returned, he had high praise for the K-1.

K-2 and K-3

Larcum Kendall built K-2 and K-3 attempting to reduce the price of the K-1 for manufacture. But both clocks were fairly unimpressive.

Various Clock Parts

Many different mechanisms internal to making a clock work are discussed in the book. They are typically mentioned in passing but together they are an important set of objects because they demonstrate the importance of how small innovations add up to dramatic improvements in human life.

The Longitude Prize

The Longitude prize was for twenty-thousand pounds (millions in today's pounds) and was to be awarded to anyone who could solve the Longitude problem.

Moons

This includes the objects of earth's moon and the moons of Jupiter. Both were used by fans of the lunar distance method of calculating longitude as a potential source of "celestial clockwork."

The Royal Observatory

The Royal Observatory is run by the Royal Academy of Astronomers. It is where Flamsteed made many of his maps and where many proponents of the lunar distance method did their work.

Harrison's Home

Harrison's home is where every one of his clocks were built, year after year for decades.

Various Ships

Ships of various names, sailing at various times raise issues in the book. They make the problem of the longitude pertinent and shows the urgent need to solve it. They are also often used to test Harrison's clocks or the K-series clocks made by Kendall.

Themes

Genius

The crucial theme of this book is the awe-inspiring power of genius to transform human life. John Harrison was raised in the British countryside and had no formal education whatsoever. As a child, he learned crafts from his father and read all he could. He built his first pendulum clock before he was twenty and did so without a job as a watchmaker's apprentice. No known clockmaker lived anywhere near his town of north Lincolnshire at the time. Harrison was truly incredible and built a variety of clocks around town that function to this day. He created a remarkable number of innovations in clock building in the process. He invented, for instance, a brass and steel pendulum that could aid in keeping time despite temperature changes. Harrison and his brother-in-law, James, were able to build a clock that lost never more than a second per month as a result of Harrison's ingenuity. We know that Harrison knew of the Longitude Prize by 1727 and set out to win it. He left with his new clock to London to make his case before the Board of Longitude. The Board was so impressed and surprised by Harrison that they gave him loans to work on clocks. He produced five major timepieces in his life time, the H-series, H-1, H-2, H-3, H-4, and H-5. Each clock was a masterpiece and each clock, up to H-4, was an improvement on the previous one. Harrison used these clocks to solve the problem of longitude, a problem that Britain's best astronomers could not solve using a lunar method. He showed that a solution to an age-old problem could be solved by "trapping time in a box."

What we also see in this book is that genius is no respecter of person. It appears in individuals in unexpected times and places, and will appear regardless of temperament or station of birth. Yet whenever it appears, it is striking and can often lead to major changes across the world. Harrison's genius led to the incredible ease with which contemporary societies keep track of time and saved countless lives of sailors in previous centuries. His clock also made navigation for the British Navy possible, which the author speculates could have changed the course of history.

The Resentment of Genius

Not only is genius a theme of Longitude but so is the resentment of genius. Often in history, geniuses are so different from the regular population that they threaten to uproot established modes of life. This makes many uncomfortable, particularly if they stand to pay costs due to the upheaval the genius brings about. In Longitude, Harrison is the genius. The establishment is the Royal Academy of Astronomers which wishes to maintain the status of the problem of the Longitude as a problem only they can solve. They do not wish to be made to look foolish and irrelevant by a country-bumpkin who thinks he can solve the celestial, transcendent problem of the longitude with a little, ticking box.

The story is more detailed than this, however. Members of the Royal Academy, particularly James Bradley and Nevil Maskelyne, pull some dirty tricks to prevent Harrison from achieving his hard-won recognition for solving an age-old problem. They very likely sabotaged the trials of his clocks. Maskelyne almost certainly did. His men dropped one of Harrison's clocks in transit. He ran the trial for H-4 in the sun, where the heat would superheat the internal workings of the clock. He appears to have falsified records. Bradley attempted to delay William Harrison's voyage to test H-4 for as long as he could to allow Nevil Maskelyne to prove the effectiveness of the lunar distance method.

It is not that these Royal Astronomers resented genius per se. They were great admirers of Newton, for instance. They resented inconvenient genius, genius that would cost them. But so often that is precisely the effect that genius has on the world.

Elitism

The final major theme of Longitude is elitism. Not only do many of the Royal Astronomers resent Harrison's genius, they do so because they believe a man without the extensive education required to become a Royal Astronomer wasn't worthy of solving the problem of Longitude. In Chapter 9, we see the motivation for the elitism when we meet two astronomers, Hadley and Godfrey, who invent a method that can calculate lunar distance. This put a lunar solution within closer reach. Edmund Halley also took up a study of the moon's motions and made several successful predictions about celestial movements. His heir, James Bradley, continued his search. Bradley saw his mission as a Royal Astronomer as primarily aiding navigation. Bradley teamed up with a German mapmaker, Tobias Mayer to compete for the longitude prize. The problem with the lunar method, however, is that it took a great deal of calculation. Anyone who could complete these calculations had to be very intelligent.

It was for this reason the astronomers found Harrison's clock idea so outrageous. Harrison "offered the world a little ticking thing in a box" (99). Due to the astronomers' elitism, Harrison would face much adversity after he finished his greatest work, the H-4, in 1759. In general, Harrison's experience illustrates that the Royal Astronomers were more interested in maintaining respect and prestige for their group than producing a genuine solution to the problem of Longitude. Again, not all of them opposed Harrison but many were threatened by his clocks. Yet for many, the solution to the problem was not worthy of Harrison. We also learn about the struggles that astronomers had gone through in developing a solution, and did not want their work to be in vain. This would make them even more foolish, something they did not want to allow.

Style

Perspective

The perspective is the third-person. The author writes about all the conflicts from his perspective as a historian. The author clearly admires Harrison and is fully on his side. He tells the story of Harrison's trials though in the mode of an accomplished writer of history. The story ebbs and flows between different narrative speeds. Sometimes the author tells us an important story that explains the motivations and interests of the main part of the book. But in slower sections he tells brief, but well-written, stories about experiencing the night sky, seeing Harrison's clocks in person, or the reaction of a young person to viewing the clocks. In the faster sections, the author describes in detail the fight between Harrison and the Board of Longitude or the great triumphs that Harrison pulled off by means of his clocks.

The author is a man of science and possesses an admiration for the independent inquirer, willing to fight elites on behalf of the truth, even if those elites are themselves scientists. As a result there is an interesting interplay between respecting expertise but not respecting experts just because they are experts. Oftentimes the experts get it wrong, like the Royal Astronomers did. Inspiration can come to the most unexpected people and a critical, honest mind must be open to seeing the truth even when it is inconvenient.

Tone

The author's tone is generally positive and excited. He is happy to tell the story of a man he regards as one of history's great geniuses. He loves Harrison's "lone wolf" persona, struggling against the scientific establishment of his day. The tone in many ways is upbeat, as this is ultimately a story of victory. The author is excited, which is reflected in his work. The tone is also hopeful. The author shows that Harrison experienced his fair share of trials and tribulations but always there is the sense that the truth will win out in the end, that the Royal Astronomers will have to eventually accept the awesome genius of the H-series clocks. And in the end, this proves correct. This also makes the tone triumphant. Harrison is a fighter, a man who never gives up his search to make the best, most accurate clock that he is capable of making, and he will let no one stand in his way. The author describes Harrison's determination with admiration and ultimately shows Harrison's vindication comes to him in life and even much more so after his death. Yet the book has another kind of tone as well; it has an almost wistful and transcendent air. In some ways, the author thinks Harrison trapped the universe in a box. The original problem of longitude was thought to be one of finding in the heavens a celestial clock. And in this way, the problem took on a kind of transcendent power. The author often speaks of Harrison as accomplishing a transcendent task. There is a wistful quality, where the author seems to long to experience that exciting period of history himself.

Structure

The structure of the book is fairly straightforward. The book is only 175 pages, yet it contains fifteen chapters. Each chapter covers a distinct element of the story. Sometimes the chapters begin with a story that winds its way into the main plot line, but in general each chapter can stand alone, and as a whole, the chapters tell a well-ordered story. Chapter 1 begins by describing the longitude problem to us in its most general detail, setting up the key challenge of the book. Chapter 2 explains the historical events that led up to a public motivation to solve the longitude problem. Chapter 3 introduces the attempts to find an astronomical solution to the problem. In Chapter 3, we see the beginnings of the tradition of the lunar or star-based solution to the problem of the longitude. In Chapter 4, we are introduced to the problems facing a clock-based solution. And we're thereby acquainted with a tension between the two methods, with the astronomical method initially appearing superior. Chapter 5 tells another story about historical events that motivated a solution to the longitude problem, further demonstrating the need for a solution after introducing two different traditions engaged in trying to solve the problem, while both are for the time are inadequate. Chapter 6 introduces us to the Board of Longitude and the Longitude Prize, and Chapter 7 introduces us to our hero, John Harrison. Chapter 8 is the story of Harrison's first two clocks. Chapter 9 introduces us to the hostility of some astronomers to Harrison's solution, and Chapter 10 is the story of Harrison's third clock. The story in these chapters builds as the major conflict is introduced and Harrison's genius is demonstrated. Chapters 11, 12 and 13 play out the major conflict, ultimately resolving it somewhat in Harrison's favor. The book begins its denouement in Chapter 14 describing efforts to mass produce Harrison's designs. The book concludes with Chapter 15, which describes the long lasting historical effects of Harrison's impressive inventions.

Quotes

"The placement of the prime meridian is a purely political decision." (4)

"The zero-degree parallel of latitude is fixed by the laws of nature, while the zero-degree meridian of longitude shifts like the sands of time." (4)

"In literally hundreds of instances, a vessel's ignorance of her longitude led swiftly to her destruction." (13)

"Time is to clock as mind is to brain." (34)

"As far as they could see, the answer would come from the heavens - from the clockwork universe and not from any ordinary clock." (40)

"One method is by a Watch to keep time exactly. But, by reason of the motion of the Ship, the Variation of Heat and Cold, Wet and Dry, and the Difference of Gravity in different Latitudes, such a watch hath not yet been made." (52)

"... bot (sic) however we got the ice broke ... and indeed he became as at last vastly surprised at the thoughts or methods I had taken." (76)

"John Harrison, having with great labour and expense, contrived and executed a Machine for measuring time at sea, upon such Principle, as seem to us to Promise a very great and sufficient degree of exactness." (79)

"Hogarth described H-1 as 'one of the most exquisite movements ever made.'" (87)

"Instead of the accolades he might have expected for his achievements, he was to be subjected to many unpleasant trials that began after the completion of his masterpiece, the fourth time keeper, H-4, in 1759." (99)

"I think I may make bold to say, that there is neither any other Mechanical or Mathematical thing in the World that is more beautiful or curious in texture than this my watch or Timekeeper for Longitude ... and I heartily thank Almighty God that I have lived so long, as in some measure to complete it." (106)

"'I don't know,' she answered. 'I just like it.'" (175)

"He wrested the world's whereabouts from the stars, and locked the secret in a pocket watch." (175)

Topics for Discussion

What motivates John Harrison to build his clocks? Money? Prestige? The rewards of clockbuilding? Solving the problem of Longitude? Please describe what combination of motives you believe most plausible. Defend your answer.

What motives Nevil Maskelyne to thwart John Harrison? Is it the money? The prestige of solving the problem first? The glory of the stars? Elitism? Jealousy? Please describe the combination of motives you believe most plausible. Defend your answer.

Please describe why you believe the Royal Astronomers were hostile to John Harrison's clocks.

To what extent was John Harrison mistreated by the Board of Longitude? Describe the two greatest injustices he suffered.

Why is Harrison's clock-building so impressive? What does it say about him as a person?

Please explain what the problem of Longitude is. Explain how the lunar distance method would solve it. Explain how Harrison's clocks solved it.

Why did the Board of Longitude and the British Parliament continue to make it harder to win the Longitude Prize? Was it merely to keep the prize money? Was it to protect the Royal Astronomers? To motivate the inventors to keep trying? Explain your answer.