Christiaan Huygens

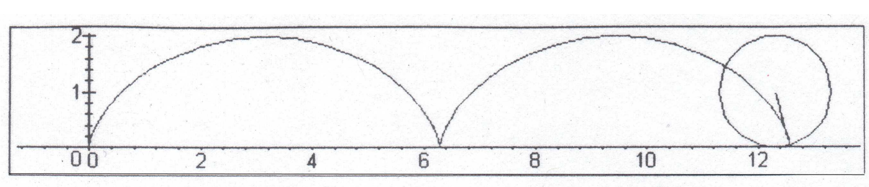
Dutch mathematician, astronomer and physicist **Christiaan Huygens** (April 14, 1629 - July 8, 1695) studied all areas of science that interested him. He is most known for being the first to use a pendulum to regulate a clock. But his greatest contribution was as the leading proponent of the wave theory of light. He was one of the founders of mechanics and optical physics and is known for his revolutionary work on the catenary, probability, logarithms, cycloids, and centers of oscillation. He was also the first to determine acceleration due to gravity. Huygens also deserves credits for giving Gottfried Leibniz mathematical lessons and encouraging the latter in the work that led to his development of his calculus.

Huygens was born in The Hague into a wealthy and distinguished family. His diplomat father Constantin had studied natural philosophy, was a poet, composer, musician, and patron of the arts. He regularly corresponded with Marin Mersenne and René Descartes, who frequently visited the Huygens' home. For Christiaan, their visits introduced him to the top scientific circles of the period. Huygens' father tutored his son, who he called "mon Archimède," at home until he was sixteen, teaching him geometry and how to make mechanical models. From 1645 to 1647, Huygens studied law at the University of Leiden before turning to science and mathematics. Frans Van Schooten acquainted Huygens with the new analytic geometry of Descartes' *La Géométrie*. From 1647 to 1649, he continued his studies at the College of Orange at Breda, where one of his teachers was John Pell. At about this time, Huygens corresponded with Mersenne, who challenged him to solve a number of problems, including discovering the shape of a rope supported from its ends (the catenary). Huygens was unsuccessful, but he solved a related problem as to how to hang weights on the rope so it hung in a parabolic shape.

In 1651, Huygens demonstrated his geometrical skills with his first published work, *Theoremata de quadratura hyperboles, ellipsis et circuli*. That same year he published an essay, *Cyclometriae*, in which he showed the fallacy of the methods used by Grégoire de Saint Vincent, who claimed to have solved the famous problem of antiquity, the squaring of a circle. In 1657, due to the encouragement of Blaise Pascal, Huygens published the first book on probability theory. From an early age Huygens showed a marked mechanical bent and talent for drawing. He introduced improvements in the construction of the telescope by devising a new and better way of grinding and polishing lenses. As a result he detected the Saturnian moon Titan and gave a correct explanation of the nature of the Saturnian rings. As his astronomical observations required exact means of measuring time, in 1656, Huygens built the world's first pendulum clock. It was far more reliable than early European mechanical clocks that were driven by the controlled fall of a weight or the spring-driven mechanisms that appeared in the mid 15th century. For nearly 300 years, the most accurate clocks in the world used pendulums, although many improvements were made on Huygens' original design.

Huygens' scientific reputation was such that Louis XIV offered him a pension if he would live and work in Paris. Apart from occasional visits to Holland, Huygens remained in the French capital from 1666 to 1681, although his situation became precarious when the French invaded the Low Countries in 1671. Huygens was one of the founding members of the French Academy of Sciences. In his most work *Horologium Oscillatorium sive de motu pendulorum* (1673), he described the theory of pendulum motion. He gave a complete account of the descent of heavy bodies under their own weights in a vacuum, either vertically down or along smooth curves, and also derived the law of centrifugal force for uniform circular motion. In 1676, Huygens further contributed to timepieces by building a properly working chronometer that used a balance wheel and a spiral spring instead of a pendulum. Almost all watches featured balance wheels and spiral springs until the invention of the quartz crystal oscillator. He presented the first watch built to his specifications to Louis XIV.

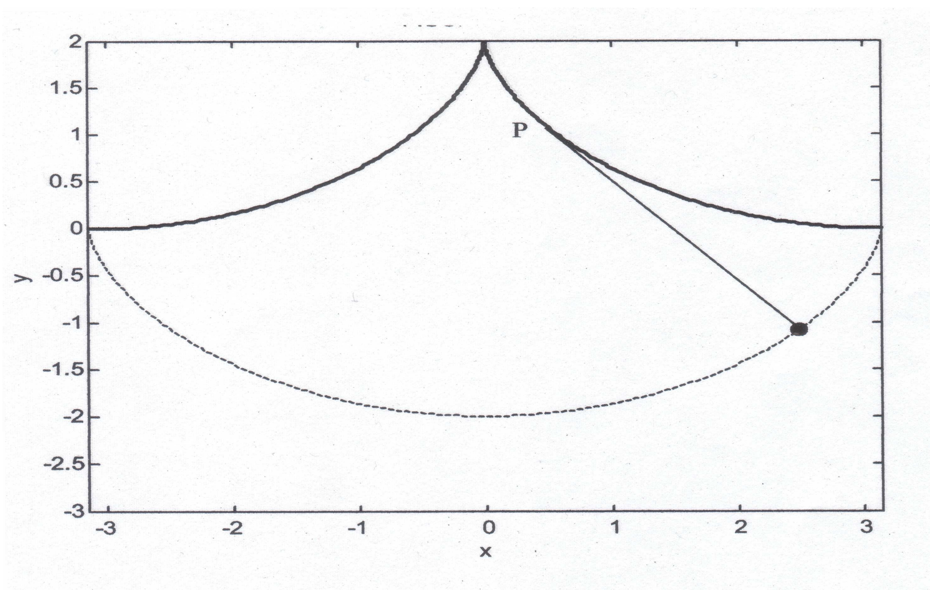
Horology is the science or art of measuring time or making timepieces. In searching for improvements in horology, Huygens knew that the oscillations of a simple pendulum did not occur at equal intervals of time but depended upon the magnitude of the swing. The pendulum works well enough if its movements are small, but as the swing of the pendulum varies so does the time it takes. It is only a slight difference, but an important one to make a clock precise. Another way of phrasing this is if an object is placed on the side of a smooth hemispherical bowl and released, the time it takes to reach the lowest point will be slightly dependent of the height from which it is released. In 1659, prompted by Blaise Pascal's challenge, Huygens had shown that the cycloid is the solution to the tautochrone problem, that is, the cycloid is the curve for which the time taken by a particle sliding down to the lowest point, subject only to gravity, is independent of its starting point. The cycloid (Figure 4.6) is the plane locus of a fixed point on the circumference of a circle, as the circle rolls upon a straight line without slipping. If two balls are released from two points of a cycloid path and they are made to fall at the same time, they will hit each other at the lowest point of the curve, even if one started very near and the other very far from this point.



Cycloid

Figure 4.6

Huygens wondered what would happen if one replaced the hemispherical bowl with one whose cross section was an inverted cycloidal arch. Eureka! It happened that for such a bowl, the object reached the lowest point in exactly the same time, no matter from what heights on the inner surface of the bowl the object is released. Huygens had one last problem to solve. How does one get a pendulum to oscillate in a cycloidal, rather than a circular arc? Huygens introduced the *involute* of a plane curve, which is the locus of a fixed point on a nonflexible string as it is unwound, under tension from the curve. (The locus of the centers of curvature, on each normal, is called the *evolute* of the original curve.) Huygens proved that the involute of a cycloid is another cycloid. He found that to make the pendulum bob swing along a cycloid, the string needed to “unwrap” from a curve that is the evolute of a cycloid, so that the cycloid is the involute of the shape. Thus he suspended a pendulum from a point at the cusp between two inverted cycloidal semi-arcs (Figure 4.7) with the length of the pendulum equal to the length of one of the semi-arcs. In this way a pendulum bob will swing in an arc that is an arc of a cycloid of exactly the same size and shape as the cycloid of which the semiarches are parts. Thus a pendulum bob swinging along a cycloidal arc takes exactly the same time to complete swings of small or large amplitude.



The Cycloid Pendulum

Figure 4.7

At first glance, the cycloid problem may seem little more than a mathematical curiosity, but it became the linch-pin of one of the world's greatest inventions, an accurate timepiece. Pure research must never be abandoned. No one can foresee how the polishing of pretty mathematical and scientific pebbles may be used to build a great edifice.

When his health deteriorated Huygens returned to The Hague, intending only a temporary stay. But his patron in France, Jean-Baptiste Colbert died, and Louis XIV revoked the Edict of Nantes that had granted certain liberties to Protestants. Calvinist Huygens remained in Holland for the rest of his life, living off the income of his family's properties. He spent his time in the construction of enormous lenses, including those of focal length 123 feet, 180 feet, and 210 feet, which he later donated to the Royal Society of London. About this time he discovered the achromatic eyepiece for a telescope, known by his name.

In *Traité de la Lumière,* which had largely been completed by 1678 but not published until 1690, Huygens developed the concept of the wavefront. He described light as a vibration spreading through all-prevailing "ether" consisting of microscopic particles. He formulated the basic postulate of wave theory, now known as "Huygens' principle": every point on a wavefront is the source for a new spherical wave. His theory was supported by his observation that two intersecting beams of light did not bounce off each other as would be expected if they were composed of particles. Huygens correctly believed that light must travel more slowly when it is refracted towards the normal. He calculated the speed of light as 2.2×10^8 meters per second using astronomical observations from Danish astronomer Olaus Roemer. The last five years of his life were marked by continued poor health and increasing feelings of loneliness and melancholy because of his scientific isolation. Shortly before his death Huygens wrote the book *The Discovery of Celestial Worlds: Theories about Inhabitants, Plants and*

Products of Planetary Worlds, published in 1698, three years after his death, in which he speculated about life not only on planets of the solar system, but also about life on worlds of other star systems.

Quotation of the Day: “We shall be less apt to admire what this world calls great … when we know that there are a multitude of such Earths inhabited and adorned as well as our own. [The Universe is populated with] so many Suns, so many Earths … And how much our wonder and admiration be increased when we consider the prodigious distance and multitude of the stars.” – Christiaan Huygens