Christiaan Huygens

Born: 14 April 1629 in The Hague, Netherlands
Died: 8 July 1695 in The Hague, Netherlands

Christiaan Huygens came from an important Dutch family. His father Constantin Huygens had studied natural philosophy and was a diplomat. It was through him that Christiaan was to gain access to the top scientific circles of the times. In particular Constantin had many contacts in England and corresponded regularly with Mersenne and was a friend of Descartes.

Tutored at home by private teachers until he was 16 years old, Christiaan learned geometry, how to make mechanical models and social skills such as playing the lute. His mathematical education was clearly influenced by Descartes who was an occasional visitor at the Huygens' home and took a great interest in the mathematical progress of the young Christiaan.

Christiaan Huygens studied law and mathematics at the University of Leiden from 1645 until 1647. Van Schooten tutored him in mathematics while he was in Leiden. From 1647 until 1649 he continued to study law and mathematics but now at the College of Orange at Breda. Here he was fortunate to have another skilled teacher of mathematics, John Pell. Through his father's contact with Mersenne, a correspondence between Huygens and Mersenne began around this time. Mersenne challenged Huygens to solve a number of problems including the shape of the rope supported from its ends. Although he failed at this problem he did solve the related problem of how to hang weights on the rope so that it hung in a parabolic shape.

In 1649 Huygens went to Denmark as part of a diplomatic team and hoped to continue to Stockholm to visit Descartes but the weather did not allow him to make this journey. He followed the visit to Denmark with others around Europe including Rome.

Huygens's first publications in 1651 and 1654 considered mathematical problems. The 1651 publication *Cyclometriae* showed the fallacy in methods proposed by Gregory of Saint-Vincent, who had claimed to have squared the circle. Huygens' 1654 work *De Circuli Magnitudine Inventa* was a more major work on similar topics.

Huygens soon turned his attention to lens grinding and telescope construction. Around 1654 he devised a new and better way of grinding and polishing lenses. Using one of his own lenses, Huygens detected, in 1655, the first moon of Saturn. In this same year he made his first visit to Paris. He informed the mathematicians in Paris including Boulliau of his discovery and in turn Huygens learnt of the work on probability carried out in a correspondence between Pascal and Fermat. On his return to Holland Huygens wrote a small work *De Ratiociniis in Ludo Aleae* on the calculus of probabilities, the first printed work on the subject.

The following year he discovered the true shape of the rings of Saturn. However others had different theories including Roberval and Boulliau. Boulliau had failed to detect Saturn's moon Titan so Huygens realised that he was using an inferior telescope. By 1656 Huygens was able to confirm his ring theory to Boulliau and the results were reported to the Paris group. In *Systema Saturnium* (1659), Huygens explained the phases and changes in the shape of the ring. Some, including the Jesuit Fabri, attacked not only Huygens theories but also his observations. However by 1665 even Fabri was persuaded to accept Huygens' ring theory as improving telescopes confirmed his observations.

Work in astronomy required accurate timekeeping and this prompted Huygens to tackle this problem. In 1656 he patented the first pendulum clock, which greatly increased the accuracy of time measurement. His work on

the pendulum was related to other mathematical work which he had been doing on the cycloid as a result of the challenge by Pascal. Huygens believed that a pendulum swinging in a large are would be more useful at sea and he invented the cycloidal pendulum with this in mind. He built several pendulum clocks to determine longitude at sea and they underwent sea trials in 1662 and again in 1686. In the *Horologium Oscillatorium sive de motu pendulorum* (1673) he described the theory of pendulum motion. He also derived the law of centrifugal force for uniform circular motion. As a result of this Huygens, Hooke, Halley and Wren formulated the inverse-square law of gravitational attraction.

Huygens returned to Paris in 1660 and went to meetings of various scientific societies there. He wrote, in a letter to his brother:-

... there is a meeting every Tuesday [*at Montmor's house*] *where twenty or thirty illustrious men are found together. I never fail to go ... I have also been occasionally to the house of M Rohault, who expounds the philosophy of M Descartes and does very fine experiments with good reasoning on them.*

At these societies he met many mathematicians including Roberval, Carcavi, Pascal, Pierre Petit, Desargues and Sorbière. After Pascal visited him in December 1660 Huygens wrote

... we talked of the force of water rarefied in cannons and of flying, I showed him my telescopes...

In 1661 Huygens visited London, particularly to find out more about the newly forming Royal Society meeting at that time in Gresham College. He was greatly impressed with Wallis and the other English scientists whom he met and, from this time on, he was to continue his contacts with this group. He showed his telescopes to the English scientists and they proved superior to those in use in England. The Duke and Duchess of York came to observe the Moon and Saturn through Huygens' telescope. While in London Huygens saw Boyle's vacuum pump and he was impressed. After his return to the Hague he carried out a number of Boyle's experiments for himself. Huygens was elected to the Royal Society of London in 1663.

At this time Huygens patented his design of pendulum clock with the solution of the longitude problem in mind. In 1665 he learnt that the Royal Society was investigating other forms of clock, in particular Hooke was experimenting with a spring regulated clock. Huygens wrote to Hooke doubting this approach which he felt would be unduly affected by temperature changes. Despite this Huygens did begin to experiment with clocks regulated by springs, but their accuracy was poorer than his pendulum clocks.

Huygens accepted an invitation from Colbert in 1666 to become part of the Académie Royale des Sciences. He arrived in Paris that year to discover that the Society was not yet organised. After meetings were held with Roberval, Carcavi, Auzout, Frenicle de Bessy, Auzout and Buot in Colbert's library the Society moved to the Bibliothèque du Roi where Huygens took up residence. He assumed leadership of the group basing much on his knowledge of the way the Royal Society operated in England.

Huygens' work on the collision of elastic bodies showed the error Descartes' laws of impact and his memoir on the topic was sent to the Royal Society in 1668. The Royal Society had posed a question on impact and Huygens' proved by experiment that the momentum in a fixed direction before the collision of two bodies is equal to the momentum in that direction after the collision. Wallis and Wren also answered this question.

Circular motion was a topic which Huygens took up at this time but he also continued to think about Descartes' theory of gravity based on vortices. He seems to have shown signs of being unhappy with Descartes' theory around this time but he still addressed the Académie on this topic in 1669 although after his address Roberval and Mariotte argued strongly, and correctly, against Descartes's theory and this may have influenced Huygens.

From his youth Huygens' health had never been robust and in 1670 he had a serious illness which resulted in him leaving Paris for Holland. Before he left Paris, believing himself to be close to death he asked that his

unpublished papers on mechanics be sent to the Royal Society. The secretary to the English ambassador was called and described Huygens reasons:-

... he fell into a discourse concerning the Royal Society in England which he said was an assembly of the choicest wits in Christendom ... he said he chose to deposit those little labours ... in their hands sooner than any else. ... he said he did foresee the dissolution of this Academy because it was mixed with tinctures of envy because it was supported upon suppositions of profit because it wholly depended upon the humour of a prince and the favour of a minister...

By 1671 Huygens returned to Paris. However in 1672 Louis XIV invaded the Low Countries and Huygens found himself in the extremely difficult position of being in an important position in Paris at a time France was at war with his own country. Scientists of this era felt themselves above political wars and Huygens was able, with much support from his friends, to continue his work.

In 1672 Huygens and Leibniz met in Paris and thereafter Leibniz was a frequent visitor to the Académie. In fact Leibniz owes much to Huygens from whom he learnt much of his mathematics. In this same year Huygens learnt of Newton's work on the telescope and on light. He, quite wrongly, criticised Newton's theory of light, in particular his theory of colour. His own work, *Horologium Oscillatorium sive de motu pendulorum* appeared in 1673 and showed that Huygens had moved far from Descartes' influence.

Horologium Oscillatorium contains work on the pendulum. In it Huygens proves that the cycloid is tautochronous, an important theoretical result but one which had little practical application to the pendulum. He also solves the problem of the compound pendulum. However there is much more than work on pendulums. Huygens describes the descent of bodies in a vacuum, either vertically or along curves. He defines evolutes and involutes of curves and, after giving some elementary properties, finds the evolutes of the cycloid and of the parabola. Huygens attempts for the first time in this work to study the dynamics of bodies rather than particles.

Papin worked as an assistant to Huygens around this time and after he left to work with Boyle, Huygens was joined by Tschirnhaus. Another bout of illness in 1676 saw Huygens return to the Hague again. He spent two years there, in particular studying the double refraction Bartholin had discovered in Iceland spar crystal. He also worked on the velocity of light which he believed was finite and was pleased to hear of Römer's experiments which gave an approximate velocity for light determined by observing Jupiter's moons.

By 1678 Huygens had returned to Paris. In that year his *Traité de la lumiere* appeared, in it Huygens argued in favour of a wave theory of light. Huygens stated that an expanding sphere of light behaves as if each point on the wave front were a new source of radiation of the same frequency and phase. However his health became even more unreliable and he became ill in 1679 and then again in 1681 when he returned to the Hague for the last time. La Hire, who had always argued against foreigners in the Académie, sent his best wishes to Huygens but he clearly hoped that he would not return so that he might himself might acquire his position.

The longitude problem had remained a constant cause for Huygens to continue work on clocks all his life. Again after his health returned he worked on a new marine clock during 1682 and, with the Dutch East India Company showing interest, he worked hard on the clocks. Colbert died in 1683 and a return to Paris without the support of his patron seemed impossible. His father died in 1687, having reached 91 years of age, and the following year his brother left for England. Huygens missed having people around him with whom he could discuss scientific topics. In 1689 he came to England.

In England Huygens met Newton, Boyle and others in the Royal Society. It is not known what discussions went on between Huygens and Newton but we do know that Huygens had a great admiration for Newton but at the same time did not believe the theory of universal gravitation which he said

appears to me absurd.

In some sense of course Huygens was right, how can one believe that two distant masses attract one another when there is nothing between them, nothing in Newton's theory explains how one mass can possible even know the other mass is there. Writing about Newton and the *Principia* some time later Huygens wrote:-

I esteem his understanding and subtlety highly, but I consider that they have been put to ill use in the greater part of this work, where the author studies things of little use or when he builds on the improbable principle of attraction.

He departed with much sadness at the thoughts of his scientific isolation in Holland.

In the final years of his life Huygens composed one of the earliest discussions of extraterrestrial life, published after his death as the *Cosmotheoros* (1698). He continued to work on improving lenses and on a spring regulated clock and on new pendulum clocks.

Huygens described the 31-tone equal temperament in *Lettre touchant le cycle harmonique*. This has led indirectly to a tradition of 31-tone music in the Netherlands in this century.

In a letter to Tschirnhaus written in 1687, Huygens explained his own approach:-

.. great difficulties are felt at first and these cannot be overcome except by starting from experiments ... and then be conceiving certain hypotheses ... But even so, very much hard work remains to be done and one needs not only great perspicacity but often a degree of good fortune.

Huygens scientific achievements are summed up in [4] as follows:-

... Huygens was the greatest mechanist of the seventeenth century. He combined Galileo's mathematical treatment of phenomena with Descartes' vision of the ultimate design of nature. Beginning as an ardent Cartesian who sought to correct the more glaring errors of the system, he ended up as one of its sharpest critics. ... the ideas of mass, weight, momentum, force, and work were finally clarified in Huygens' treatment of the phenomena of impact, centripetal force and the first dynamical system ever studied - the compound pendulum.

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