Augustin Jean Fresnel

Born: 10 May 1788 in Broglie, France
Died: 14 July 1827 in Ville-d'Avray, France

Augustin Fresnel's parents were Jacques Fresnel and Augustine Mérimée. Jacques Fresnel was an architect who undertook major building works. In 1785 he was employed by Victor-François de Broglie, the Second Duke and marshal of France under Louis XV and Louis XVI, to undertake major improvements on his château. It was while he was working on this project that he met Augustine Mérimée the daughter of the overseer of de Broglie's estate and the two were married. Jacques Fresnel was still working on de Broglie's estate when his son Augustin was born. After work on de Broglie's château had been completed Jacques and Augustine, with their son Augustin, went to Cherbourg where Jacques was employed on the construction of the harbour.

We should note that Jacques and Augustine Fresnel were Jansenists; that is they were followers of Cornelius Otto Jansen (1585-1638) who led the Roman Catholic reform movement named after him. Jansen argued that men cannot achieve salvation through their actions since it is predestined who Christ will lead to eternal life, the select few, and who are doomed to damnation, the multitude. Augustin was brought up with strict Jansenist values in a stern atmosphere which would strongly influence him for the rest of his life.

The French Revolution began with the storming of the Bastille on 14 July 1789 when Augustin was one year old. Louis XVI was executed on 21 January 1793 and there followed the reign of terror. In 1794, when Augustin was now six years old, the political situation in France was so difficult that the construction work on the harbour at Cherbourg had to be halted. The Fresnel family went to Mathieu, a village north of Caen. There young Fresnel spent the rest of his childhood years, and there his elementary education was provided by his parents. There is no record of any educational achievements by the young boy at this stage and, although it may be a little harsh on his parents to say so, it appears that they completely failed to bring out their son's talents.

At age twelve Fresnel began his studies at the École Centrale in Caen. Here he was first introduced to science and he began to show a liking for mathematics, particularly as a result of some fine teaching. There was little doubt in Fresnel's mind at this time regarding his future career for he was firmly set on engineering. He had the right interests, skills, and background for such a career and it was with this in mind that he entered the École Polytechnique in Paris in 1804. After two years there he entered the École des Ponts et Chaussées, completing the course there in three years after which he was qualified as a civil engineer. He was then employed by the Corps des Ponts et Chaussées who sent him to Vendée. In 1804 Napoleon had established the military and administrative town of La Roche-sur-Yon in the centre of the Vendée region. The town was built with wide rectangular streets, barracks and a large parade ground. Fresnel was employed on a programme of road building which was designed to link this town with the rest of Vendée.

Another major French engineering project was the building of a major road through France connecting Spain with northern Italy. Fresnel began working on this project in 1812 when he was based in Nyon but already he was undertaking scientific work in his spare time. One topic which fascinated Fresnel was that of light and he began to undertake experiments in the middle of 1814. On 1 March 1815 Napoleon, who had been exiled on Elba, landed at Cannes with some of his guards. Fresnel was so upset by this turn of events that he left his engineering job and offered to fight for the King against Napoleon. By 20 March many troops had joined Napoleon and he had reached Paris. Of course this meant that Fresnel had put himself in a difficult position, and as a consequence he lost his engineering post and was put under police surveillance. Fresnel had few options left but to return to his home in Mathieu and this he did.

In fact circumstances had conspired to give Fresnel the free time he needed to concentrate on his experiments with light. During this period his work on optics convinced him of the validity of the wave theory of light which was, at that time, totally discarded in favour of the corpuscular theory. After Napoleon was defeated at Waterloo, Fresnel was reinstated into his old engineering appointment. After this he had less time for his research on light which he was only able to undertake in his vacations. He was transferred to an engineering post in Rennes but continually requested leave so that he could go to Paris to continue his scientific investigations.

By applying mathematical analysis to his work Fresnel removed many of the objections to the wave theory of light. Much of his initial work was undertaken without knowledge of the latest contributions by other scientists. He neither knew of the wave theories that had been postulated by Huygens, Euler and Young, nor did he know of the latest developments in the corpuscular theory supported by the majority of scientists. Fresnel began by undertaking experiments with diffraction and made a breakthrough when he attached a piece of black paper to one edge of a diffracter and observed that then the bright bands within the shadow vanished. From this he correctly deduced that these bright bands were produced by light coming from both edges of the diffracter but since bright bands outside the shadow remained he deduced that they must result from light reflected from only one edge of the diffracter.

He was able to calculate formulae which gave the position of the bright and dark lines based on where the vibrations were in phase and where they were out of phase. He published his first paper in October 1815 on his wave theory of light and made a first attempt to explain the phenomenon of diffraction. He then used his same mathematical formulae which worked for his diffraction experiments to give theoretical results on interference patterns obtained by reflecting a light source with two mirrors. He verified the theoretical results by experiment. At this stage he had carried out fairly similar investigations that Thomas Young had carried out between 1797 and 1799 in Cambridge, but Fresnel next moved forward to a new understanding by developing a theory based on a new mathematical formulation. He put forward the idea that [1]:-

... elementary waves arise at every point along the arc of the wave front passing the diffracter and mutually interfere. The problem was to determine the resultant vibration produced by all the wavelets reaching any point behind the diffracter. The mathematical difficulties were formidable, and a solution was to require many months of effort.

Fresnel published his first tentative results in July 1816 but asked that the readers of his article show patience while he worked out further consequences of the mathematics. After working for a while on polarisation of light during 1817, in particular the influence of reflection on polarised light, he returned to his theories of diffraction when the Académie des Sciences announced that the Grand Prix for 1819 would be awarded to the best work on diffraction. It was a great chance for Fresnel to put his revolutionary work before the world and he was very confident of his theory since his mathematical deductions from the one simple hypothesis led to results which he had verified experimentally giving a highly accurate agreement between theory and experimental evidence. He completed his mathematical work just before the time for submission and this allowed him to calculate the intensity of light at every point behind the diffracter using what were later called Fresnel's integrals.

In 1819 the committee to judge the Grand Prix of the Académie des Sciences, with Arago as chairman, and including Poisson, Biot and Laplace, met to consider Fresnel's submission. It was a committee which was not well disposed to the wave theory of light, most believing in the corpuscular model. However Poisson was fascinated by the mathematical model which Fresnel proposed and succeeded in computing some of the integrals to find further consequences beyond those which Fresnel had deduced. Poisson wrote [3]:-

Let parallel light impinge on an opaque disk, the surrounding being perfectly transparent. The disk casts a shadow - of course - but the very centre of the shadow will be bright. Succinctly, there is no darkness anywhere along the central perpendicular behind an opaque disk (*except immediately behind the disk*).

This was a remarkable prediction, but Arago asked that Poisson's predictions based on Fresnel's mathematical model be tested. Indeed the bright spot was seen to be there exactly as Fresnel's theory predicted. Arago stated in his report on Fresnel's entry for the prize to the Académie des Sciences [3]:-

One of your commissioners, M Poisson, had deduced from the integrals reported by [*Fresnel*] *the singular result that the centre of the shadow of an opaque circular screen must, when the rays penetrate there at incidences which are only a little more oblique, be just as illuminated as if the screen did not exist. The consequence has been submitted to the test of direct experiment, and observation has perfectly confirmed the calculation.*

Fresnel was awarded the Grand Prix and his work was a strong argument for a wave theory of light. However polarisation of light produced by reflection still provided a strong argument in favour of the corpuscular theory, since no explanation from a wave theory had ever been made. Fresnel and Arago, now very confident that they could explain this effect with Fresnel's theory, undertook further work on polarisation and Fresnel discovered what was later called circularly polarised light. No hypothesis led to the experimental results obtained other than that light is a transverse wave and, in 1821, Fresnel published a paper in which he claimed with certainty that light is a transverse wave.

Although Fresnel had made many converts to the wave theory of light, even from the most ardent of those previously believing in the corpuscular theory, his assertion that light is a transverse wave was a step too far for most. Even Arago dissented from this claim but Fresnel stunned his critics when he next showed that double refraction could be deduced from the transverse wave hypothesis.

The author of [2] writes:-

Although his work in optics received scant public recognition during his lifetime, Fresnel maintained that not even acclaim from distinguished colleagues could compare with the pleasure of discovering a theoretical truth or confirming a calculation experimentally.

After 1824 he devoted less time to his researches on light. He was employed by the Lighthouse Commission and as part of his effort he developed the use of compound lenses instead of mirrors for lighthouses. To this work [1]:-

... he brought the same inventiveness, concentration, and perseverance previously manifest in his scientific work.

In 1823 Fresnel was elected to the Académie des Sciences. He was also elected to the Royal Society of London and he received its Rumford Medal in 1827.

Fresnel died of tuberculosis in 1827 at the age of 39. He had struggled throughout his life against ill health but it is remarkable that he was able to undertake an exceptionally high workload despite suffering from severe fatigue. Perhaps it was the strict religious upbringing by his parents which gave him the strength to overcome his illness for so long. He saw [1]:-

... the highest merit in personal achievement, performance of duty, and service to society. Serious, intent, haunted by thoughts of an early grave, Fresnel bound himself closely to these ideals, shunning pleasures and amusements and working to the point of exhaustion. Despite the urgency of everything he attempted, Fresnel was always attentive to detail, systematic, and thorough. In science no less than in politics he held tenaciously to his convictions and defended them with courage and vigour. ... he voiced outrage when the behaviour of others fell short of his own high ethical standards. At times this approached a rankling self-righteousness, but generally his contemporaries saw him as reserved, gentle, and charitable.

Article by: *J J O'Connor* and *E F Robertson*