# 1905: The year of the enlightenment

The dual nature of light - composed of waves and particles - was first proposed by Albert Einstein 100 years ago. **Cormac O'Raifeartaigh** describes this crucial point in the birth of modern physics.

The ideas elucidated by Einstein in his 1905 "Special Theory of Relatively" (describing the motion of particles moving at close to the speed of light),have long been considered of massive importance as a foundation block for the construction of modern physics.But,another revolutionary proposal by Einstein,also made in 1905,was equally important.This proposal - which shocked the science world - concerned the nature of light,with Einstein describing what he believed light actually was.

## RADIATION

The concept of the 'quantum' was first mooted in 1900 when it became clear that the standard,'classical' theories of physics could not give a satisfactory description of the energy radiated by a hot body (a failure known as 'the ultra-violet catastrophe').

The distinguished German physicist,Max Planck,managed to derive a formula that exactly matched experimental observation - however, his analysis necessitated an assumption that energy was not emitted continuously, but in the form of minute, discrete bundles or 'quanta'.While this assumption gave good agreement between theory and experiment,it was considered to be a mathematical curiosity of no physical significance.

Over the next few years,the young Einstein became greatly interested in Planck's radiation formula.Einstein intuitively felt that, far from being a mathematical artefact,the 'quantum hypothesis' was of broad significance in the study of radiation.Using sophisticated statistical methods,Einstein arrived at a daring conclusion in 1905 - 'the energy of a light ray....is not continuously distributed,but consists of a finite number of energy quanta'.

In the same paper, Einstein demonstrated that his proposal offered a convincing explanation for the 'photoelectric effect',the phenomenon whereby incident light radiation causes a metal to emit electrons.

## SHOCK

Einstein's proposal shocked the world of science. Where Planck had allowed that radiation (or light) might - in some circumstances - be emitted or absorbed in bundles,Einstein was proposing that the radiation itself was made up of minute bundles or particles of energy (now called photons).The idea was firmly rejected by most scientists (including Planck) for many years.It seemed to be in direct conflict with experimental observation of the wave nature of light,and with Maxwell's highly successful theory of electromagnetic waves and light.How could anyone propose that light behaves like a wave in some circumstances,and like a stream of particles in others? (We now know that all quantum 'waves' exhibit this wave-particle duality.)

## ACCEPTANCE

It took more than fifteen years for Einstein's quantum view of light to be accepted; although he was awarded the 1921 Nobel Prize in Physics for 'his law of the photoelectric effect and other contributions',his theory only gained wide acceptance in 1923.In that year, X-ray scattering studies gave unequivocal evidence of light colliding with electrons in particle-like fashion (the 'Compton effect'). Further support for quantum physics came to light in 1925 with the observation of electron diffraction - not only could a light wave behave like particles,but particles such as electrons could behave like waves.

## QUANTUM THEORY

When an underlying, formal quantum theory emerged in the late 1920s (developed by Heisenberg,Schrödinger, Dirac and others),it had Einstein's wave-particle duality at its core. The new theory proved spectacularly successful in predicting experimental results in the sub-atomic world;however, it was probabilistic in nature and posed great challenges of physical interpretation.

Like many scientists,Einstein was dismayed by the philosophical implications of the theory, and felt it might be incomplete (hence the oversimplified claim that 'Einstein disliked quantum theory').In fact,Einstein made many other contributions to the theory, not least the discovery of the principle on which laser technology is based. Today, quantum theory lies at the heart of much of modern technology, from the silicon chip to the laser, yet problems of interpretation remain.It should never be forgotten that,far from being a disbeliever, Einstein laid a cornerstone of quantum theory with his revolutionary view of the nature of light.

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