Electron Breakthroughs 1897-1997

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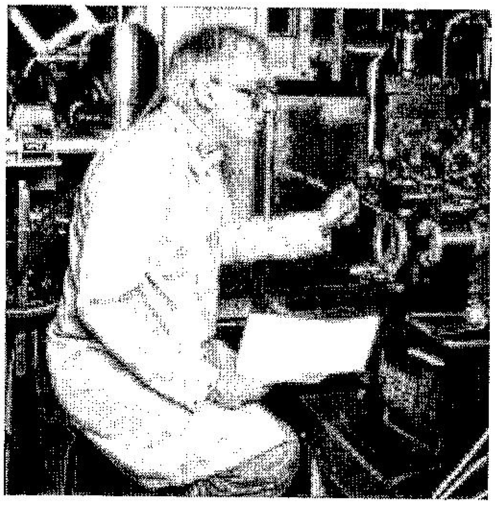
Professor Michael Pepper



One hundred years after Cambridge physicist J.J. Thomson made the epoch-making discovery of the electron that was to usher in the modern age, other physicists, working like 'J.J.' in the world-renowned Cavendish Laboratory, have achieved a discovery which once again pushes forward mankind's knowledge of this elementary particle.

It was in 1897 that John Joseph Thomson identified the electron working in the old Cavendish Laboratory, Cambridge University's Department of Physics, which was then in Free School Lane. Using equipment set in a delicate glass tube less than two feet long, he made the discovery that was not only one of the most important in the history of science but was to change the world in which we live.

By passing a spark or electric current through gas at low pressure across electrodes in a sealed tube, he observed streams of bright lights coming from the cathode, the negative electrode. Thomson realised these were negatively charged sub-atomic particles, which were later known as electrons. Today, billions of times a day, when people turn on their television sets or computers they re-enact that original experiment as the electron beam inside the cathode tube scans around within the set to make the picture. The particles J.J. identified are the smallest irreducible units in solids outside the atomic nucleus.

A century later the research group led by Professor Michael Pepper has succeeded for the first time in isolating and manipulating a single electron, and so devising a way its electric charge can be measured to a degree of accuracy unknown in the past - possibly to one part in 100 million. This breakthrough may have far-reaching implications in the development of technologies.

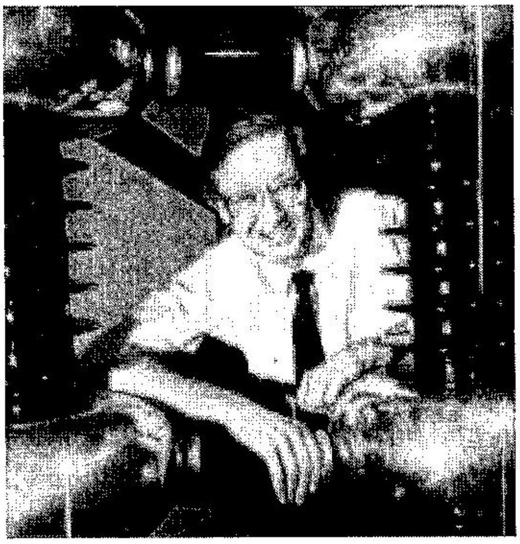
Unlike the original J.J. experiment, it took batteries of highly-complex equipment to find the answer for which Professor Pepper had been searching. It was true scientists had been able to calculate the charge but only through a ratio of other known factors and then not to anything like the degree of accuracy which the new discovery makes possible. "It was as though a fog suddenly lifts and you can see something quite new. The effect emerged in full glory. It was very striking," said Professor Pepper. "We had been looking for it for a long time as we felt it had to be there. When it appeared it was very satisfying. The charge on the electron is the last great constant of physics to be explored in its own right." He went on, "With research funding being difficult you have to be in the discovery business these days to keep a research group together, and that is our approach."

The new work built on some of the theories explored by Sir Nevill Mott, the great physicist and Nobel prizewinner, who was Cavendish Professor of Experimental Physics. For over 60 years he was probably the most influential figure in the exploration of electron behaviour. When Professor Pepper realised his team was on the verge of a breakthrough he was delighted to be able to discuss it with Sir Nevill, just before his death last year at the age of 90. "He chuckled at the news. It was very pleasing," said Professor Pepper.

The pioneering research was the first exploration of properties of electrons in one dimension, easiest to imagine as a wire, two dimensions being a sheet. Professor Pepper's team found a way to squeeze electrons into shape within a semi-conductor. They then succeeded in pushing a single stream of electrons through a 'split gate' by using sound waves to pinch off single electrons. Professor Pepper explained the effect as rather like separating out the number of surfers on the top of a wave until only one surfer is left on each wave. It was like recreating J.J.'s original experiment, except 100 years down the line a quantum version was now possible, showing that electron waves can behave as particles.

No physics laboratory in the world can claim a more glorious history than the Cavendish where scientists have achieved well over 20 Nobel prizes in its 123 years of history. Subsequent discoveries and breakthroughs at the laboratory since the electron have included the proton (1920), the neutron (1932), the isotopes of light elements (1919), the artificial splitting of the atom (1932), the structure of DNA (1953) and the discovery of pulsars (1967). Today, work with electrons has led to research in a huge variety of fields. Head of Department, Professor Archie Howie, is an expert on the electron microscope. His successor, Professor Malcolm Longair, works in astrophysics and cosmology.

Ironically, the man who is the current Cavendish Professor of Physics, Richard Friend, could be the one to shortcut the need for the cathode tube in J.J.'s original experiment. A flat television screen projected on to a wall is likely to be one of the practical spin-offs from his work with light-emitting polymers. Electrons are still involved, but not the cathode tube. "It is rather amazing that the flat screen, for instance, could put J.J.'s tube out of business," said Professor Howie, "It will do away with the equipment that is now used when people switch on their television screens."



Professor Colin Humphreys believes he has discovered the way electrons move in superconductors

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A huge saving in energy consumption at every level, with household electricity bills cut by 20 per cent, could result from a new theory on how electrons move through superconductors by Professor Colin Humphreys, Goldsmiths' Professor of Materials Science. Twenty per cent of the cost of electricity is due to electrical resistance during transmission from power stations to the home. If this resistance could be eliminated the price of electricity would come down.

Eleven years ago scientists identified new materials, certain ceramic substances high in oxygen, which lost all their resistance when cooled down to the temperature of liquid nitrogen. Thus cooled, these substances, now known as superconductors, allow electricity to flow quite freely through. However, for commercial exploitation it is too costly to cool the superconductors to the necessary temperature to lose their resistance. The heart of the problem was that nobody understood why superconductors had this property. "The world's best scientists have been working on this," said Professor Humphreys.

Now, in the year of the centenary of the discovery of the electron, he believes he has solved the problem of how electrons move through superconductors. That in turn brings nearer the possibility of harnessing their superconductivity at room temperature. "That would meet the global warming targets overnight," said Professor Humphreys, who announced his breakthrough at an international symposium attended by three Nobel prizewinners in Cambridge to celebrate the centenary of J.J.'s discovery.

He has found that electrons do not travel randomly through the superconductor. They travel in pairs as though on parallel tramlines. "The force which holds these electrons together is very strong. In fact it is magnetic. Now I hope that we might get this effect at room temperature, and if we do there will be a huge number of implications," explained Professor Humphreys. In such a case, costs of highly expensive magnetic resonance imaging equipment used in hospitals would come down dramatically. Levitating trains, running about 1cm above the track, giving a smooth, fast ride, would become economically feasible.

The Department of Materials Science and Metallurgy is working on another very exciting project involving electrons that could cut power bills even more spectacularly - research on a newly-discovered blue light laser created when an electron is forced to jump over a barrier and down again in a material called gallium nitride. The blue light can be converted to white and other colours. What his team is hoping is that this process can be used to create very long-lasting light bulbs, consuming just one tenth of the power of ordinary light bulbs. "We are leading the world in this research," said Professor Humphreys.

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