Josephson Junction Encyclopedia Article

Josephson Junction

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The process of electron tunneling was discovered in 1957 by the Japanese physicist Leo Esaki and the Norwegian physicist Ivar Giaever. Tunneling is the process by which a charged particle is able to pass through an apparently insurmountable energy barrier. The process is possible because of the wave nature of particles. In 1962, Brian Josephson, then a graduate student at Cambridge University, predicted tunneling could occur with *Cooper pairs* of electrons. Cooper pairs are electron pairs that form when a substance is cooled to the point where it becomes superconductive (usually, close to absolute zero). Josephson predicted that Cooper pairs could pass from one point to another even if there was no voltage drop between the two points. He said that the current would flow in one direction (DC current) if there was no external voltage applied to the system or in both directions (AC current) if there was. He also hypothesized that these currents would be very sensitive to magnetic fields in their vicinity. Josephson's predictions were confirmed by laboratory experiments completed by Anderson and Rowell for DC currents and by Shapiro for AC currents. A *Josephson junction* consists of a pair of superconducting metals separated by a thin sheet (about 10 Å thick) of insulating material. In the absence of an external electrical source, a small DC current flows across the insulating barrier. When an external voltage is applied, a high frequency AC current develops, but with no net flow in either direction. As predicted, the presence of an external magnetic field near a Josephson junction causes very rapid changes in the current across the junction. The sensitivity of the Josephson junction is valuable in a number of applications. Since relatively small magnetic fields induce significant current changes, the junction can be used in the design of computers and scientific instruments. For example, one type of device, the SQUID (superconducting quantum interference device) is used as a voltmeter for low current measurements, as a medical device, as a magnetometer for sensitive geological measurements, and in high-speed computers.