Squids Encyclopedia Article

Squids

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SQUID is an acronym for Superconducting QUantum **Interference** Device. Superconductors are materials that conduct electric currents with minimum resistance at low temperatures. Examples are common materials such as mercury, lead, and tin, and more exotic compounds that have been developed to superconduct at higher temperatures ranging up to 133K.

SQUIDs operationally rely on quantum mechanical interference similar to that demonstrated in a basic double-slit quantum experiment. In such experiments, a single particle (e.g., an **electron**) is shot at a double slit. Instead of acting as a particle, however, and going through just one of the slits, the particle acts as a wave going through both slits, and an interference pattern appears on a screen behind the double slits.

The SQUID operates in a similar way. A ring made of superconducting material is fabricated so that it has two *Josephson junctions* on opposite sides of the ring. A **Josephson junction** is a thin layer (a few atomic layers thick) of insulating material sandwiched between two superconducting materials. An **electric current** is run through the SQUID that can take two paths, through either Josephson junction and then recombine on the other side of the ring. In this simple setup, the two currents are mathematically represented by electron-pair wavefunctions. Each wavefunction has the same phase, so the currents constructively interfere yielding the original current.

SQUIDs are highly sensitivity to magnetic fields. When a magnetic field is produced that goes through the center of the ring (but not through the superconductor itself), a phase difference is generated in the electron-pair wavefunctions, so that they now interfere destructively instead of constructively. By measuring the current as a function of time, the phase shift can be extracted, and the **magnetic flux** and magnetic field can be determined. In this way, the SQUID operates like the double-slit experiment: the electrons have a choice between two paths, but without trying to detect which path the electrons take, an interference pattern results.

Because of its sensitivity to magnetic fields, the SQUID can be used as a precision magnetometer, a device used for measuring extremely tiny magnetic fields. For example, a ring 5 mm in diameter can detect magnetic fields much less that a millionth the size of Earth's magnetic field. Recently, SQUID "microscopes" have been constructed by various research groups and have been used to map out the magnetic fields of the human heart and the brain.