Electricity's "speed"

The drift speed of electrons in a wire is very slow, only about 0.05 mm/s for Example 18–14, which means it takes an electron about 20×10^3 s, or $5\frac{1}{2}$ h, to travel only 1 m. This is not, however, how fast "electricity travels": when you flip a light switch, the light—even if many meters away—goes on nearly instantaneously because electric fields travel essentially at the speed of light $(3 \times 10^8\ \mathrm{m/s})$. We can think of electrons in a wire as being like a pipe full of water: when a little water enters one end of the pipe, almost immediately some water comes out the other end.

* 18–9 Superconductivity

At very low temperatures, well below 0°C, the resistivity (Section 18–4) of certain metals and certain compounds or alloys becomes zero as measured by the highest-precision techniques. Materials in such a state are said to be **superconducting**. This phenomenon was first observed by H. K. Onnes (1853–1926) in 1911 when he cooled mercury below 4.2 K (−269°C). He found that at this temperature, the resistance of mercury suddenly dropped to zero. In general, superconductors become superconducting only below a certain *transition temperature* or *critical temperature*, T_C, which is usually within a few degrees of absolute zero. Current in a ring-shaped superconducting material has been observed to flow for years in the absence of a potential difference, with no measurable decrease. Measurements show that the resistivity ρ of superconductors is less than $4 \times 10^{-25}\ \Omega \cdot \mathrm{m}$, which is over 10^{16} times smaller than that for copper, and is considered to be zero in practice. See Fig. 18–26.

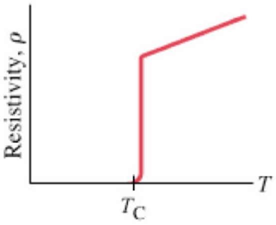

FIGURE 18–26 A superconducting material has zero resistivity when its temperature is below T_C, its "critical temperature." At T_C, the resistivity jumps to a "normal" non-zero value and increases with temperature as most materials do (Eq. 18–4).

High-temperature superconductors

Much research has been done on superconductivity to try to understand why it occurs, and to find materials that superconduct at higher, more accessible temperatures to reduce the cost and inconvenience of refrigeration at the required very low temperature. Before 1986 the highest temperature at which a material was found to superconduct was 23 K, and this required liquid helium to keep the material cold. In 1987, a compound of yttrium, barium, copper, and oxygen (YBCO) was developed that can be superconducting at 90 K. Since this is above the boiling temperature of liquid nitrogen, 77 K, liquid nitrogen is sufficiently cold to keep the material superconducting. This was an important breakthrough since liquid nitrogen is much more easily and cheaply obtained than is the liquid helium needed for conventional superconductors. Since then, superconductivity at temperatures as high as 160 K have been reported, though in fragile compounds.

Considerable research is being done to develop high-T_C superconductors as wires that can carry currents strong enough to be practical. Most applications today use a bismuth-strontium-calcium-copper oxide, known (for short) as BSCCO. A major problem is how to make a useable, bendable wire out of the BSCCO, which is very brittle. One solution is to embed tiny filaments of the high-T_C superconductor in a metal alloy matrix with the superconducting wire wrapped around a tube carrying liquid nitrogen to keep the BSCCO below T_C. The wire can not be resistanceless, because of the silver connections, but the resistance is much less than that of a conventional copper cable.

* 18–10 Electrical Conduction in the Human Nervous System

An interesting example of the flow of electric charge is the human nervous system, which provides us with the means for being aware of the world, for communication within the body, and for controlling the body's muscles. Although the detailed functioning of the hugely complex nervous system is still