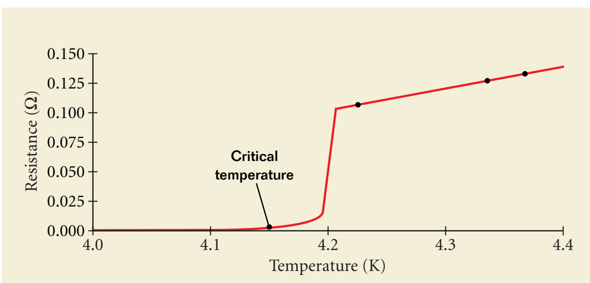
Why it Matters

Superconductors

This express train in Shanghai, China, which utilizes the Meissner effect, levitates above the track and travels at up to 430 km/h in normal operations.

Take a moment to imagine the many things that could be created with materials that conduct electricity with *zero* resistance. There would be no heating or reduction in the current when conducting electricity with such a material. These materials exist and are called *superconductors*.

Superconductors have zero resistance below a certain temperature, called the *critical temperature*. The graph of resistance as a function of temperature for a superconductor resembles that of a normal metal at temperatures well above the critical temperature. But when the temperature is near or below the critical temperature, the resistance suddenly drops to zero, as the graph below shows. This graph shows the resistance of mercury just above and below its critical temperature of 4.15 K.



Today, there are thousands of known superconductors, including common metals such as aluminum, tin, lead, and zinc. However, for common metals that exhibit superconductivity, the critical temperature is extremely low—near absolute zero. For example, aluminum reaches superconductivity at 1.19 K, just a little more than one degree above absolute zero. Temperatures near absolute zero are difficult to achieve and maintain. Interestingly, copper, silver, and gold, which are excellent conductors at room temperature, do not exhibit superconductivity.

An important recent development in physics is the discovery of high-temperature superconductors. The excitement began with a 1986 publication by scientists at the IBM Zurich Research Laboratory in Switzerland. In this publication, scientists reported evidence for superconductivity at a temperature near 30 K. More recently, scientists have found superconductivity at temperatures as high as 150 K. However, 150 K is still –123°C, which is much colder than room temperature. The search continues for a material that has superconducting qualities at room temperature. This important search has both scientific and practical applications.

One of the truly remarkable features of superconductors is that once a current is established in them, the current continues even if the applied potential difference is removed. In fact, steady currents have been observed to persist for many years in superconducting loops with no apparent decay. This feature makes superconducting materials attractive for a wide variety of applications.

Because electric currents produce magnetic effects, current in a superconductor can be used to float a magnet in the air over a superconductor. This effect, known as the Meissner effect, is used with high-speed express trains, such as the one shown in the figure above. This type of train levitates a few inches above the track.

One useful application of superconductivity is superconducting magnets. Such magnets are being considered for storing energy. The idea of using superconducting power lines to transmit power more efficiently is also being researched. Modern superconducting electronic devices that consist of two thin-film superconductors separated by a thin insulator have been constructed. They include magnetometers (magnetic-field measuring devices) and various microwave devices.