interference and diffraction, are significant only when the size of objects or slits is not much larger than the wavelength. And there are no known objects or slits to diffract waves only $10^{-30}$ m long, so the wave properties of ordinary objects go undetected.

But tiny elementary particles, such as electrons, are another matter. Since the mass $m$ appears in the denominator of Eq. 27–8, a very small mass should have a much larger wavelength.

**EXAMPLE 27–11** **Wavelength of an electron.** Determine the wavelength of an electron that has been accelerated through a potential difference of 100 V.

**APPROACH** If the kinetic energy is much less than the rest energy, we can use classical $\text{KE} = \frac{1}{2}mv^2$ (see end of Section 26–9). For an electron, $m_0c^2 = 0.511\,\text{MeV}$. We then apply conservation of energy: the KE acquired by the electron equals its loss in PE. After solving for $v$, we use Eq. 27–8 to find the de Broglie wavelength.

**SOLUTION** The gain in kinetic energy will equal the loss in potential energy ($\Delta\text{PE} = eV - 0$): $\text{KE} = eV$, so $\text{KE} = 100\,\text{eV}$. The ratio $\text{KE}/m_0c^2 = 100\,\text{eV}/(0.511\times10^6\,\text{eV}) \approx 10^{-4}$, so relativity is not needed. Thus

$$\frac{1}{2}mv^2 = eV$$

and

$$v = \sqrt{\frac{2\,eV}{m}} = \sqrt{\frac{(2)(1.6\times10^{-19}\,\text{C})(100\,\text{V})}{(9.1\times10^{-31}\,\text{kg})}} = 5.9\times10^6\,\text{m/s}.$$

Then

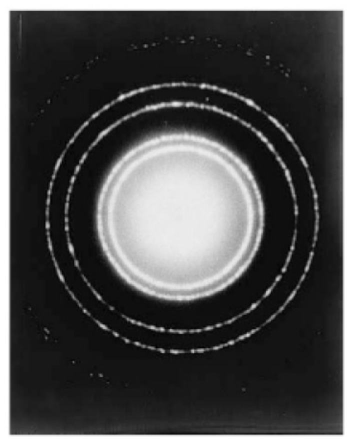
$$\lambda = \frac{h}{mv} = \frac{(6.63\times10^{-34}\,\text{J}\cdot\text{s})}{(9.1\times10^{-31}\,\text{kg})(5.9\times10^6\,\text{m/s})} = 1.2\times10^{-10}\,\text{m},$$

or 0.12 nm.

**EXERCISE E** As a particle travels faster, does its de Broglie wavelength decrease, increase, or remain the same?

From Example 27–11, we see that electrons can have wavelengths on the order of $10^{-10}$ m, and even smaller. Although small, this wavelength can be detected: the spacing of atoms in a crystal is on the order of $10^{-10}$ m and the orderly array of atoms in a crystal could be used as a type of diffraction grating, as was done earlier for X-rays (see Section 25–11). C. J. Davisson and L. H. Germer performed the crucial experiment; they scattered electrons from the surface of a metal crystal and, in early 1927, observed that the electrons were scattered into a pattern of regular peaks. When they interpreted these peaks as a diffraction pattern, the wavelength of the diffracted electron wave was found to be just that predicted by de Broglie, Eq. 27–8. In the same year, G. P. Thomson (son of J. J. Thomson) used a different experimental arrangement and also detected diffraction of electrons. (See Fig. 27–12. Compare it to X-ray diffraction, Section 25–11.) Later experiments showed that protons, neutrons, and other particles also have wave properties.

**FIGURE 27–12** Diffraction pattern of electrons scattered from aluminum foil, as recorded on film.



Thus the wave–particle duality applies to material objects as well as to light. The principle of complementarity applies to matter as well. That is, we must be aware of both the particle and wave aspects in order to have an understanding of matter, including electrons. But again we must recognize that a visual picture of a "wave–particle" is not possible.

*Wave–particle duality and complementarity apply to matter as well as light*