De Broglie Waves

In the chapter on waves, we treated waves and particles as if there were a clear distinction between the two. For most of the history of science, this was believed to be the case. However, in the early twentieth century, scientists were confronted with experimental evidence suggesting that the properties of matter are not always as clear-cut as everyone had assumed.

The dual nature of light

This scientific revolution began in 1900, when Max Planck introduced the possibility that energy could come in discrete units. In 1905, Einstein extended Planck's theory, suggesting that all electromagnetic waves (such as light) sometimes behave like particles. According to this theory, light can behave both like a wave and like a particle; some experiments reveal its wave nature, and other experiments display its particle nature. Although this idea was initially greeted with skepticism, it explained certain phenomena that the wave theory of light could not account for and was soon confirmed empirically in a variety of experiments.

Matter waves

The idea that light has a dual nature led Louis de Broglie to hypothesize that perhaps all matter has wavelike characteristics. De Broglie believed that there should not be two separate branches of physics, one for electromagnetic waves and another for matter. In his doctoral thesis, submitted in 1924, he proposed a theory of matter waves to reconcile this discrepancy. At that time, there was no experimental evidence to support his theory.

De Broglie's calculations suggested that matter waves had a wavelength, λ, often called the de Broglie wavelength, given by the following equation:

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

The variable h in this equation is called Planck's constant, which is approximately equal to 6.63×10^{-34} J•s. The variable p is the object's momentum, which is equivalent to its mass, m, times its velocity, v. Note that the dual nature of matter suggested by de Broglie is evident in this equation, which includes both a wave concept (λ) and a particle concept (mv).

De Broglie's equation shows that the smaller the momentum of an object, the larger its de Broglie wavelength. But even when the momentum of an object is very small from our perspective, h is so small that the wavelength is still much too small for us to detect. In order to detect a wavelength, one must use an opening comparable in size to the wavelength because waves passing through such an opening

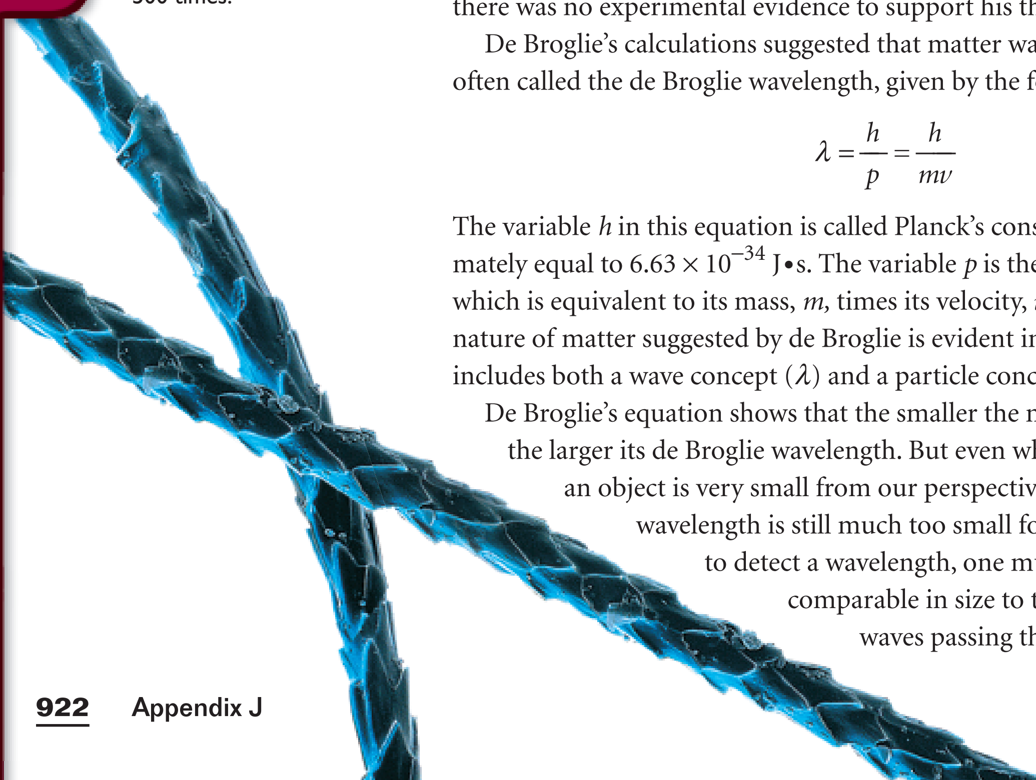

Figure 1
This image of cat hairs, produced by an electron microscope, is magnified 500 times.