5-5. According to statistical mechanics, the average kinetic energy of a particle at temperature T is $3kT/2$, where k is the Boltzmann constant. What is the average de Broglie wavelength of nitrogen molecules at room temperature?

5-25. The wave function describing a state of an electron confined to move along the x axis is given at time zero by

$$\Psi(x,0) = Ae^{-x^2/4\sigma^2}$$

Find the probability of finding the electron in a region dx centered at (*a*) $x = 0$, (*b*) $x = \sigma$, and (*c*) $x = 2\sigma$. (*d*) Where is the electron most likely to be found?

5-38. An excited state of a certain nucleus has a half-life of 0.85 ns. Taking this to be the uncertainty Δt for emission of a photon, calculate the uncertainty in the frequency Δf, using Equation 5-25. If $\lambda = 0.01$ nm, find $\Delta f/f$.

5-43. Using the relativistic expression $E^2 = p^2c^2 + m^2c^4$, (*a*) show that the phase velocity of an electron wave is greater than c; (*b*) show that the group velocity of an electron wave equals the particle velocity of the electron.

5-46. A particle of mass m moves in a one-dimensional box of length L. (Take the potential energy of the particle in the box to be zero so that its total energy is its kinetic energy $p^2/2m$.) Its energy is quantized by the standing-wave condition $n(\lambda/2) = L$, where λ is the de Broglie wavelength of the particle and n is an integer. (*a*) Show that the allowed energies are given by $E_n = n^2E_1$, where $E_1 = h^2/8mL^2$. (*b*) Evaluate E_n for an electron in a box of size $L = 0.1$ nm and make an energy-level diagram for the state from $n = 1$ to $n = 5$. Use Bohr's second postulate $f = \Delta E/h$ to calculate the wavelength of electromagnetic radiation emitted when the electron makes a transition from (*c*) $n = 2$ to $n = 1$, (*d*) $n = 3$ to $n = 2$, and (*e*) $n = 5$ to $n = 1$.