With the result for μ appropriate to this regime,

$$f(\varepsilon) \simeq (n/n_Q)\exp(-\varepsilon/\tau) \ , \tag{4}$$

with the usual choice of the origin of ε at zero for the energy of the lowest orbital. The form (4) assures us that the average occupancy of any orbital is always $\leq n/n_Q$, which is $\ll 1$, consistent with our original picture of the classical regime.

A fermion is any particle—elementary or composite—with a half-integral spin. A fermion is limited by the Pauli exclusion principle to an orbital occupancy of 0 or 1, with an average occupancy anywhere between these limits. At low temperatures it is clear that many low-lying orbitals will have one fermion in each orbital. At absolute zero all orbitals with $0 < \varepsilon < \varepsilon_F$ will be occupied with $f = 1$. Here ε_F is the energy below which there are just enough orbitals to hold the number of particles assigned to the system. This energy is called the **Fermi energy**. Above ε_F all orbitals will have $f = 0$ at $\tau = 0$. As τ increases the distribution function will develop a high energy tail, as in Figure 7.3.

Bosons have integral or zero spin. They may be elementary or composite; if composite, they must be made up of an even number of elementary particles if these have spin $\frac{1}{2}$, for there is no way to arrive at an integer from an odd number of half-integers. The Pauli principle does not apply to bosons, so there is no limit on the occupancy of any orbital. At absolute zero the ground orbital—the orbital of lowest energy—is occupied by all the particles in the system. As the temperature is increased the lowest single orbital loses its population only slowly, and each excited orbital—any orbital of higher energy—will contain a relatively small number of particles. We shall discuss this point carefully. Above $\tau = \tau_0$ the ground orbital loses its special feature, and its occupancy becomes much like that of any low-lying excited orbital.

FERMI GAS

A Fermi gas is called degenerate when the temperature is low in comparison with the Fermi energy. When the inequality $\tau \ll \varepsilon_F$ is satisfied the orbitals of energy lower than the Fermi energy ε_F will be almost entirely occupied, and the orbitals of higher energy will be almost entirely vacant. An orbital is occupied fully when it contains one fermion. A Fermi gas is said to be nondegenerate when the temperature is high compared with the Fermi energy, as in the classical regime treated in Chapter 6.

The important applications of the theory of degenerate Fermi gases include conduction electrons in metals; the white dwarf stars; liquid ^{3}He; and nuclear matter. The most striking property of a fermion gas is the high kinetic energy