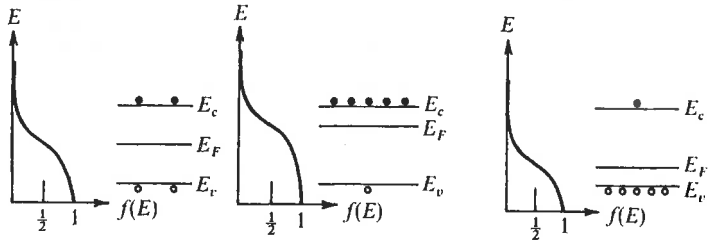
The Fermi-Dirac distribution function is symmetrical around the Fermi level E_F. Thus, if the number of energy states in the conduction and valence bands is the same, and if the number of electrons in the conduction band and the number of holes in the valence band is also the same, the Fermi level must be located in the middle of the energy gap. This is approximately what happens in an intrinsic semiconductor. The Fermi level in an intrinsic semiconductor is often referred to as the *intrinsic Fermi level* and is denoted by the symbol E_i.

In an n-type semiconductor the concentration of electrons in the conduction band is larger than in the intrinsic case. Since, however, the density



(a) Intrinsic. (b) n-Type (c) p-Type

Fig. 4.6 Illustration of the Fermi-Dirac distribution function for intrinsic, n- and p-type semiconductor.

of energy states in the conduction band is the same as in the intrinsic case, it follows that in an n-type semiconductor the Fermi level, and with it the entire Fermi-Dirac distribution function, will be shifted upward in the energy-band picture. In contrast, in a p-type semiconductor the Fermi level and the Fermi-Dirac distribution function will both be shifted downward. These two cases are illustrated in Fig. 4.6b and c.

For energies that are at least several kT units above or below the Fermi level, the Fermi-Dirac distribution function can be approximated by the simpler formulas

$$f(E) \doteq e^{-(E-E_F)/kT} \qquad \text{for } E > E_F \tag{4.2}$$

and

$$f(E) \doteq 1 - e^{-(E_F-E)/kT} \qquad \text{for } E < E_F. \tag{4.3}$$

It is useful to regard the second term of the last expression as the probability of occupation of a center located at energy E *by a hole.*

If, instead of Fermi-Dirac statistics, Boltzmann statistics had been employed in the derivation of the distribution function, these expressions