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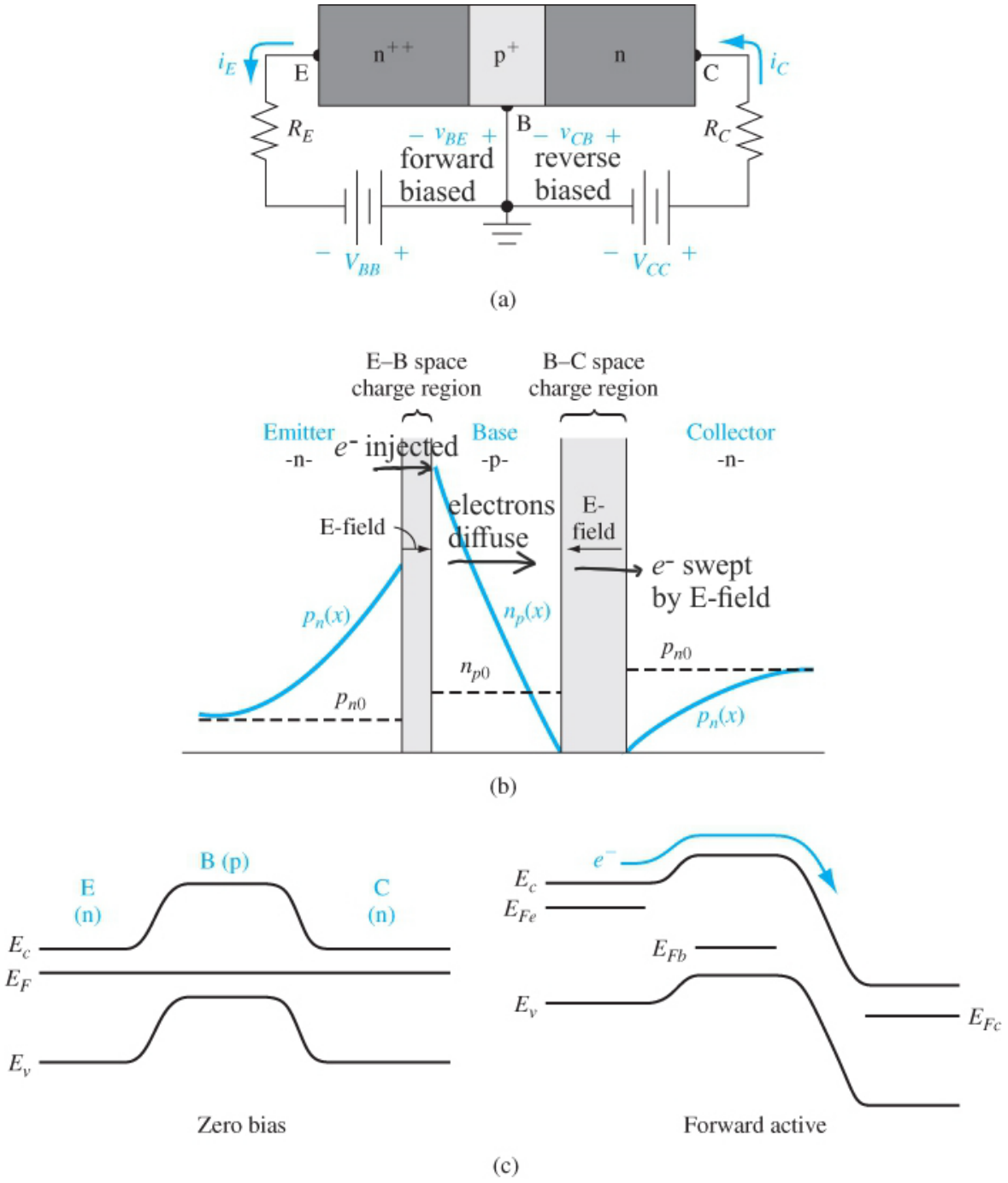

Figure 12.4 | (a) Biasing of an npn bipolar transistor in the forward-active mode, (b) minority carrier distribution in an npn bipolar transistor operating in the forward-active mode, and (c) energy-band diagram of the npn bipolar transistor under zero bias and under a forward-active mode bias.

- The base (p-type) should be thin (in terms of L_n) so the minority electron concentration (and diffusion current) does not go to zero.

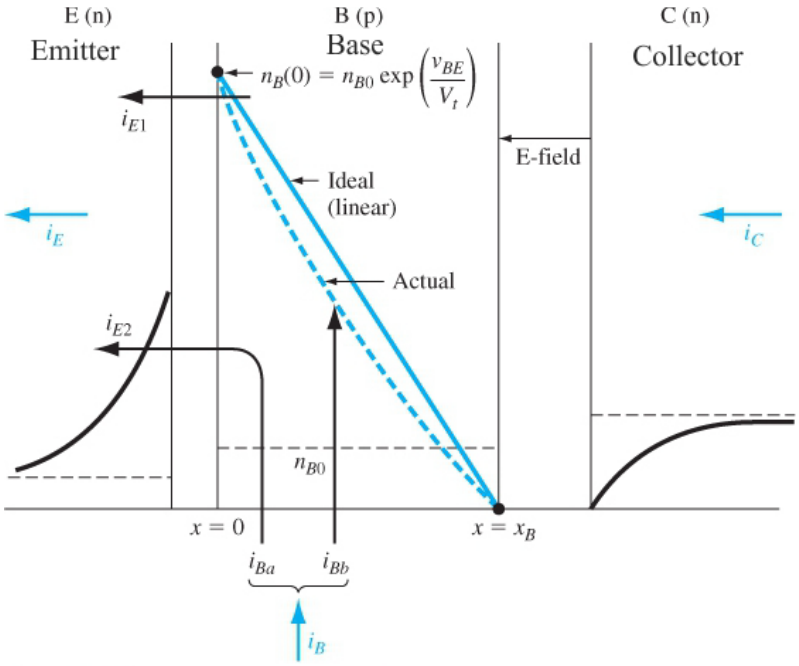

Figure 12.6 | Minority carrier distributions and basic currents in a forward-biased npn bipolar transistor.

- The collector current i_C is equal to the ideal [assumes linear change in $n(x)$] diffusion current through the base-

$$i_C = eD_n A_{BE} \frac{d\,n(x)}{dx} = eD_n A_{BE} \left(\frac{n_B(0) - 0}{0 - x_B} \right) = \frac{-eD_n A_{BE}}{x_B} n_{B0} e^{v_{BE}/V_t}$$

$$= I_S e^{v_{BE}/V_t} \quad \text{(A)}$$

where A_{BE} is the cross-sectional area of the base-emitter junction and n_{B0} is the thermal equilibrium electron concentration in the base.

- The emitter current i_E has two components. The main component $i_{E1} = i_C$ is due to the electrons flowing across the base. The second component $i_{E2} = i_{Ba}$, due to holes crossing the BE junction, is part of the base current i_B, and can be expressed as $i_{E2} = I_{S2}\, e^{v_{BE}/V_t}$ (A). Overall, the emitter current can be expressed as $i_E = i_{E1} + i_{E2} = I_{SE}\, e^{v_{BE}/V_t}$ (A).
- Now, we can define the **common-base current gain** $\alpha \equiv i_C / i_E < 1$.
- The base current i_B has two components. The first component $i_{Ba} = i_{E2} \propto e^{v_{BE}/V_t}$ is due to the portion of the majority holes in the base crossing the BE junction. The second component i_{Ba} is the portion of the holes that recombine with the minority electrons in the base, i.e., why the actual curve for $n(x)$ is not linear. As it is related to the electron population, $i_{Bb} \propto e^{v_{BE}/V_t}$.
- Now, we can define the **common-emitter current gain** $\beta \equiv i_C / i_B >> 1$.