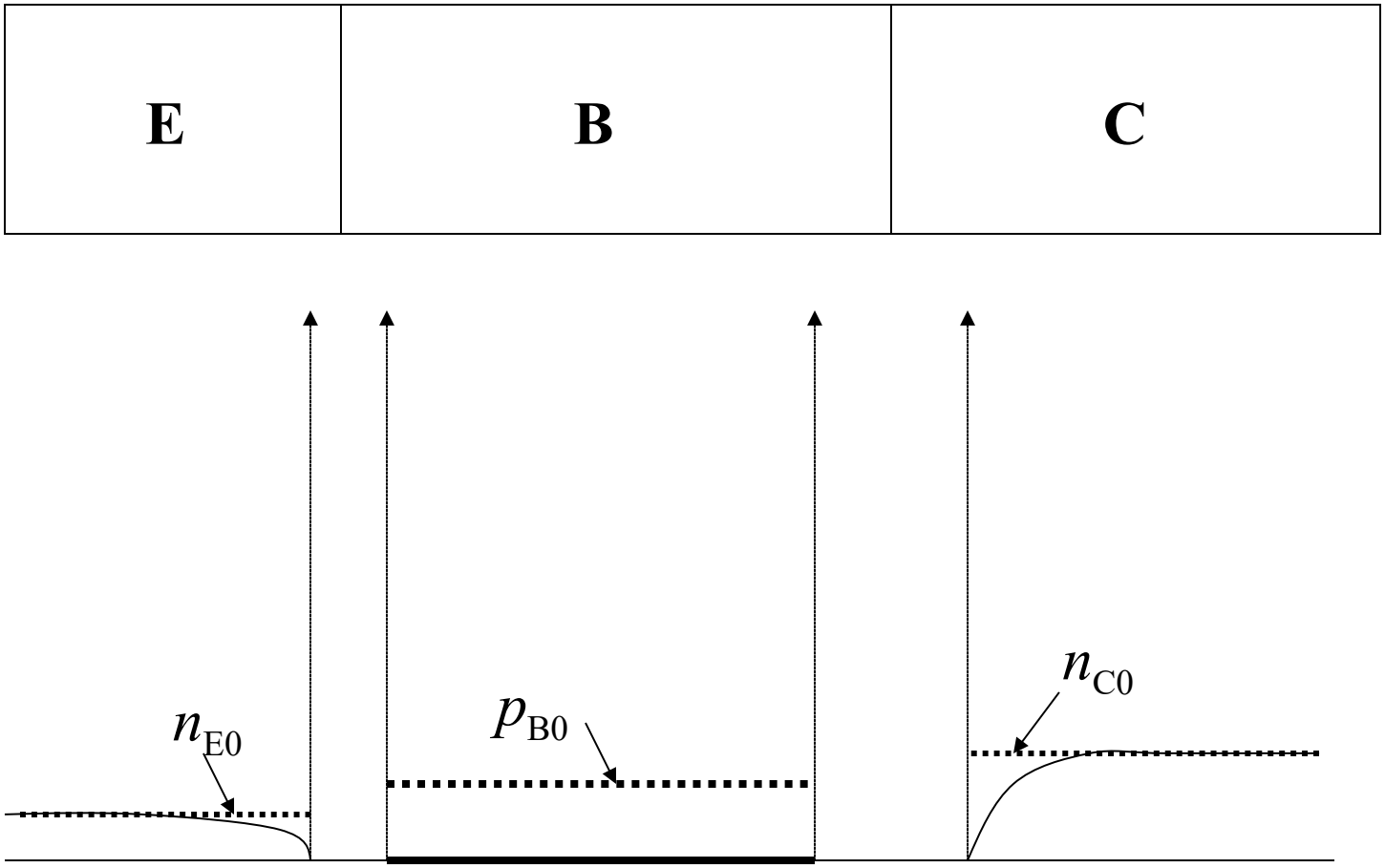
Chapter 11-2. Deviations from the ideal

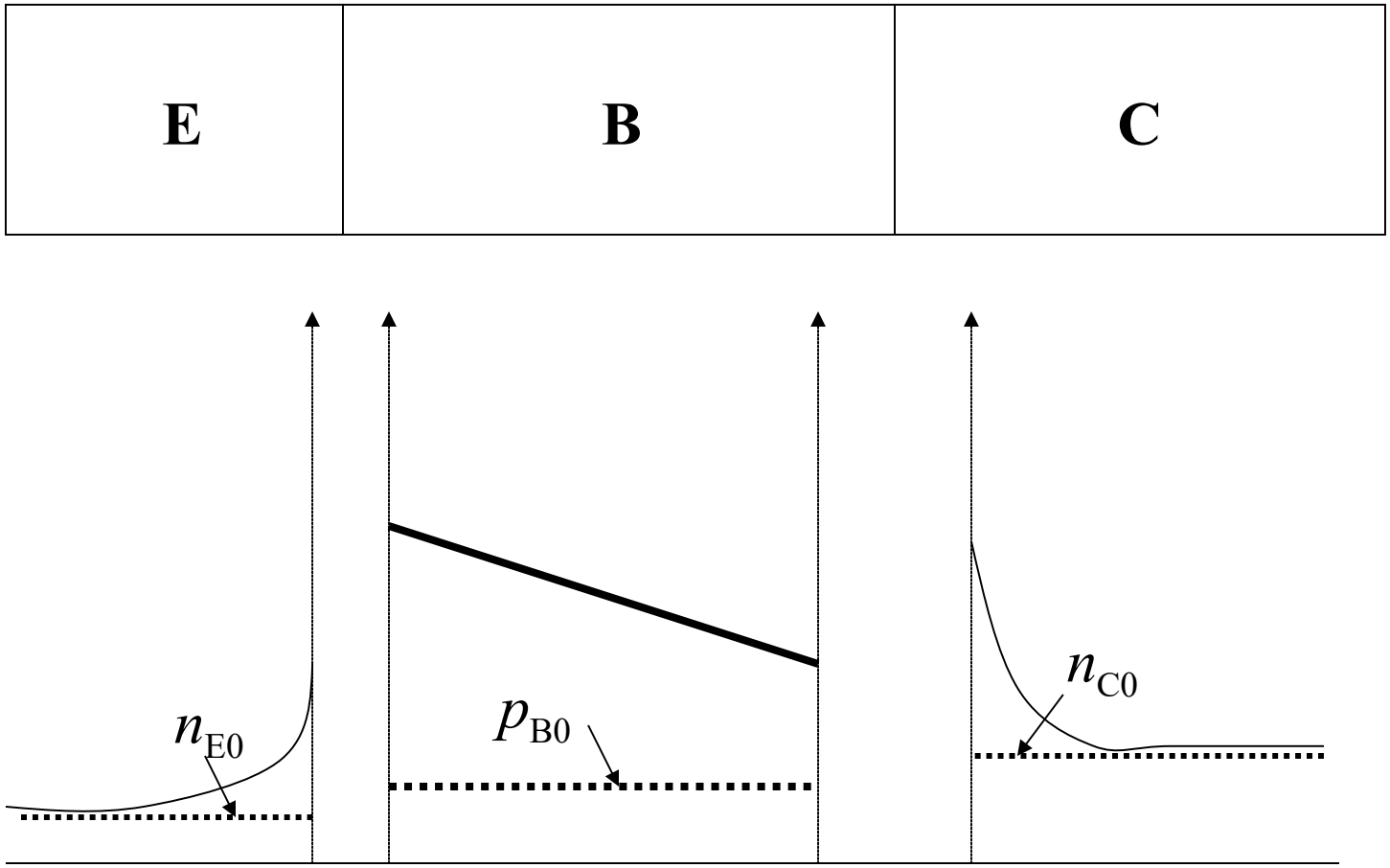
The measured characteristics deviates slightly from the ideal characteristics discussed. We will discuss some of the non-idealities of the BJT characteristics.

- Base-width modulation
- Punch-through
- Avalanche multiplication and breakdown
- Others
  - base resistance, depletion region recombination-general

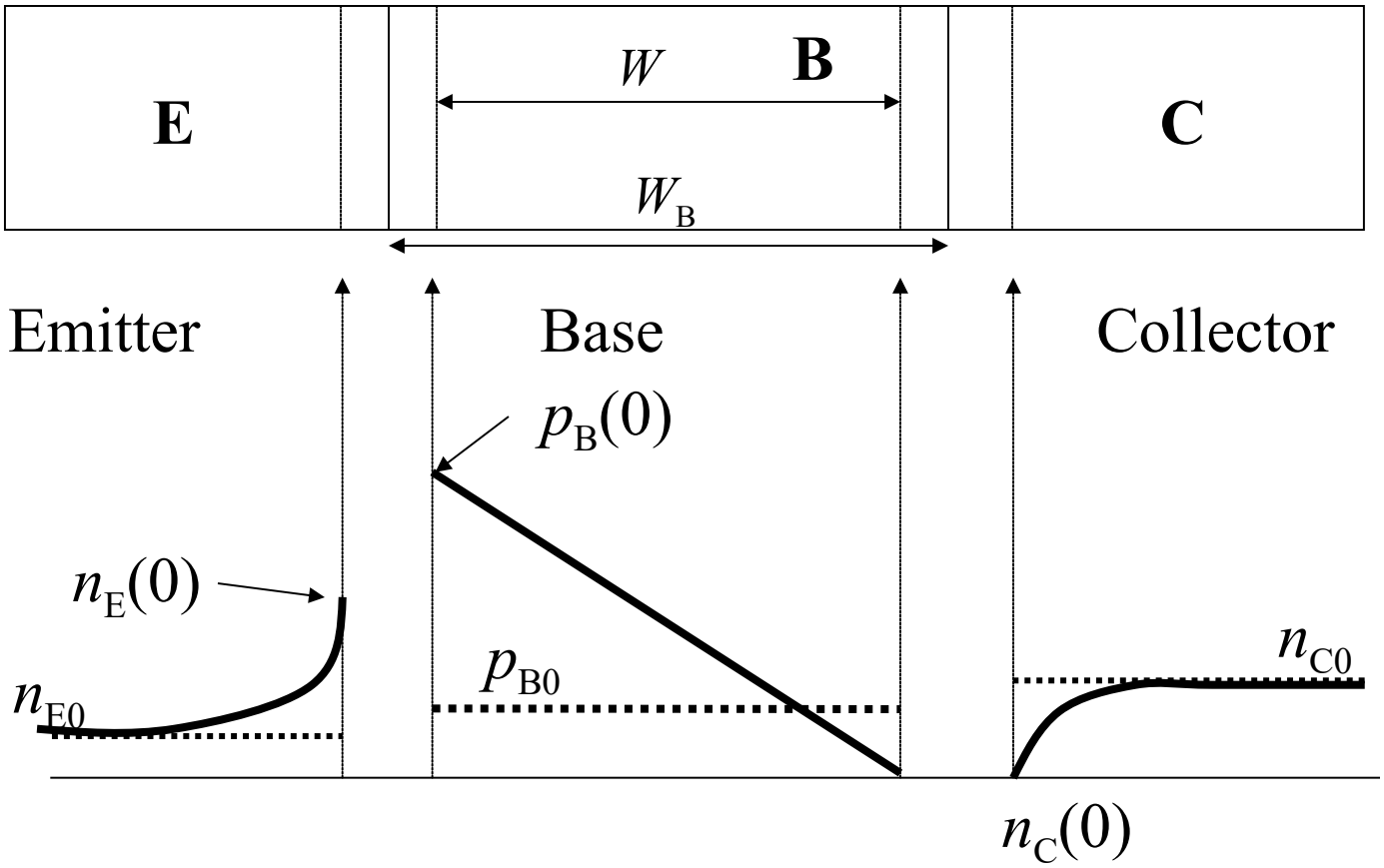
Review: BJT in “cut-off”



Review: BJT in saturation



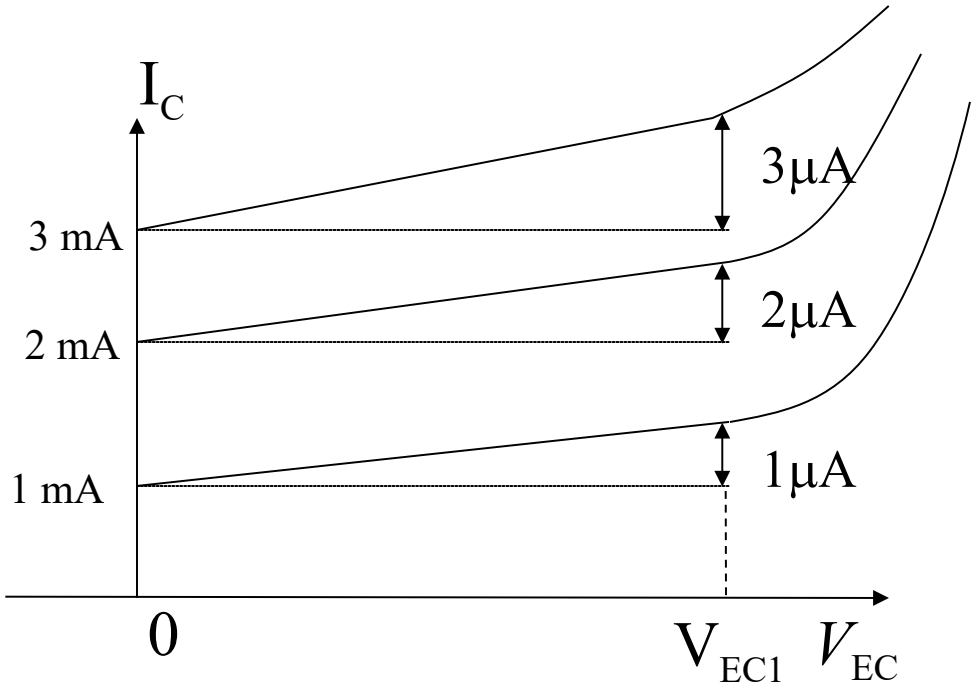
Base width modulation



$$I_C \approx qAD_B \frac{\Delta p_B(0) - 0}{W_B} = qAD_B \frac{p_{B0}}{W_B} e^{\frac{qV_{EB}}{kT}}$$

Base width modulation

When the reverse bias applied to the C-B junction increases, the C-B depletion width increases and W decreases. Thus, the collector current, I_C increases. This is also known as "Early Effect". More prominent in narrow-base transistors.



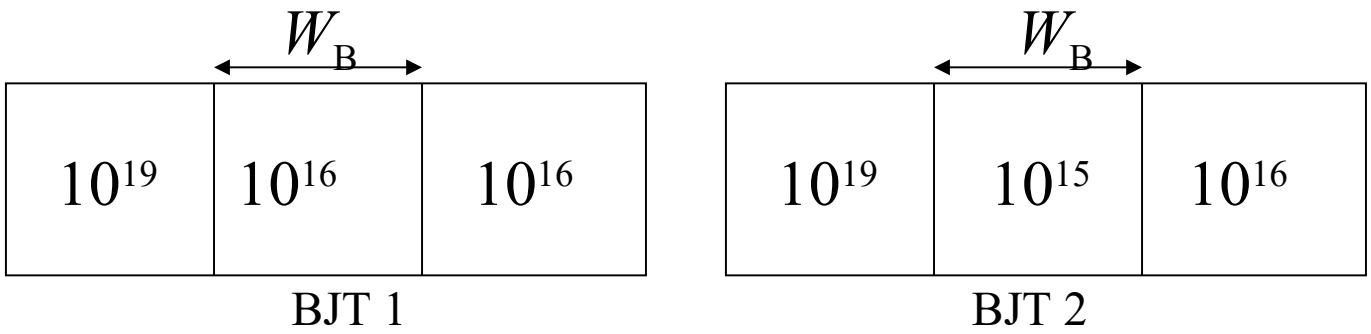
Punch-through

Punch-through can be viewed as base width modulation carried to the extreme, i.e., punch-through occurs when $W \rightarrow 0$. For C-B voltage beyond punch-through, the E-B barrier lowers and results in large increase in carrier injection from emitter to collector.

Large increase in collector currents at high V_{CE0} occurs due to two reasons:

Punch-through or
Avalanche multiplication

Example 1



Two transistors are identical except that the base doping is different.

A. Which transistor will have higher base-width-modulation effect?

B. Which one will have higher punch-through voltage?

Approximate value of punch-through voltage can be obtained by equating the depletion layer width on the base side to the base-width, W_B.

$$W_B \approx x_{nCB} = \left[\frac{2\varepsilon_{Si}}{q}\frac{N_C}{N_B(N_C+N_B)}(V_{bi(CB)}-V_{CB})\right]^{\frac{1}{2}} \approx \left[\frac{2\varepsilon_{Si}}{q}\frac{N_C}{N_B(N_C+N_B)}V_{CB}\right]^{\frac{1}{2}}$$

Other effects

Base series resistance

Current crowding

Recombination-generation current

Modern BJT structures:

Heterojunction bipolar transistor (HBT)