EECS130
Integrated Circuit Devices

Professor Ali Javey

11/13/2007

BJTs- Lecture 2

Reading Assignment: Chapters 10 and 11

Announcements

- HW9 is due Tuesday (Nov. 20) in class.
- MT2 results
- Class project is now assigned

Schematic representation of pnp

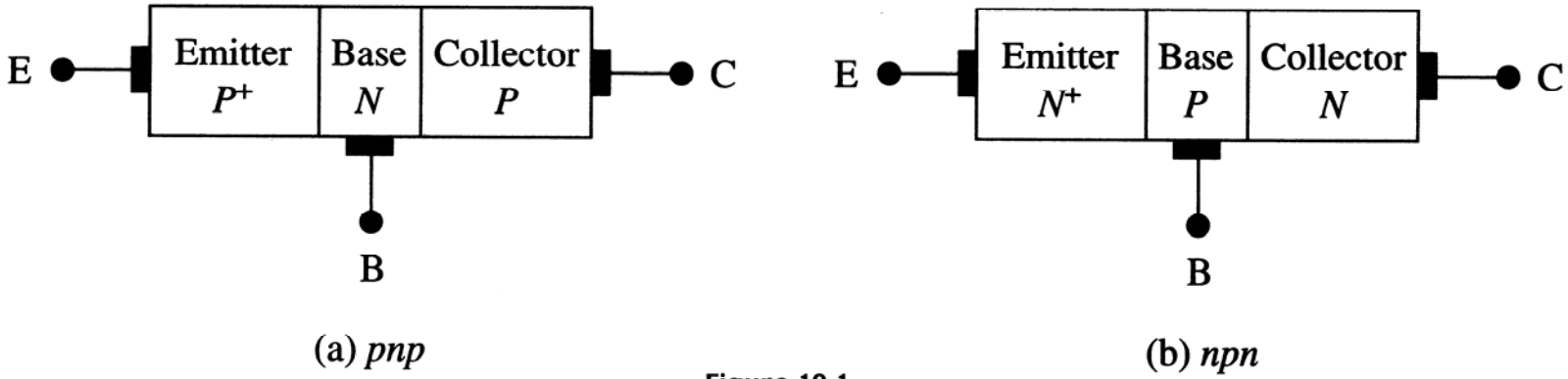
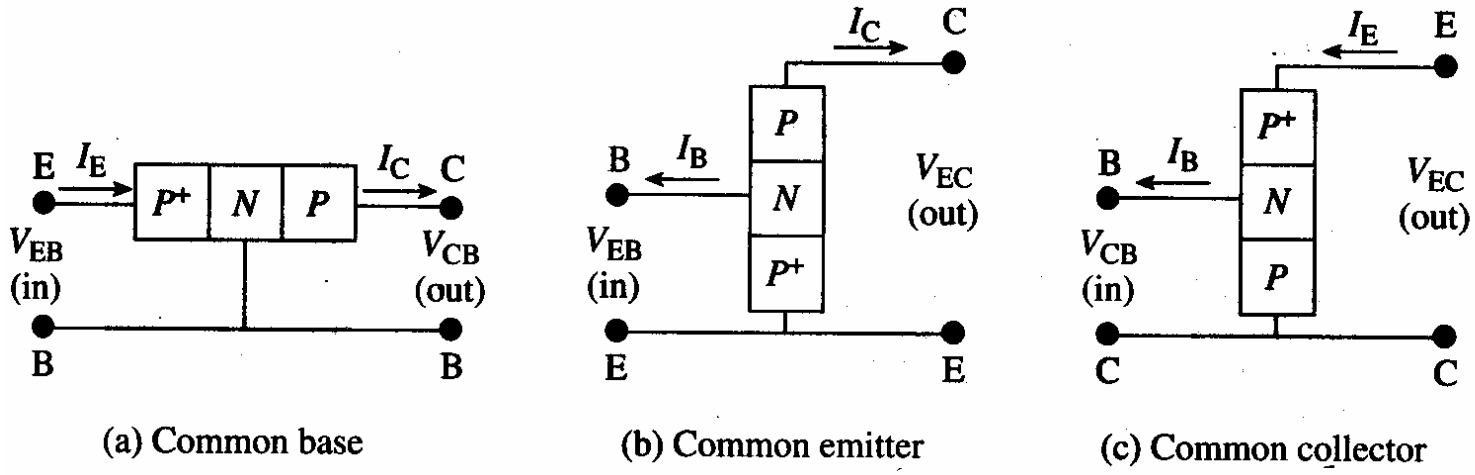


Figure 10.1

Emitter is heavily doped compared to collector. So, emitter and collector are not interchangeable.

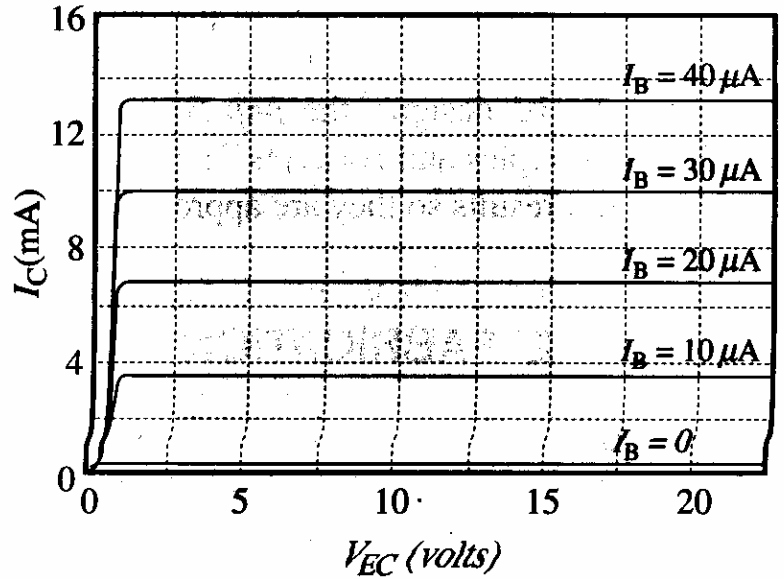
The base width is small compared to the minority carrier diffusion length. If the base is much larger, then this will behave like back-to-back diodes.

Circuit Applications

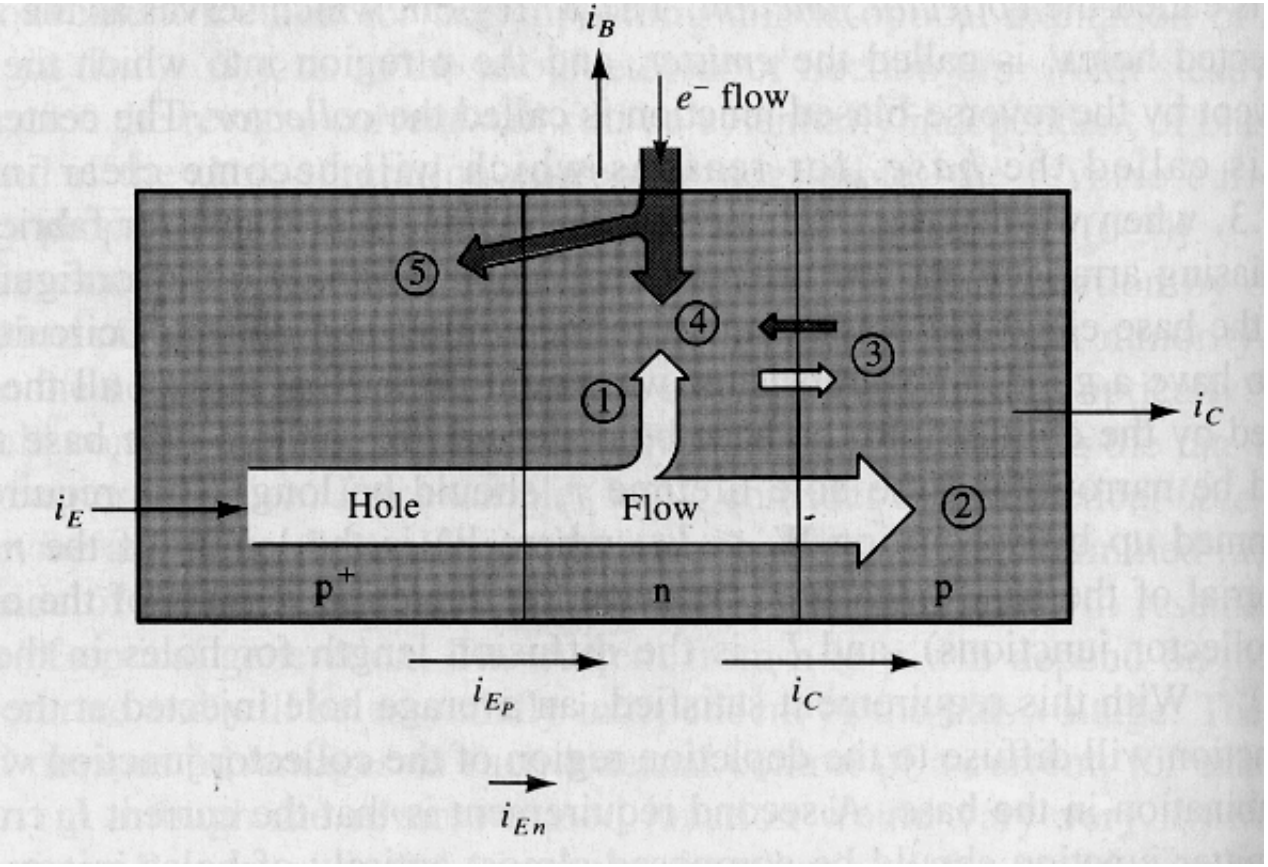


(a) Common base (b) Common emitter (c) Common collector

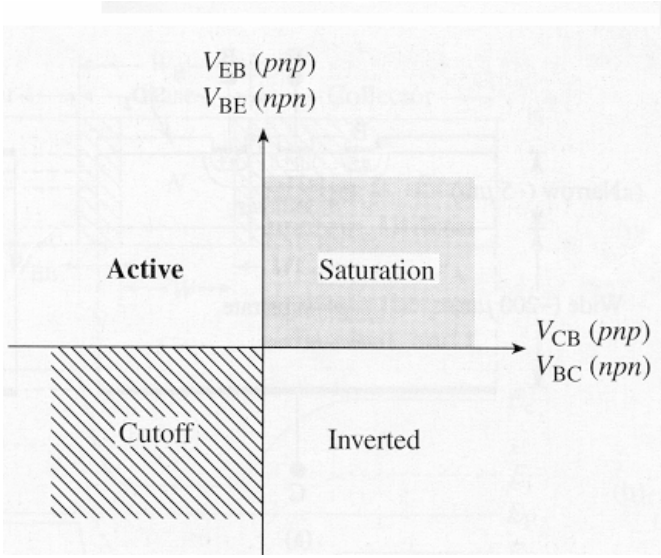
Notice I_B vs. I_C!!

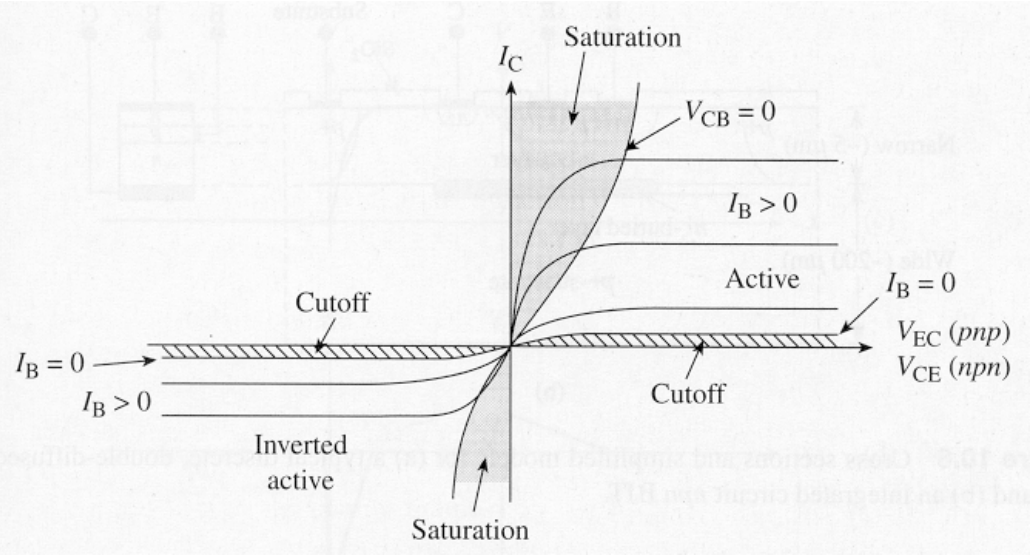


Qualitative BJT Operation



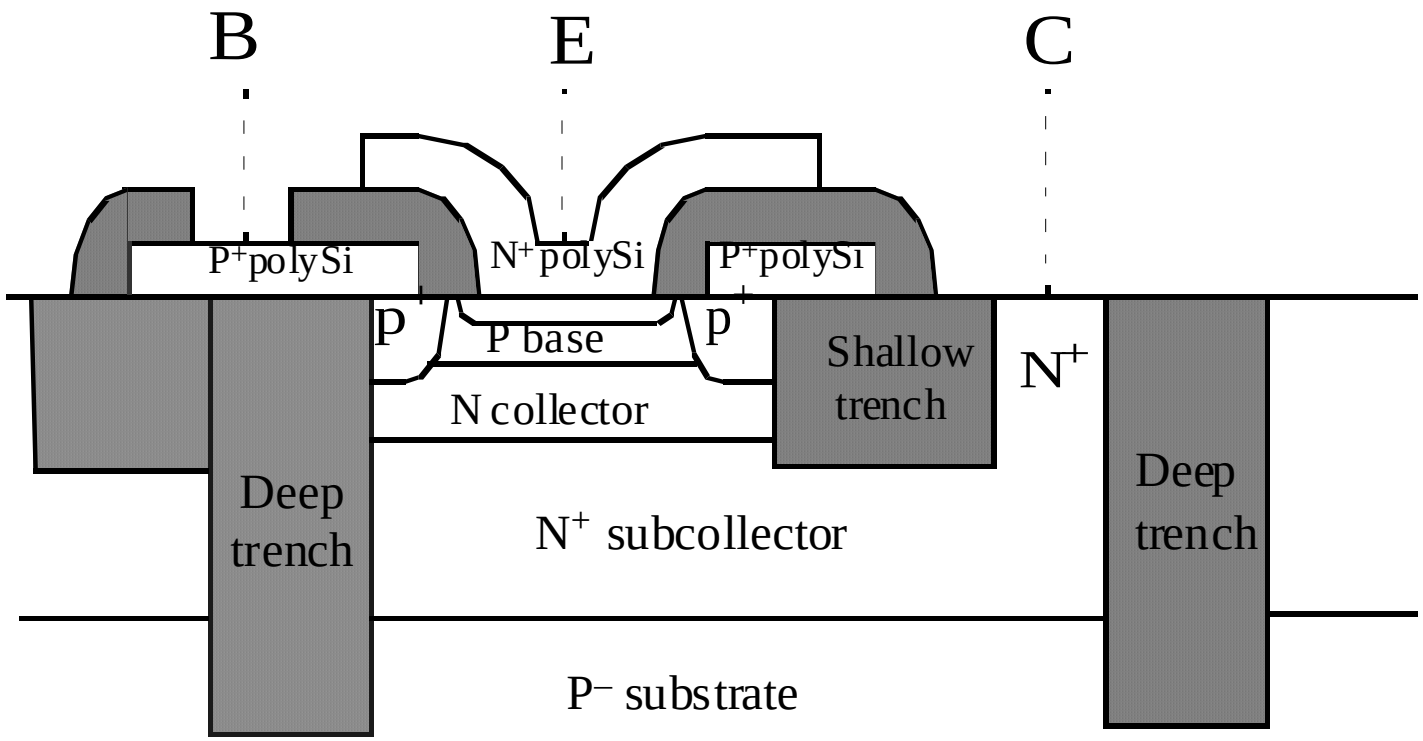
Modes of Operation





- Cutoff: Base diode not turned on ($V_{BE} < 0.6V$) so I_B, $I_C = 0$
- Saturation: Base diode turned on, but I_C limited by low V_{CE}.
- Active: I_C controlled by I_B, no effect of V_{CE}

BJT Physical Structure

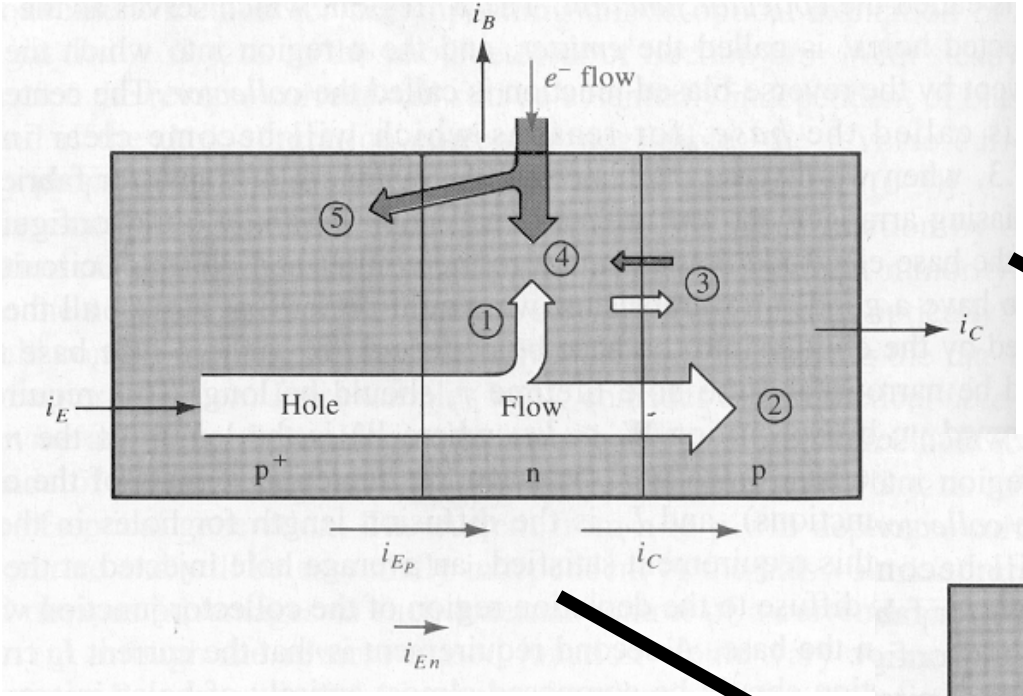


Question

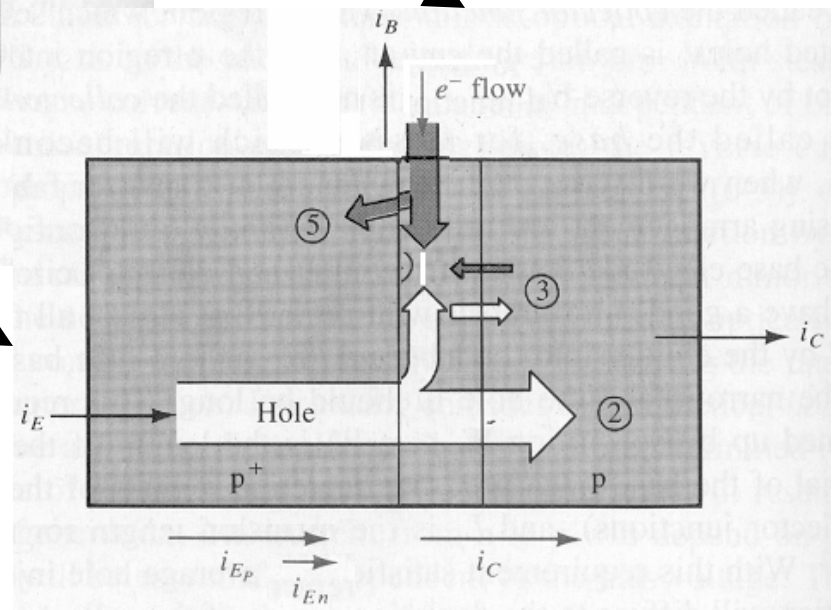
- How can you increase I_C/I_B?

BJT Amplification

$$\beta = \frac{I_C}{I_B}$$



Increasing β



As base width decreases, more currect is collected at collector, i.e., $I_B << I_C$

BJT Design

- Important features of a good transistor:
  - Injected minority carriers do not recombine in the neutral base region
  - Emitter current is comprised almost entirely of carriers injected into the base (rather than carriers injected into the emitter

Performance Parameters

- Emitter Efficiency:
  - Decrease 5 relative to 2 to increase gain

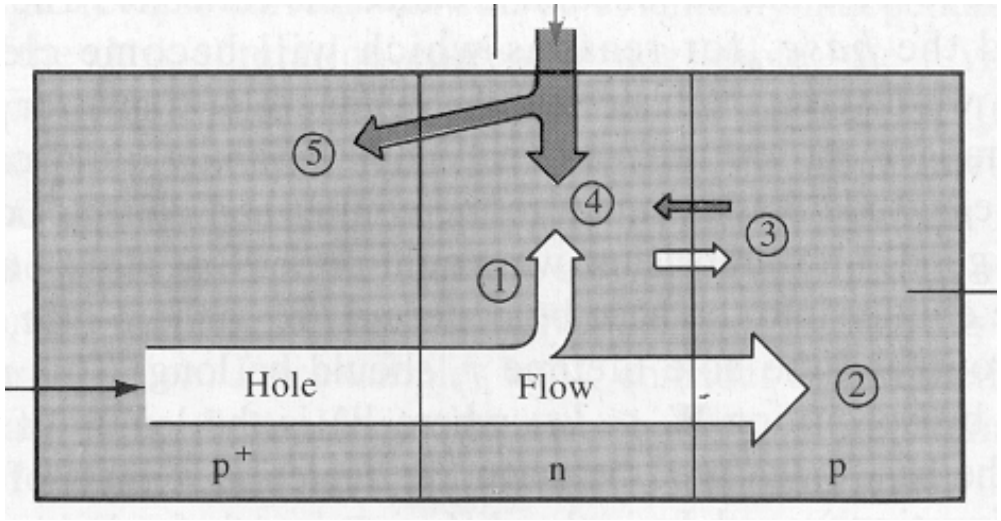
$$\gamma = \frac{I_{Ep}}{I_{Ep} + I_{En}}$$

- Base Transport Factor:
  - Decrease 1 relative to 2 to increase gain

$$\alpha_T = \frac{I_{Cp}}{I_{Ep}}$$

- Common Base dc Current Gain:
  - (2) + (3) vs. (1+2) + (5)

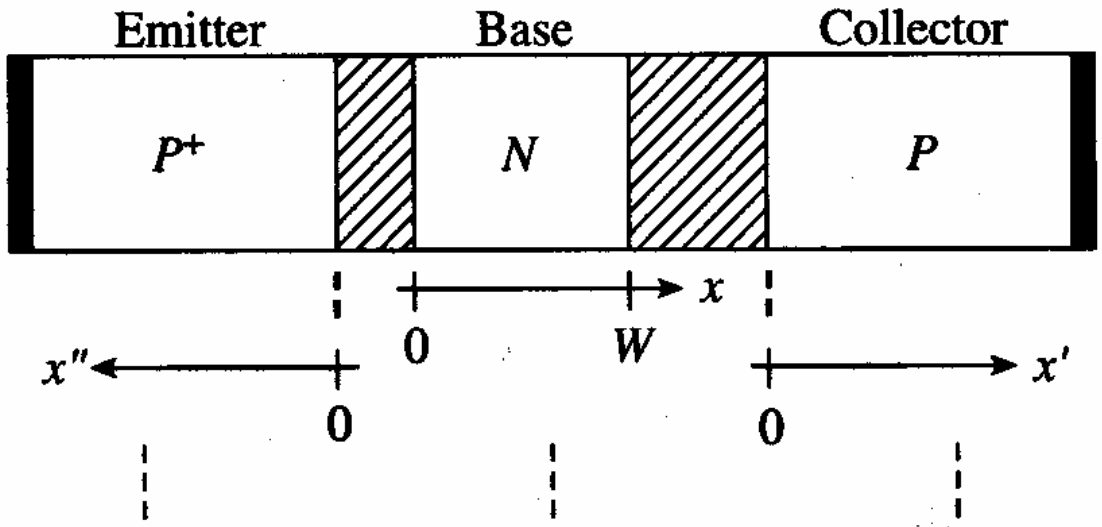
$$\alpha_{dc} = \frac{I_C}{I_E} = \gamma \alpha_T$$



- Common Emitter dc Current Gain:
  - (2) + (3) vs. (4+5)

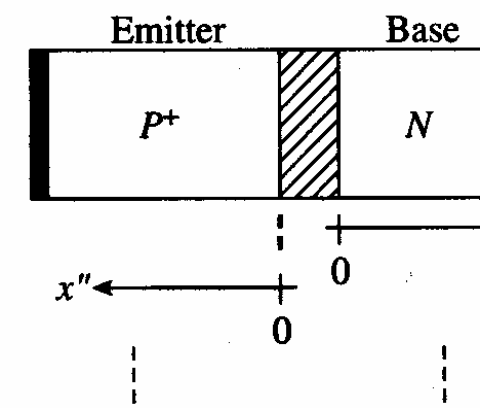
$$\beta_{dc} = \frac{I_C}{I_B} = \frac{\alpha_{dc}}{1 - \alpha_{dc}}$$

Qualitative Solution - Definitions



$N_E = N_{AE}$	$N_B = N_{DB}$	$N_C = N_{AC}$
$D_E = D_N$	$D_B = D_P$	$D_C = D_N$
$\tau_E = \tau_n$	$\tau_B = \tau_p$	$\tau_C = \tau_n$
$L_E = L_N$	$L_B = L_P$	$L_C = L_N$
$n_{E0} = n_{p0} = n_i^2/N_E$	$p_{B0} = p_{n0} = n_i^2/N_B$	$n_{C0} = n_{p0} = n_i^2/N_C$

Emitter Region Formulation



- Diffusion equation:

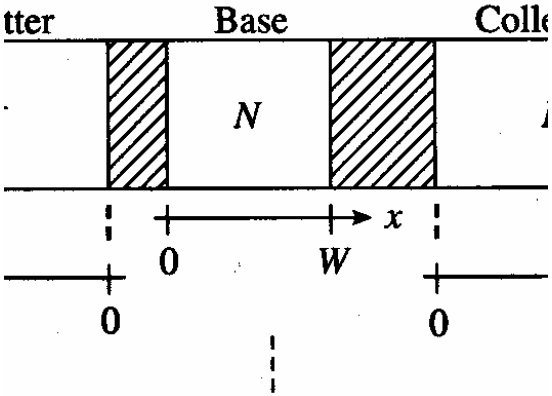
$$0 = D_E \frac{d^2 \Delta n_E}{dx''^2} - \frac{\Delta n_E}{\tau_E}$$

- Boundary Conditions

$$\Delta n_E (x'' \to \infty) = 0$$

$$\Delta n_E (x'' = 0) = n_{E0} (e^{qV_{EB}/kT} - 1)$$

Base Region Formulation



- Diffusion equation:

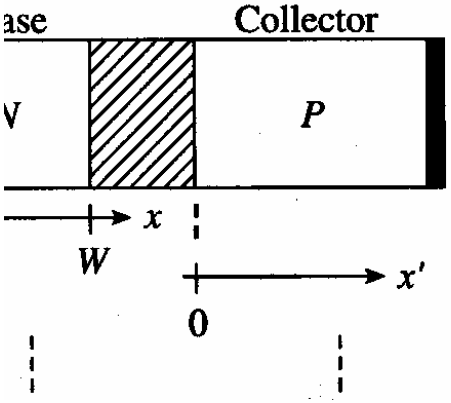
$$0 = D_B \frac{d^2 \Delta n_B}{dx^2} - \frac{\Delta p_B}{\tau_B}$$

- Boundary Conditions

$$\Delta p_B(0) = p_{B0}(e^{qV_{EB}/kT} - 1)$$

$$\Delta p_B(W) = p_{B0}(e^{qV_{CB}/kT} - 1)$$

Collector Region Formulation



- Diffusion equation:

$$0 = D_C \frac{d^2 \Delta n_C}{dx'^2} - \frac{\Delta n_C}{\tau_C}$$

- Boundary Conditions

$$\Delta n_C(x' \to \infty) = 0$$

$$\Delta n_C(x' = 0) = n_{C0}(e^{qV_{CB}/kT} - 1)$$