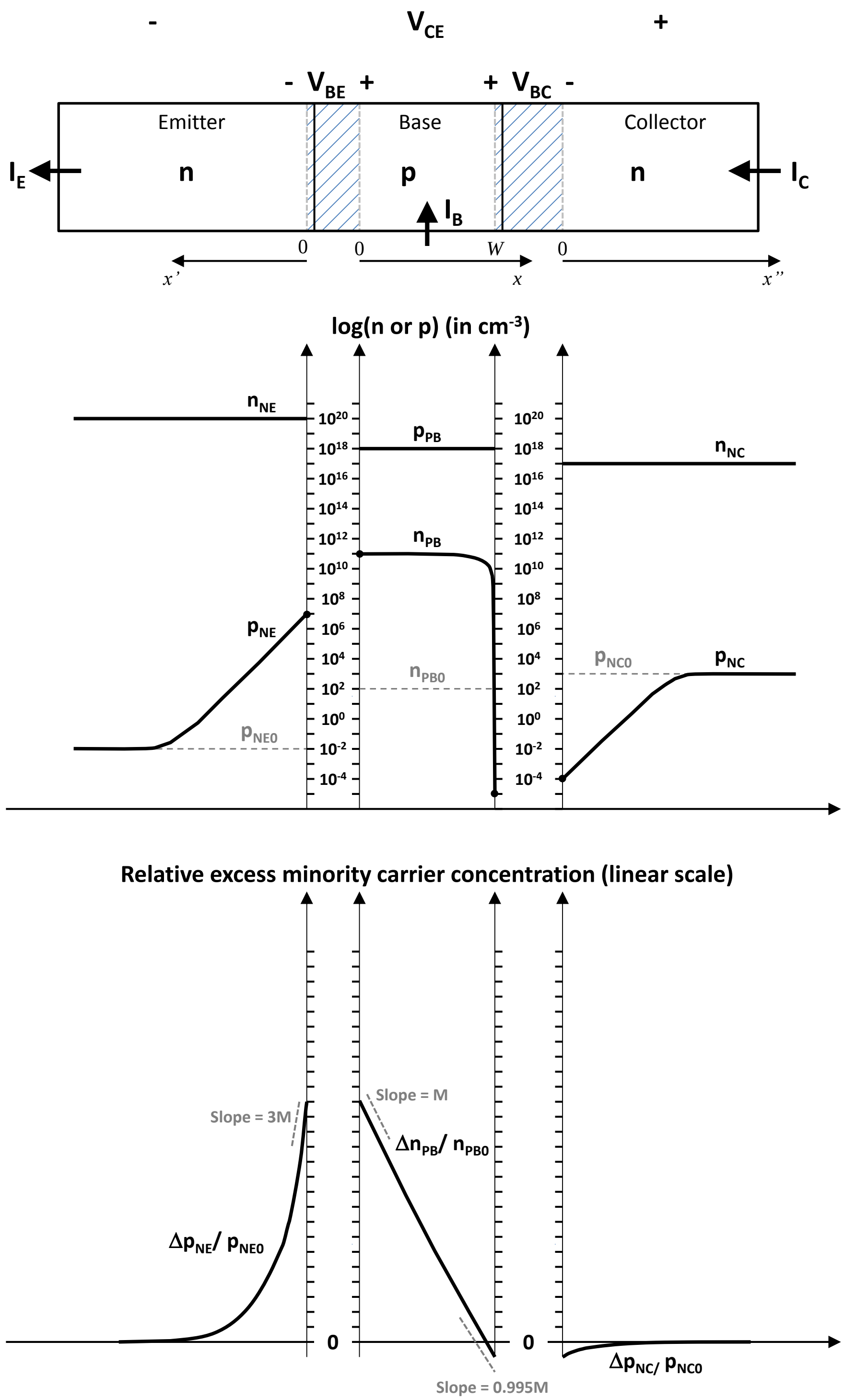
Consider an npn bipolar transistor at T = 300 K that is biased in the common-emitter configuration. The device has the structural parameters and minority/majority carrier profiles as shown in the figure below. The hatched regions indicate the depletion regions. Assume that the diffusion coefficients are the same for all three regions of the device.



The definitions of the parameters in the figure, as well as a few constants, are given below:

n_{NE} = Majority electron concentration in the emitter

p_{NE} = Minority hole concentration in the emitter

p_{NE0} = Equilibrium minority hole concentration in the emitter

Δp_{NE} = Excess minority hole concentration in the emitter

---

p_{PB} = Majority hole concentration in the base

n_{PB} = Minority electron concentration in the base

n_{PB0} = Equilibrium minority electron concentration in the base

Δn_{PB} = Excess minority electron concentration in the base

---

n_{NC} = Majority electron concentration in the collector

p_{NC} = Minority hole concentration in the collector

p_{NC0} = Equilibrium minority hole concentration in the collector

Δp_{NC} = Excess minority hole concentration in the collector

---

V_{BE} = Base-emitter voltage

V_{BC} = Base-collector voltage

V_{CE} = Collector-emitter voltage

---

k_B = Boltzmann's constant = 8.617 x 10^{-5} eV/K

In a bipolar transistor, γ is a parameter called the emitter efficiency, and α_T is the base transit factor. These parameters are given by:

$$\gamma = \frac{I_{EN}}{I_E} \quad \text{and} \quad \alpha_T = \frac{I_{CN}}{I_{EN}},$$

where I_E is the emitter current, and I_{EN} and I_{CN} are the electron components of the emitter and collector currents, respectively.

The common-emitter DC current gain of bipolar transistor, β_{DC}, is given by:

$$\beta_{DC} = \frac{I_C}{I_B},$$

while the common-base DC current gain of a bipolar transistor, α_{DC}, is given by:

$$\alpha_{DC} = \frac{I_C}{I_E}.$$

Answer the following questions about this device:

(a) What are the terminal voltages, V_{BE}, V_{BC} and V_{CE}? (0.25)

(b) What mode (Saturation, Active, Cutoff or Inverted Active) is this device operating in? Explain your answer in one sentence. (0.25)

(c) What are the intrinsic carrier concentrations in the emitter, base and collector? (0.5)

(d) Is this a heterojunction or homojunction bipolar transistor? In other words, are the three device regions made of the same semiconductor or different semiconductors? Explain your answer in two sentences or less. (0.5)

(e) What is the base transit factor, α_T? (0.5)

(f) What is the emitter efficiency, γ? (0.5)

(g) What is the common-emitter DC current gain, β_{DC}? (0.5)

(h) While keeping I_B constant, V_{CE} is increased to 1.6 V. This leads to a reduction in the base width, W, by 1%. Calculate the Early voltage, V_A, which is defined below. Assume that α_T remains unchanged. (1.0 pt)