Problems

1. A silicon npn bipolar transistor with $N_E = 10^{18}$ cm^{-3}, $N_B = 10^{17}$ cm^{-3} and $N_C = 10^{16}$ cm^{-3}, w_E = 1 μm, w_B = 0.5 μm , and w_C = 4 μm is biased with V_{BE} = 0.6 V and V_{CB} = 0 V. Use m_n = 1000 cm^2/V-s, m_p = 300 cm^2/V-s and $t_n = t_p$ = 100 ns. The emitter area equals 10^{-4} cm^2.

   a) Calculate the width of the quasi-neutral regions in the emitter, base and collector.

   b) Calculate the minority-carrier diffusion lengths in the emitter, base and collector. Calculate the ratio of the minority-carrier diffusion length and the quasi-neutral region width in each region.

   c) Calculate the excess-minority-carrier charge density per unit area in the emitter, base and collector.

   d) Calculate the emitter current while ignoring the recombination in the depletion region.

   e) Calculate the base transit time and the current due to recombination of electrons in the base.

   f) Calculate the emitter efficiency and the base transport factor.

   g) Calculate the transport factor and the current gain assuming there is no recombination in the depletion regions.

   h) Calculate the collector capacitance, the majority-carrier charge density in the base and the Early voltage.

2. A silicon npn bipolar transistor has an emitter doping, N_E = 2 x10^{18} cm^{-3}, an emitter width w_E = 1 μm, and a base doping of 2 x 10^{17} cm^{-3}. A current gain of 100 and an early voltage of 100 V is desired. Using m_n = 1000 cm^2/V-s, m_p = 300 cm^2/V-s and $t_n = t_p$ = 100 ns, find the corresponding base width and base doping. The emitter area equals 10^{-4} cm^2.