參考用

Use the parameter values below in the following problems.
The permittivity of free space $\varepsilon_o = 8.85 \times 10^{-14}$ F/cm. For silicon at $\phi_T = kT/q = 25.8$ mV, the relative dielectric constant $K_s = 11.8$, the intrinsic concentration $n_i = 1.5 \times 10^{10}\text{cm}^{-3}$.

1.(20%) In a semiconductor, the Fermi level is 250 meV below the conduction band. What is the probability of finding an electron in a state kT above the conduction-band edge at room temperature?

2.(20%) Derive the dc current-voltage characteristic for a p^+n diode as

$$I = I_o(e^{V/\phi_T} - 1)$$

where

$$I_o \simeq qA(\frac{D_p p_{no}}{L_p})$$

Hint:

$$\frac{1}{q}\frac{\partial J_p}{\partial x} + \frac{p - p_o}{\tau_p} = -\frac{\partial p}{\partial t}$$

$$J_p = \frac{I_p}{A} = q(\mu_p pE - D_p\frac{dp}{dx})$$

3.(20%) (a) For an n^+pn transistor in active mode with long emitter width, long base width, and long collector width, sketch the minority carrier distribution in emitter, base, and collector regions.
(b) Repeat (a) with short emitter width and short base width.
(c) $\beta_o \equiv I_C/I_B$, state why the gain decreases at both low I_C currents and high I_C currents.
(d) Sketch the energy-band diagrams before and after the punch-through breakdown.

4.(20%) Assume an ideal MOS capacitor on p-type Si with $N_a = 10^{15}\text{cm}^{-3}$ is biased at onset of strong inversion.
(a) Find the width of depletion region.
(b) Find the charge per unit area in the depletion region.
(c) Find the *threshold* voltage required for strong inversion in this ideal MOS capacitor.
(d) Find the total capacitance for this ideal MOS capacitor. Assume the SiO_2 layer is 1×10^{-5} cm, the relative dielectric constant of SiO_2 is 3.9.

5.(20%) (a) State the process of converting optical energy into electric energy in a pn junction.
(b) Derive the open-circuit voltage as

$$V_{oc} = \phi_T \ln(1 + \frac{I_L}{I_o})$$

where I_L is the *light-generated current* and I_o is the *saturation current* of the junction diode.