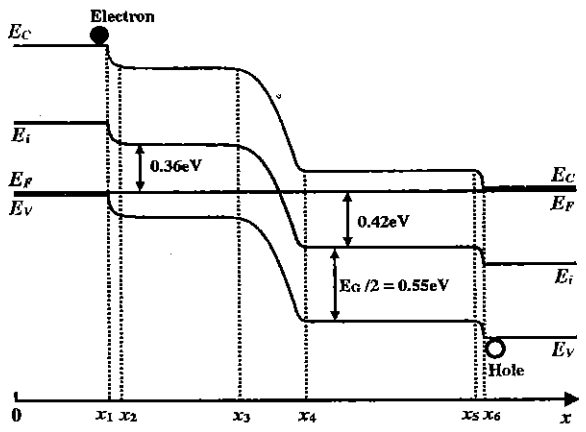
類組：電機類　科目：固態電子元件(300G)　　※請在答案卷內作答

1. A silicon sample maintained at T=300K is characterized by the energy band-diagram below. Answer the following questions.



(a) Do equilibrium conditions prevail? How do you know? (3%)

(b) Sketch the electrostatic potential $V(x)$ inside the semiconductor as a function of x. (4%)

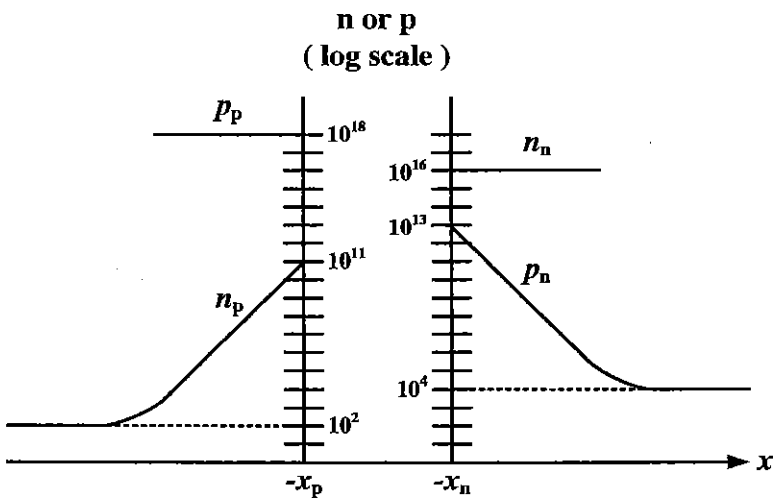
(c) Sketch the electric field $\mathcal{E}(x)$ inside the semiconductor as a function of x. (4%)

(d) Suppose the electron pictured in the diagram moves back and forth between $x = x_1$ and $x = x_6$ without changing its total energy. Sketch the kinetic energy of the electron as a function of x. (4%)

(e) Roughly sketch $\mathrm{Log}_{10}(n)$ and $\mathrm{Log}_{10}(p)$ versus x. (4%)

(f) On the same set of coordinates, make a rough sketch of the electron drift-current density and the electron diffusion-current density as a function of position. Briefly explain how you arrived at your sketch. (4%)

2. The steady state carrier concentrations inside a pn junction diode maintained at room temperature are plotted in the following figure.



(a) Is the diode forward or reverse biased? Explain how you arrived at your answer. (4%)

(b) Do low-level injection conditions prevail in the quasineutral regions? Explain how you arrived at your answer. (4%)

(c) What is the applied voltage V_A? (4%)

(You may use $n_i = 1 \times 10^{10}$ cm^{-3} @ 300K, $2.3kT = 60$ meV @ 300K, $\varepsilon_{Si} = 1 \times 10^{-12}$ F/cm and $q = 1.6 \times 10^{-12}$ C in above 2 equations)

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3. For a MOS capacitor on an n-type substrate with a doping level of N_D, biased in inversion. Consider the V_{FB}=-1.5V with a presents of oxide charge, Qox, at the center of the SiO_2. Assume x=0 at Si/SiO_2 interface, sketch qualitatively the following curves along x, where x-axis is perpendicular to the Si surface. **(20%)**
   (a) Band diagram. (5%)
   (b) Electric Field, E(x). (5%)
   (c) Charge distribution, r(x). (5%)
   (d) Potential, F(x). (5%)

4. For an n-channel MOSFET with gate oxide thickness of T_{ox}. In the following discussion, assume all device parameters remain constant, if not otherwise specified. When T_{ox} increases, **(15%)**
   (a) How will sub-threshold swing, S, change? Explain why. (5%)
   (b) How will body effect coefficient, g, change? Explain why. (5%)
   (c) Under the same bias condition, how will gate-induced-drain-leakage GIDL current change? Explain why. (5%)

5. Consider a NPN BJT with fully ionized impurity concentrations in emitter, base, and collector are $N_{DE}=10^{19}cm^{-3}$, $N_{AB}=10^{17}cm^{-3}$, and $N_{DC}=10^{16}cm^{-3}$, respectively. And where the emitter and base widths W_E=0.5um and W_B=0.2um. The ratio of diffusion coefficients in base and emitter $D_{nB} / D_{pE} = 6$ and the electron diffusion length in base is 200um, answer the problems below, **(30%)**
   (a) What is the emitter injection efficiency γ? (5%)
   (b) What is the current transport factor α_T? (5%)
   (c) Operating at high V_{CE}, the base width is shrunk 0.05um, what is the new current gain β? And what is the name of this effect? Draw energy band diagram to qualitatively explain the effect. (10%)
   (d) When operating at high-level injection, the excess electrons push the depletion region of CB junction toward collector and the base width becomes W_B=0.5um, what is the new current gain β? And what is the name of this effect? Draw energy band diagram to qualitatively explain the effect. (10%)

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