EE105 – Microelectronic Devices and Circuits
Spring 2026, Homework #5

Assigned: **February 24, 2026**
Due: **March 3, 2026 at 11:59 PM on Gradescope**

1 Notes

Upload your notes from Lectures 10 and 11.

2 Problem Set

2.1 Problem 1: Drift Current, Resistivity and Conductivity

A 1 μm long Si bar is doped with 6×10^{15} cm^{-3} of As, and 4×10^{15} cm^{-3} of B. The semiconductor is held at a temperature of 300 K. Assume $n_i = 10^{10}$ cm^{-3}. Answer the following questions, including units when necessary.

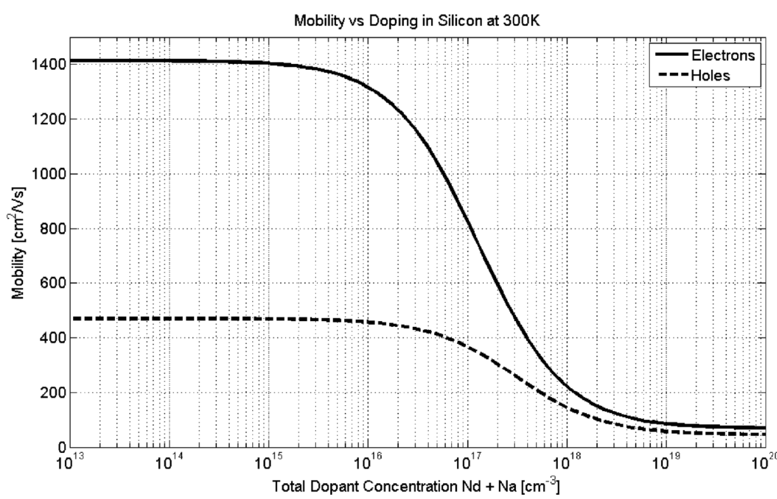

Figure 1: Mobility of free carriers as a function of total dopant concentration.

(a) What is the concentration of the free carriers n and p? Is this Si bar n-type or p-type?

(b) As temperature increases (let's say by 100 K), what would happen to the concentration of electrons and holes? Give a qualitative answer.

(c) Using the mobility values from Figure 2.1, calculate the conductivity and resisitivty of the Si bar when held at a temperature of 300 K.

(d) Suppose we want to produce a resistor of 100 Ω. What should be the cross-sectional area of the Si bar?

(e) A voltage of 1 V is applied across the 1 μm length direction. Calculate the resulting current density.

(f) If we increase the voltage applied to the bar, will the current keep increasing indefinitely?

2.2 Problem 2: Diffusion Current and Equilibrium

Consider a dominantly p-type Si material with hole density:

$$p(x) = p_0 e^{-x/\ell}.$$

(a) If no electric field is applied to the material, what is the expression for the current density $J(x)$ in the material? Expand any potential derivative term(s).

(b) A general relationship for the current density is: $J(x) = qp(x)v(x)$. Leveraging your answer from part (a), find the expression for the velocity of the holes in as a function of D_p and potentially other parameters.

(c) You want to apply an electric field to restore equilibrium in the doped Si material. What would be the expression for the electric field? Leverage Einstein's relation to provide an answer in terms of k, q, T and ℓ.

(d) At 300 K, what value of ℓ would make the magnitude of the electric field in part (b) be 1000 V/cm?

2.3 Problem 3: P-N Junctions

Given the following parameters:

$$n_i = 10^{10}\ \text{cm}^{-3}, \quad \frac{kT}{q} = 26\ \text{mV},$$

the permittivity of a vacuum is

$$\varepsilon_0 = 8.85 \times 10^{-12}\ \frac{\text{F}}{\text{m}},$$

and the permittivity of silicon is,

$$\varepsilon_{\text{Si}} = 11.7\,\varepsilon_0.$$

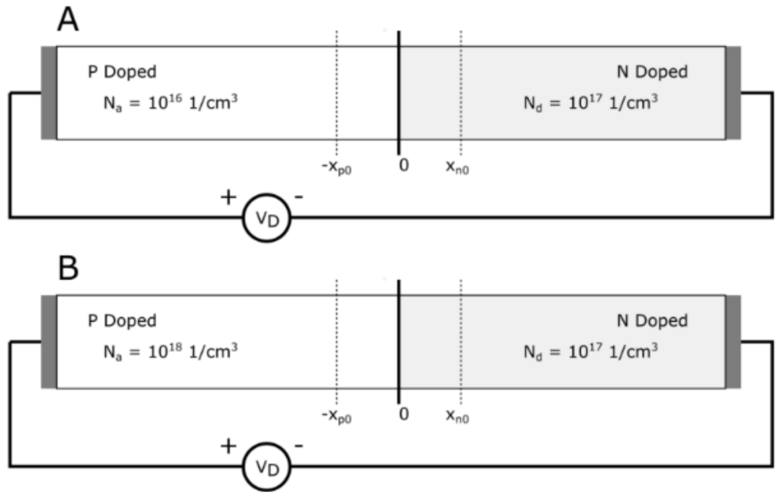

Figure 2: Two different P-N junctions A and B.

(a) What is the built-in potential for P-N Junction A and P-N Junction B?

(b) Find the depletion width for P-N Junction A and P-N Junction B? What are their respective junction capacitance per area?

(c) Find the maximum field within P-N Junction A and P-N Junction B when no external voltage is applied ($V_D = 0$ V).

(d) Sketch the charge concentration, electric field and potential in P-N junction A and P-N junction B across their length (x), using answers from parts (a)-(c) to label key values.

(e) If $V_D = -0.7$ V, are the P-N junctions reversed or forward biased? What is the new depletion width of P-N junction A and P-N junction B? What is the new junction capacitance per area?