

EE 105 Midterm 1

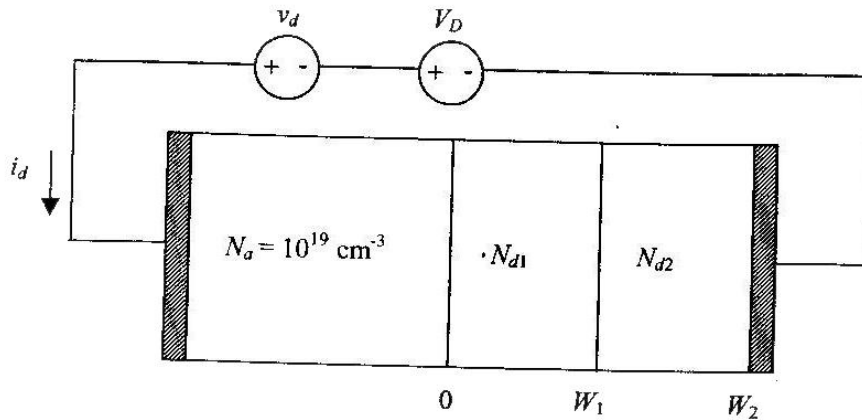
Spring 2000

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1. pn Junction Capacitor (18 pts)

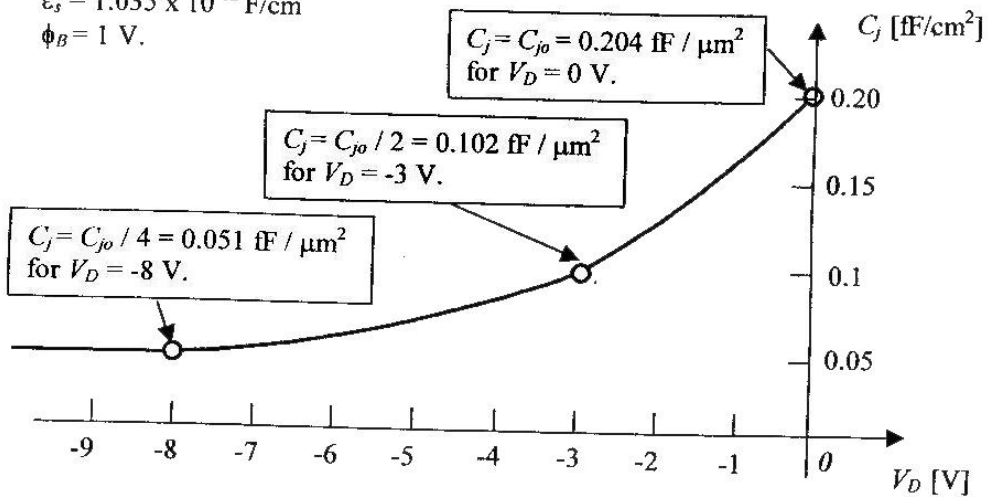
1. pn Junction Capacitor [18 pts.]



Given:

$$\epsilon_s = 1.035 \times 10^{-12} \text{ F/cm}$$

$$\phi_B = 1 \text{ V.}$$

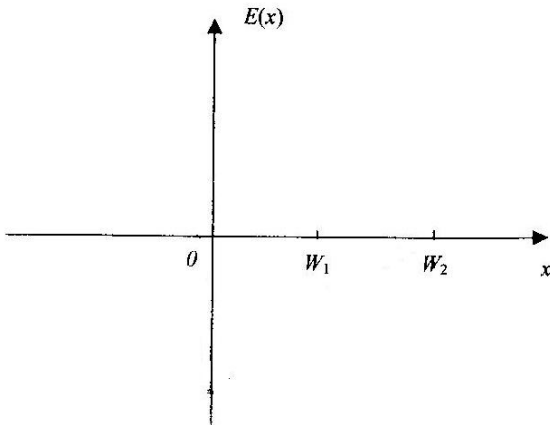


a. What is the width $X(\text{do})$ of the depletion region in thermal equilibrium in micrometers? (3 pts)

b. What is the numerical value of the width W_1 in micrometers? Hints: The depletion region is located at W_1 for $V(D) = -3$ V. You can assume that the doping concentration on the p-side is much greater than $N(d_1)$. (3 pts)

c. What is the numerical value of the width W_2 in micrometers? Hint: You can assume that the doping concentration on the p-side is much greater than either $N(d_1)$ or $N(d_2)$. (3 pts)

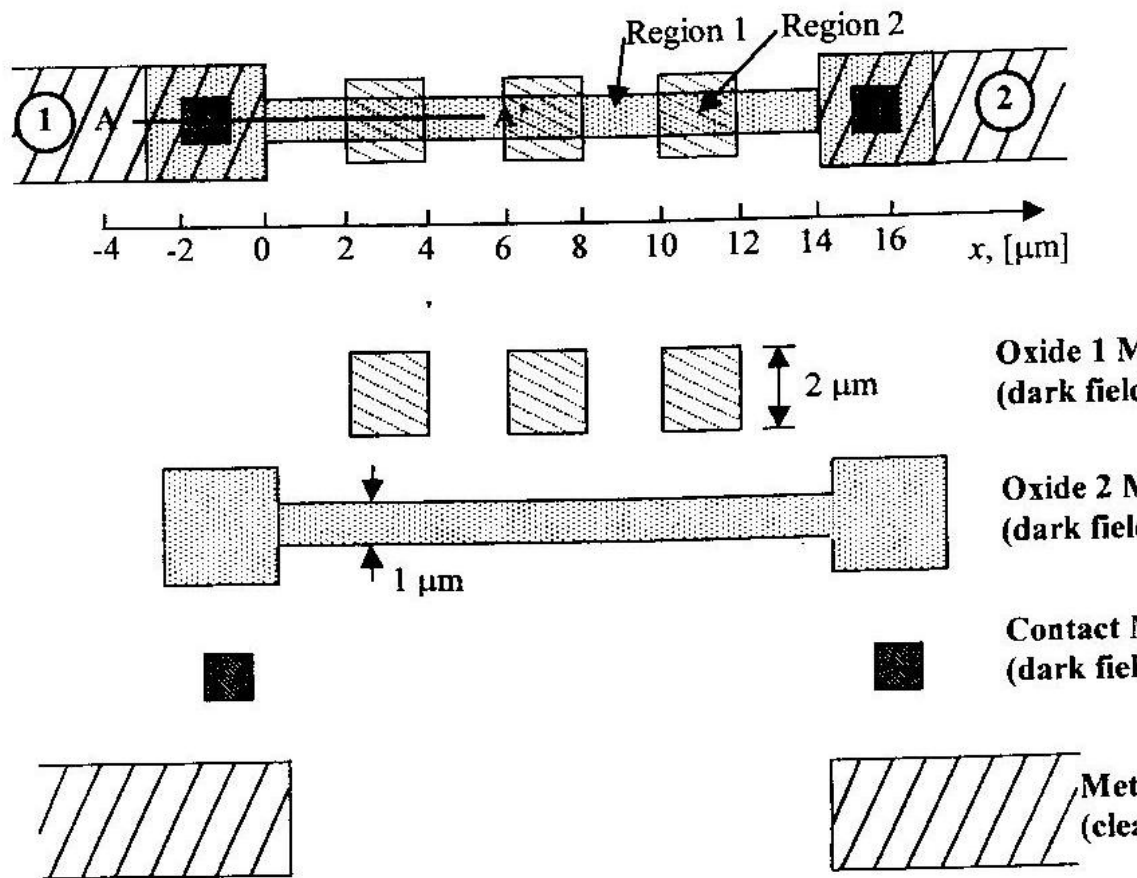
d. Sketch the electric field on the graph below for the case when the depletion region edge has just reached W_2 . Your plot should show the relative magnitudes of $N(d_1)$ and $N(d_2)$ correctly; note that $N(a) \gg N(d_1)$ and $N(d_2)$. (3 pts)



e. The area of this pn junction capacitor is 100 micrometers². If the applied voltage is $V(D)(t) = V(D) + v(d)(t) = -8V + 10mV\cos(2\pi \cdot 100 \cdot 10^6 \cdot t)$, what is the current $i(d)(t)$? The units for the current should be nA (10^{-9} A). (3 pts)

f. If the applied voltage is $v(D)(t) = V(D) + v(d)(t) = -9V + v(d)\cos(\omega \cdot t)$, What is the maximum amplitude $v(d)$ for which the current into the pn junction capacitor is exactly proportional to $dv(d)/dt$? (3 pts)

2. Integrated Circuit Resistor (20 pts)

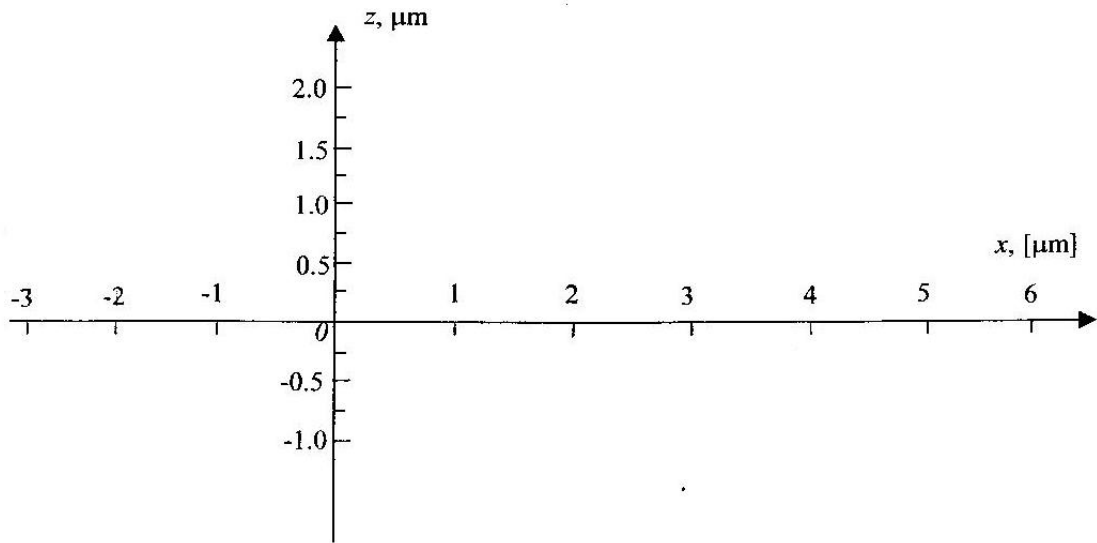


Process Sequence:

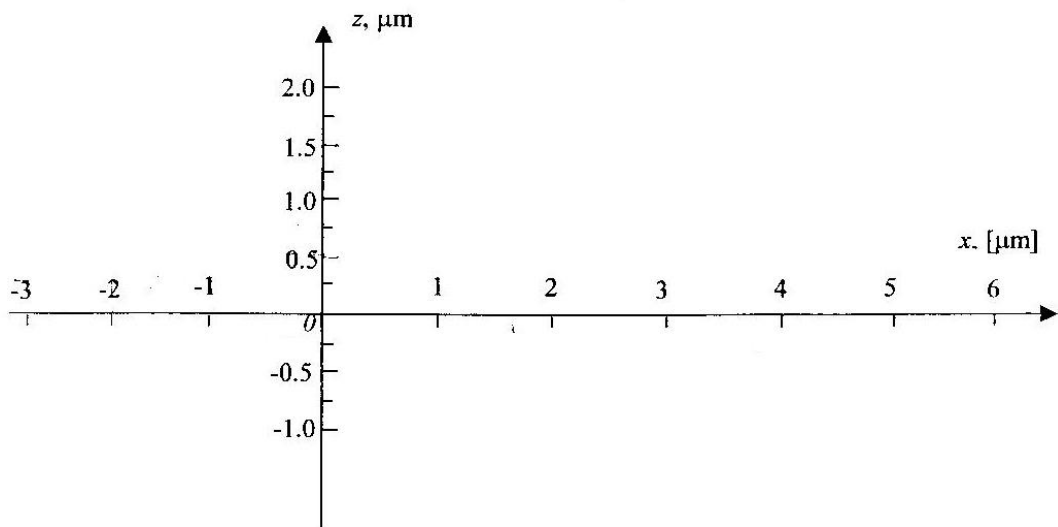
1. Starting material: boron-doped silicon, concentration $5 \cdot 10^{15}/\text{cm}^3$
2. Deposit 0.25 micrometers CVD SiO_2 and pattern with the Oxide Mask 1 (dark field)
3. Implant boron with dose $Q(a) = 5 \cdot 10^{11}/\text{cm}^2$ and anneal to a depth of 0.35 micrometers.
4. Etch off all oxide using a hydrofluoric acid wet etch.
5. Deposit 0.25 micrometers of CVD SiO_2 and pattern using the Oxide Mask 2 (dark field)
6. Implant phosphorous with dose $Q(d) = 5 \cdot 10^{11}/\text{cm}^2$ and anneal, after which the phosphorus layer's junction depth is 0.25 micrometers and the boron implant depth increases to 0.5 micrometers.
7. Deposit 0.5 micrometers of CVD SiO_2 and pattern using the Contact Mask (dark field)
8. Deposit 0.5 micrometers of aluminum and pattern using the Metal Mask (clear field)

Given: mobilities for this problem are $\mu(n) = 1000 \text{ cm}^2/(\text{Vs})$ and $\mu(p) = 400 \text{ cm}^2/(\text{Vs})$. Count the "dogbone" contact areas as 0.65 square each in finding the resistance.

a. Sketch the cross section A-A' on the graph below after step 5. Identify all layers clearly. (5 pts)



b. Sketch the cross section A-A' on the graph below after step 8. Identify all layers clearly. (5 pts)



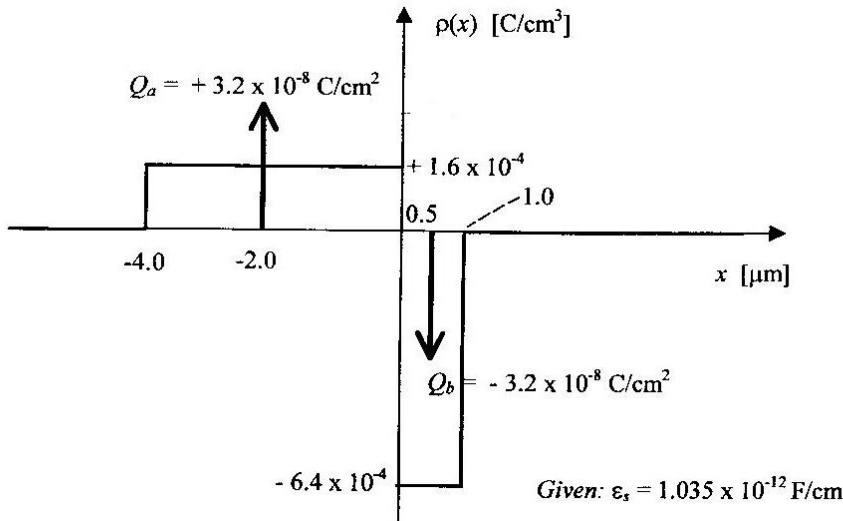
c. What is the sheet resistance $R(\text{square}1)$ of Region 1 (see the layout) in Ω/square ? (3 pts)

d. What is the sheet resistance $R(\text{square}2)$ of Region 2 (see the layout) in Ω/square ? (3 pts)

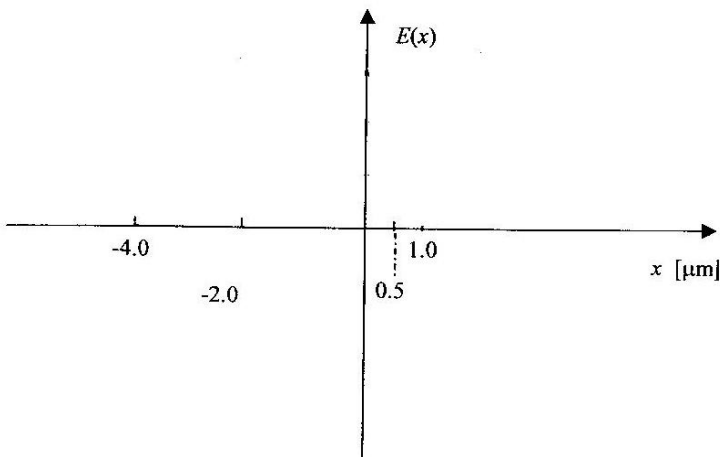
e. What is the resistance $R(1-2)$ between terminals 1 and 2 in Ω ? Make judicious approximations to find the effective width of the resistor. If you couldn't solve parts (c) and (d), use $R(\text{sheet } 1) = 200 \Omega$ and $R(\text{sheet } 2) = 175 \Omega$ in this part. (Note that these are incorrect answers to (c) and (d)). (4 pts)

3. Electrostatics (12 pts)

The charge density in a sample of silicon is plotted below.



a. Sketch the electric field $E(x)$ on the graph below. (4 pts)



b. What is the numerical value of the electric field in V/cm at $x = 0$? (4 pts)

c. What is the numerical value of the potential difference

$$\Delta(\phi) = \phi(x = +1 \text{ micrometers}) - \phi(x = -4 \text{ micrometers})$$

If you couldn't solve part (b), you can assume that the magnitude of the electric field at $x = 0$ is $|E(0)| = 8 \times 10^4$ V/cm (4 pts)