University of California at Berkeley
College of Engineering
Dept. of Electrical Engineering and Computer Sciences

EE 105 Midterm 1

Spring 2000
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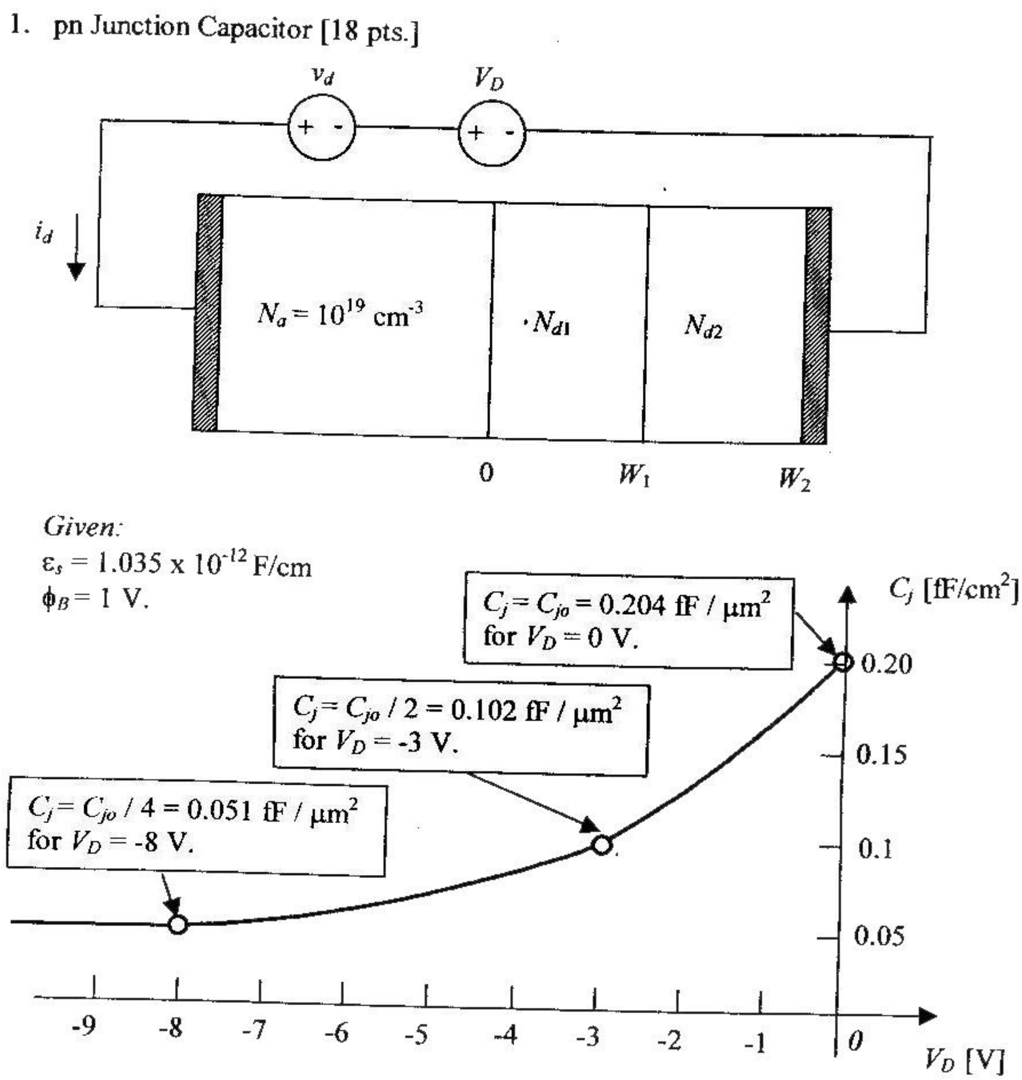
1. pn Junction Capacitor (18 pts)

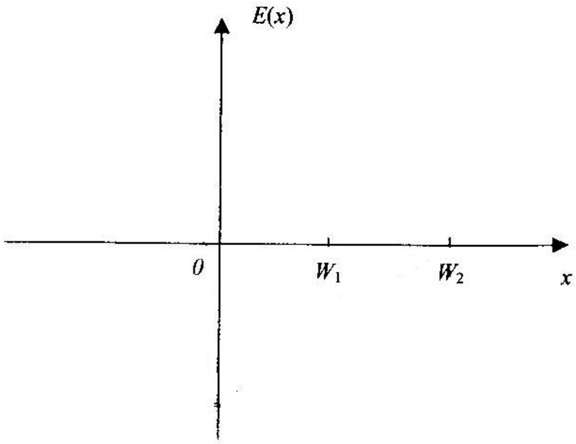


a. What is the width X(do) of the depletion region in thermal equilibrium in micrometers? (3 pts)

b. What is the numerical value of the width W1 in micrometers? Hints: The depletion region is located at W1 for V(D) = -3 V. You can assume that the doping concentration on the p-side is much greater than N(d1). (3 pts)

c. What is the numerical value of the width W2 in micrometers? Hint: You can assume that the doping concentration on the p-side is much greater than either N(d1) or N(d2). (3 pts)

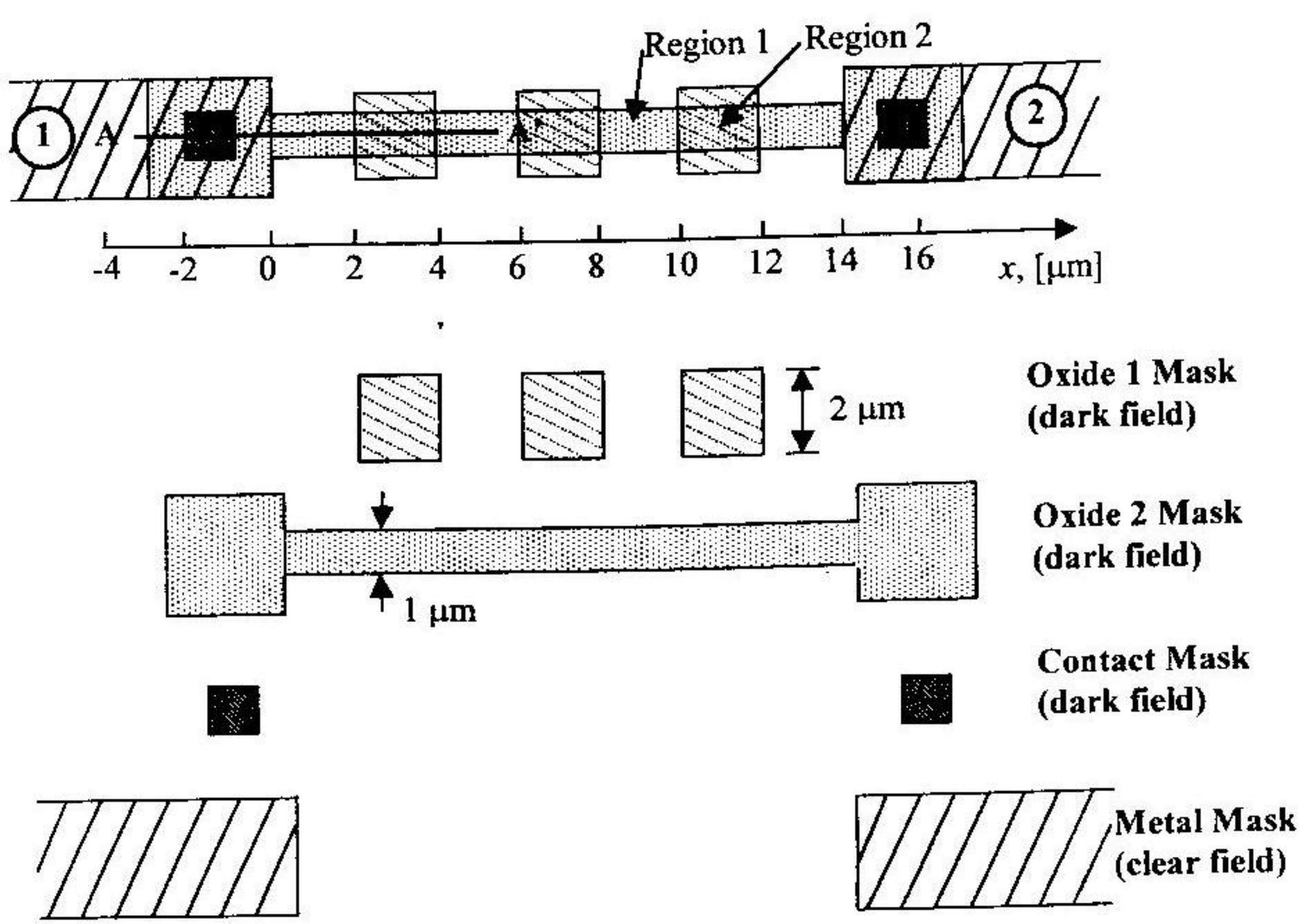
d. Sketch the electric field on the graph below for the case when the depletion region edge has just reached W2. Your plot should show the relative magnitudes of N(d1) and N(d2) correctly; note that N(a) >> N(d1) and N(d2). (3 pts)



e. The area of this pn junction capacitor is 100 micrometers^2. If the applied voltage is
V(D)(t) = V(D) + v(d)(t) = -8V + 10mVcos(2*pi*100*10^6*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*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)

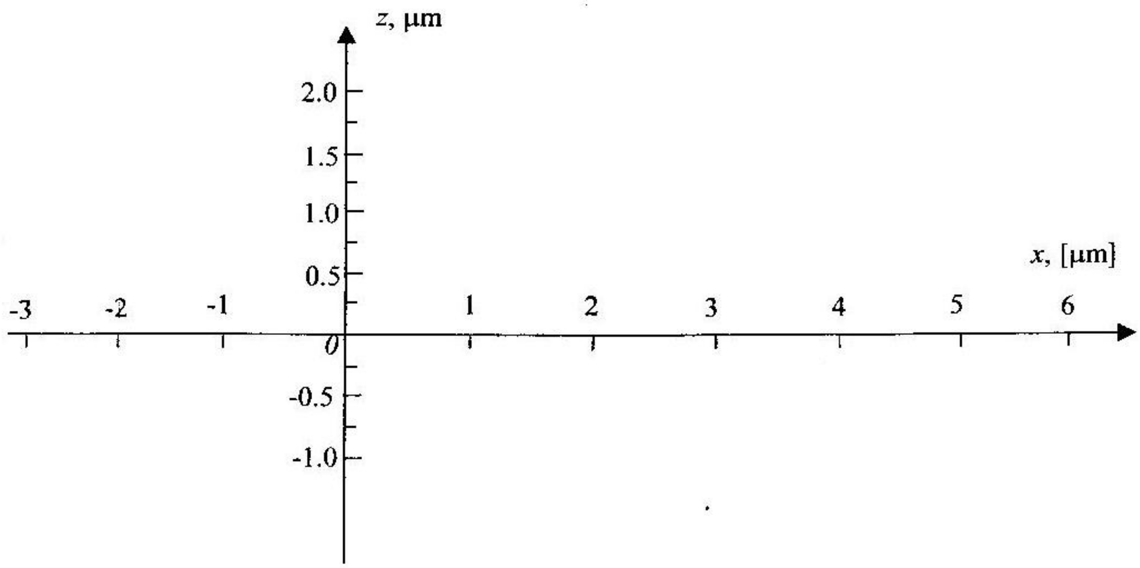


Process Sequence:

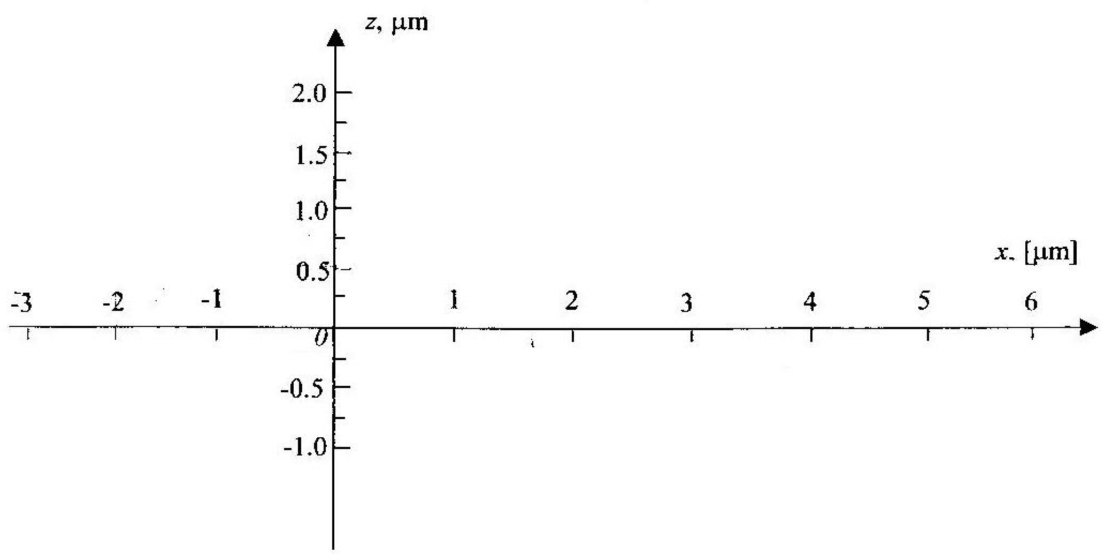
1. Starting material: boron-doped silicon, concentration 5*10^15/cm^3
2. Deposit -.25 micrometers CVD Si02 and pattern with the Oxide Mask 1 (dark field)
3. Implant boron with dose Q(a) = 5 * 10^11/cm^2 and anneal to a depth of 0.35 micrometers.
4. Etch off all oxide using a hydrofluoric acid wet etch.
5. Deposit 0.25 micrometers of CVD SiO2 and pattern using the Oxide Mask 2 (dark field)
6. Implant phosphorous with dose Q(d) = 5 * 10^11/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 SiO2 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 micro(n) 1000 cm^2/(Vs) and micro(p) = 400 cm^2/(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)



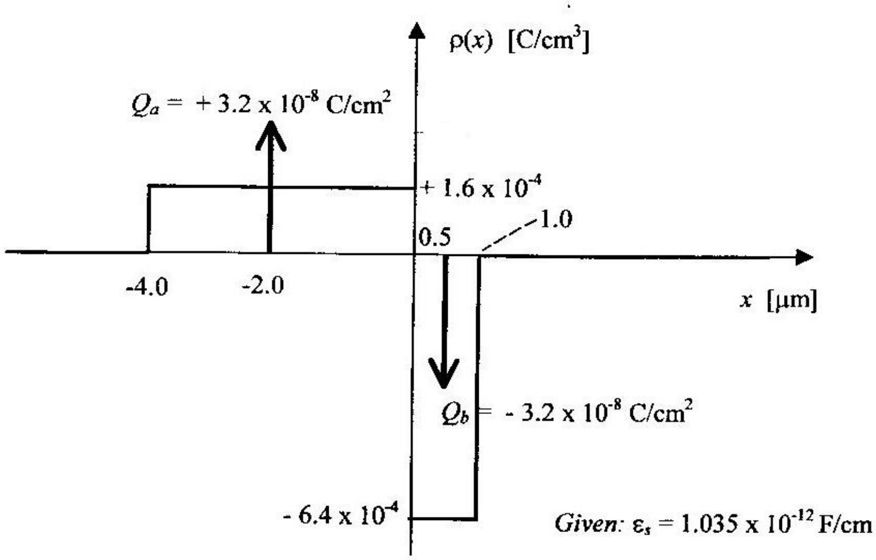
c. What is the sheet resistance R(square1) of Region 1 (see the layout) in Omega/square? (3 pts)

d. What is the sheet resistance R(square2) of Region 2 (see the layout) in Omega/square? (3 pts)

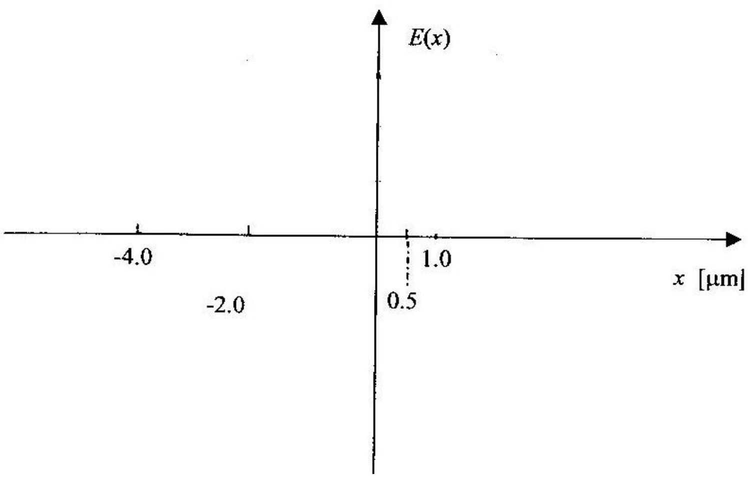
e. What is the resistance R(1-2) between terminals 1 and 2 in Omega? Make judicious approximations to find the effective width of the resistor. If you couldn't solve parts (c) and (d), use R(sheet 1) = 200 Omega and R(sheet 2) = 175 Omega in this part. (Note that these are incorrect answers to (c) and (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 micrometers) = phi(x = -4 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*10^4 V/cm (4 pts)