Homework #6

pn Junction large-signal & MOS capacitors – *100 points*
DUE @ Beginning of Class: Thursday, October 19

1) E-Book, problem 1.42 (pg. 443), *hint:* voltage drop will be the same for each of the two top diodes in the circuit (5 points)

2) E-Book, problem 1.49 (pg. 444), assume an ideal diode (3 points)

3) E-Book, problem 10.7, given ϕ_{ms} = -0.9932 V (3 points)

4) E-Book, problem 10.9, see Example 10.2 for useful information (4 points)

5) E-Book, problem 10.12 (10 points)

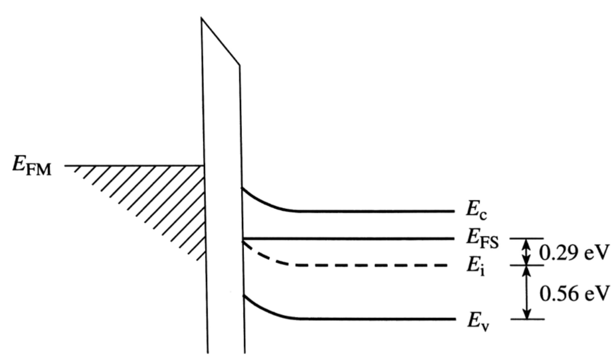
6) E-Book, problem 10.14, requires some trial-and-error and Fig. 10.16 (8 points)

7) E-Book, problem 10.23, assume no charge in oxide and use Fig. 10.16 (16 points)

8) E-Book, problem 10.30 (16 points)

9) E-Book, problem 10.31, be sure to label your band diagrams (E_{Fm}, E_{Fi}, etc) (15 points)

10) The energy band diagram for an ideal MOS capacitor with t_{ox} = 0.2 µm operated at 300 K is given below. Note that the applied gate voltage causes band bending in the semiconductor such that $E_F = E_{Fi}$ at the Si-SiO$_2$ interface. Answer the following questions: (20 points)



a) Sketch the electrostatic potential inside the semiconductor as a function of position.
b) Roughly sketch the electric field inside the oxide and semiconductor as a function of position.
c) Do equilibrium conditions prevail inside the semiconductor?
d) What is the electron concentration at the Si-SiO$_2$ interface?
e) N_D = ?
f) ϕ_s = ?
g) What is the approximate applied V_G (indicate how you arrived at answer)?

1) E-Book, problem 1.42 (pg. 443), *hint:* voltage drop will be the same for each of the two top diodes in the circuit (5 points)

1.42 (a) The reverse-saturation current of each diode in the circuit shown in Figure P1.42 is $I_S = 6 \times 10^{-14}$ A. Determine the input voltage V_I required to produce an output voltage of $V_O = 0.635$ V. (b) Repeat part (a) if the 1 kΩ resistor is changed to $R = 500\ \Omega$.

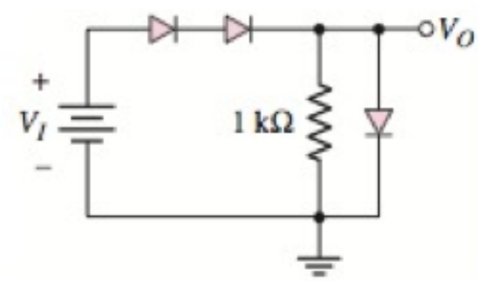


Figure P1.42

2) E-Book, problem 1.49 (pg. 444) (3 points)

1.49 (a) In the circuit shown in Figure P1.49, find the diode voltage V_D and the supply voltage V such that the current is $I_D = 0.4\,\text{mA}$. Assume the diode cut-in voltage is $V_\gamma = 0.7\,\text{V}$. (b) Using the results of part (a), determine the power dissipated in the diode.

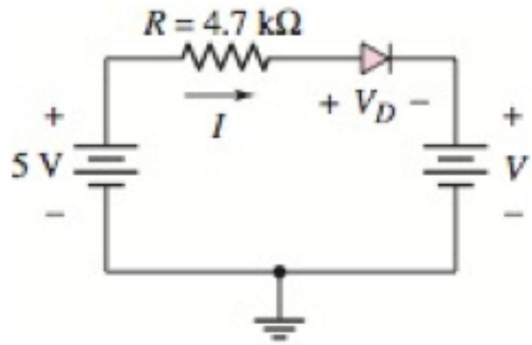


Figure P1.49

3) E-Book, problem 10.7 (3 points)

10.7 (a) Consider the MOS capacitor described in Problem 10.5. For an oxide thickness of $t_{ox} = 20$ nm $= 200$ Å and an oxide charge of $Q'_{ss} = 5 \times 10^{10}$ cm^{-2}, calculate the flat-band voltage. (b) Repeat part (a) for an oxide thickness of $t_{ox} = 8$ nm $= 80$ Å.

4) E-Book, problem 10.9 (4 points)

10.9 Consider an aluminum gate–silicon dioxide–p-type silicon MOS structure with $t_{ox} = 450$ Å. The silicon doping is $N_a = 2 \times 10^{16}$ cm^{-3} and the flat-band voltage is $V_{FB} = -1.0$ V. Determine the fixed oxide charge Q'_{ss}.

5) E-Book, problem 10.12 (10 points)

10.12 A 400-Å oxide is grown on p-type silicon with $N_a = 5 \times 10^{15}$ cm^{-3}. The flat-band voltage is -0.9 V. Calculate the surface potential at the threshold inversion point as well as the threshold voltage assuming negligible oxide charge. Also find the maximum space charge width for this device.

6) E-Book, problem 10.14 (8 points)

10.14 Consider a MOS device with the following parameters: p^+ polysilicon gate, n-type silicon substrate, $t_{ox} = 18$ nm $= 180$ Å, and $Q'_{ss} = 4 \times 10^{10}$ cm^{-2}. Determine the silicon doping concentration such that the threshold voltage is in the range $-0.35 \leq V_{TP} \leq -0.25$ V.

7) E-Book, problem 10.23 (16 points)

10.23 An ideal MOS capacitor with an n^+ polysilicon gate has a silicon dioxide thickness of $t_{ox} = 12$ nm $= 120$ Å on a p-type silicon substrate doped at $N_a = 10^{16}$ cm^{-3}. Determine the capacitance C_{ox}, C'_{FB}, C'_{min}, and $C'(\text{inv})$ at (*a*) $f = 1$ Hz and (*b*) $f = 1$ MHz. (*c*) Determine V_{FB} and V_T. (*d*) Sketch C'/C_{ox} versus V_G for parts (*a*) and (*b*).

8) E-Book, problem 10.30 (16 points)

10.30 The high-frequency C–V characteristic curve of a MOS capacitor is shown in Figure P10.30. The area of the device is 2×10^{-3} cm^2. The metal–semiconductor work function difference is $\phi_{ms} = -0.50$ V, the oxide is SiO_2, the semiconductor is silicon, and the semiconductor doping concentration is 2×10^{16} cm^{-3}. (*a*) Is the semiconductor n or p type? (*b*) What is the oxide thickness? (*c*) What is the equivalent trapped oxide charge density? (*d*) Determine the flat-band capacitance.

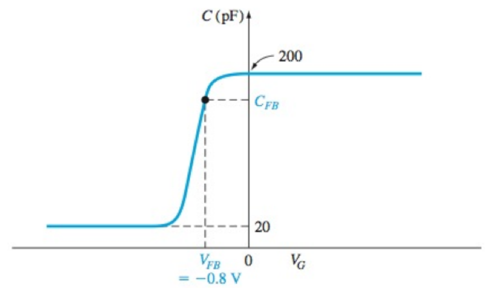


Figure P10.30 | Figure for Problem 10.30.

9) E-Book, problem 10.31 (15 points)

10.31 Consider the high-frequency C–V plot shown in Figure P10.31. (a) Indicate which points correspond to flat-band, inversion, accumulation, threshold, and depletion modes. (b) Sketch the energy-band diagram in the semiconductor for each condition.

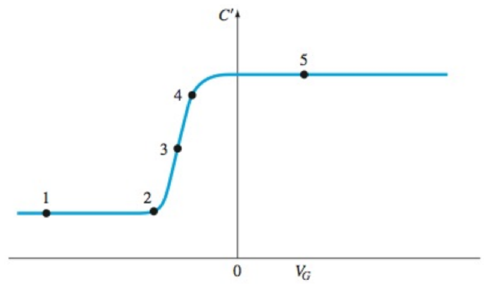


Figure P10.31 | Figure for Problem 10.31.

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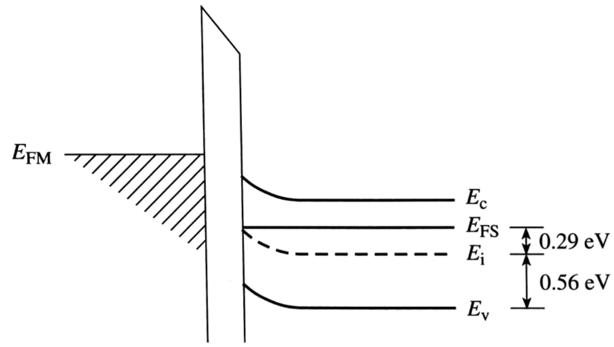

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