MidTerm - EE 5342 (print last name) ____________________________ (print first name) ______________________
9:30 AM, Thursday February 12, 2004, 105 Nedderman Hall
80 minutes allowed (last four digits of your student #) _____________ (e-mail if new)______________________

Instructions: Seat Number ____________

1. Do your own work. DO NOT REMOVE THE STAPLE ON THIS EXAM.
2. You may use either a legal copy of the text by Massobrio and Antognetti. You may write notes in your text. You may NOT pass a book or note sheet to another student. You may NOT use class notes or previously solved problems.
3. Calculator allowed. You may NOT share a calculator with another student.
4. Where values or equations are given on this cover sheet, use them in lieu of any other source. If a value is not given, explicitly state definitions and assumptions that you use.
5. Where possible, calculate parameters rather than read them from a graph.
6. Do all work in the spaces provided on this exam paper. If you write on the back of a sheet, make the notation "PTO" in your solution in order to assure that material written on the back of the page is evaluated for a grade. AN EXTRA BLANK SHEET IS ATTACHED AT THE BACK OF THE EXAM.
7. Show all calculations, making numerical substitutions and giving numerical results where possible.
8. Write answers in space given.
9. Unless stated otherwise,
   $T = 300K$, $V_t = 25.843$ mV (to agree with M&K k and q values)
10. Unless otherwise stated, the material is silicon (300K) with
    $n_i = 1.45E10\ cm^{-3}$ $N_c = 2.8E19\ cm^{-3}$ $q\chi_{Si} = 4.05$ eV
    $E_{g,Si} = 1.124$ eV. $N_v = 1.04E19\ cm^{-3}$
11. For the work function of poly silicon, use
    $\phi_{n+} = \chi_{si} = 4.05$ V
    $\phi_{p+} = \chi_{Si} + E_{g,Si}/q = 5.174$ V.
12. For minority carrier (either electrons or holes) lifetime in silicon, use the relationship
    $\tau_{min} = (4.5E\text{-}5\ sec)/(1 + N_i/1E17 + (N_i/5E17)^2)$,
    where N_i = the total impurity concentration in cm^{-3}
13. For holes in silicon doped primarily with boron, assume
    $\mu_p = \{470.5 \div [1+(N_i \div 2.23E17)^{0.719}]\}+44.9$, in cm^2/V-sec.
14. For electrons in silicon doped primarily with phosphorous, assume
    $\mu_n = \{1414 \div [1+(N_i \div 9.2E16)^{0.711}]\}+68.5$, in cm^2/V-sec.
15. For electrons in silicon doped primarily with arsenic, assume
    $\mu_n = \{1417 \div [1+(N_i \div 9.68E16)^{0.68}]\}+52.2$, in cm^2/V-sec.
    (In 12 through 16, N_i = the total impurity concentration in n- or p-type material, compensated or not).
16. Metal gate work functions should be assumed to be
    $\phi_{M,Al} = 4.1$ V for aluminum, $\phi_{M,Pt} = 5.3$ V for platinum, $\phi_{M,Au} = 4.75$ V for gold
17. The electron affinity of SiO_2 is $\chi_{SiO2} = 1.00$ V.
18. Planck constant $h = 6.625E\text{-}34$ J-s = 4.135E-15 eV-s, (1 eV = 1.602E-19 Joule).
19. free electron mass $m_o = 9.11E\text{-}28$ g.
20. Boltzmann constant, $k = 1.38E\text{-}23$ J/K
21. Electron charge, $q = 1.602E\text{-}19$ Coulomb
22. Permittivity of free space, $\varepsilon_o = 8.854E\text{-}14$ Fd/cm
23. Relative permittivity of silicon, $\varepsilon_r = 11.7$
24. Relative permittivity of silicon dioxide, $\varepsilon_{rOx} = 3.9$
25. The breakdown voltage of an abrupt (step) junction (asymmetrical or one-sided) diode with doping on the lightly doped side of N_B is $V_B = 60(Eg/1.1)^{3/2}\ (10^{16}/N_B)^{3/4}$ V. The critical field for breakdown is modeled as $E_{crit} = (120V \cdot qN_B/(\varepsilon_r\varepsilon_0))^{1/2} \cdot (Eg/1.1)^{3/4} \cdot (10^{16}/N_B)^{3/8}$
26. Each part is worth [x] points, as given in the problem.

Notes:

The objective of this test will be to demonstrate that you know how to calculate device physics derived device properties for semiconductor material (primarily silicon) and the pn junction diode (including the static dc characteristics and the small-signal ac characteristing). This is to include (but is not limited to):

carrier concentrations and Fermi energies
resistance and conductivity
mobility and diffusion coefficient
current density
capacitance
saturation current densities for a diode