

Instructions:

1. Do your own work. DO NOT REMOVE THE STAPLE ON THIS EXAM.
2. You may use either a legal copy of the text OR reference text. You may NOT pass a book or note sheet to another student. You may NOT use class notes. Do not use previously solved problems.
3. Calculator allowed. You may NOT share a calculator with another student.
4. Use values given on this cover sheet. 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,

$$T = 300\text{K}, \quad V_t = 25.843 \text{ mV (to agree with M\&K } k \text{ and } q \text{ values)}$$

10. Unless otherwise stated, the material is silicon (300K) with

$n_i = 1.45\text{E}10 \text{ cm}^{-3}$	$N_c = 2.8\text{E}19 \text{ cm}^{-3}$	$q\chi_{\text{Si}} = 4.05 \text{ eV}$
$E_{g,\text{Si}} = 1.124 \text{ eV.}$	$N_v = 1.04\text{E}19 \text{ cm}^{-3}$	

11. For the work function of poly silicon, use

$$\phi_{n+} = \chi_{\text{Si}} = 4.05 \text{ V}$$

$$\phi_{p+} = \chi_{\text{Si}} + E_{g,\text{Si}}/q = 5.174 \text{ V.}$$

12. For minority carrier (either electrons or holes) lifetime in silicon, use the relationship

$$\tau_{\text{min}} = (4.5\text{E-}5 \text{ sec}) / (1 + N_i / 7.70\text{E-}18 + (N_i / 4.71\text{E}17)^2),$$

where N_i = the total impurity concentration in cm^{-3}

13. For holes in silicon doped primarily with boron, assume

$$\mu_p = \{470.5 \div [1 + (N_i \div 2.23\text{E}17)^{0.719}] + 44.9, \text{ in } \text{cm}^2/\text{V-sec.}$$

14. For electrons in silicon doped primarily with phosphorous, assume

$$\mu_n = \{1414 \div [1 + (N_i \div 9.2\text{E}16)^{0.711}] + 68.5, \text{ in } \text{cm}^2/\text{V-sec.}$$

15. For electrons in silicon doped primarily with arsenic, assume

$$\mu_n = \{1417 \div [1 + (N_i \div 9.68\text{E}16)^{0.680}] + 52.2, \text{ in } \text{cm}^2/\text{V-sec.}$$

(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

$$\phi_{\text{M,AI}} = 4.1 \text{ V for aluminum,} \quad \phi_{\text{M,Pt}} = 5.3 \text{ V for platinum,} \quad \phi_{\text{M,Au}} = 4.75 \text{ V for gold}$$

17. The electron affinity of SiO_2 is

$$\chi_{\text{SiO}_2} = 1.00 \text{ V.}$$

18. Planck constant

$$h = 6.625\text{E-}34 \text{ J-s} = 4.135\text{E-}15 \text{ eV-s, (1 eV = 1.602E-19 Joule).}$$

19. free electron mass

$$m_o = 9.11\text{E-}28 \text{ g.}$$

20. Boltzmann constant,

$$k = 1.38\text{E-}23 \text{ J/K}$$

21. Electron charge,

$$q = 1.602\text{E-}19 \text{ Coulomb}$$

22. Permittivity of free space,

$$\epsilon_o = 8.854\text{E-}14 \text{ Fd/cm}$$

23. Relative permittivity of silicon,

$$\epsilon_r = 11.7$$

24. Relative permittivity of silicon dioxide, $\epsilon_{r\text{Ox}} = 3.9$

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 $V_B = 60(E_g/1.1)^{3/2} (10^{16}/N_B)^{3/4} \text{ V}$. The critical field for breakdown is modeled as $E_{\text{crit}} = (120\text{V} \cdot q N_B / (\epsilon_r \epsilon_o))^{1/2} \cdot (E_g/1.1)^{3/4} \cdot (10^{16}/N_B)^{3/8}$

26. Each part is worth [x] points, as given in the problem.