EE 203. Final

For k_BT at 300K, use 26 meV. Use material parameters from attached tables and figures from Sze.

1. In Si

a. (5 pts) How many equivalent conduction band valleys are there?

b. (5 pts)Where are they?

2. In Ge,

a. (5 pts) How many equivalent conduction band valleys are there?

b. (5 pts) Where are they?

3. In GaAs,

a. (5 pts) How many equivalent conduction band valleys are there?

b. (5 pts) Where are they?

4. Describe the valence band structure of semiconductors.

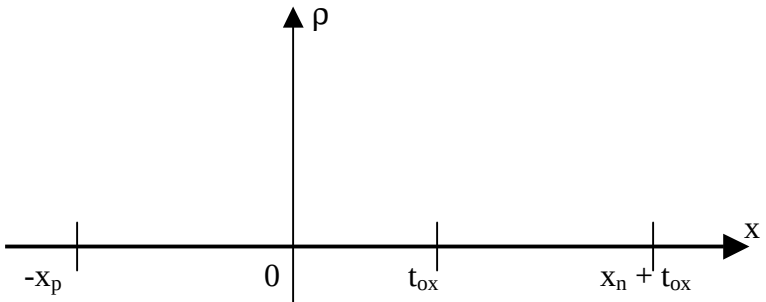
a. (5 pts) Where does the maximum occur?

b. (5 pts) Sketch the bands.

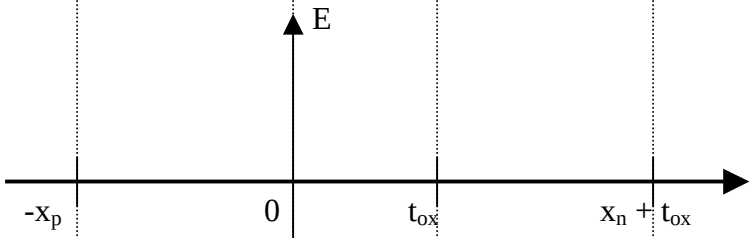
5. (10 pts) Describe the process(es) by which an electron at the valence band maximum in Si could absorb a photon equal to the bandgap. Illustrate the process(es) on a sketch of the E-k diagrams.

6. Consider a p-type ($N_A = 10^{18}$ cm^{-3}) Si / 10 nm SiO_2 / n-type Si ($N_D = 10^{18}$ cm^{-3}) structure at 0 bias and T=300K, i.e. a pn junction with a 10 nm oxide between the n and p regions. Using the depletion approximation as we did for the pn diode.

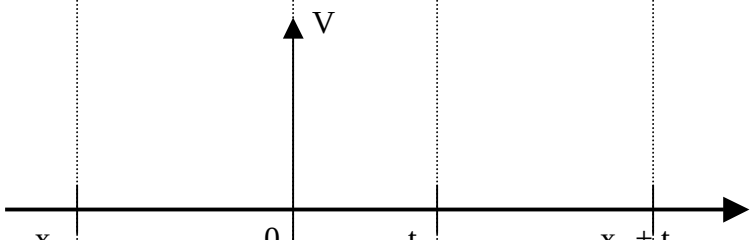
a. (10 pts) Sketch the charge distribution.
Label maximum and minimum points.



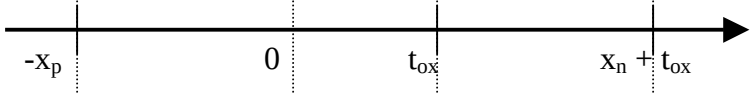
b. (10 pts) Sketch the electric field.
($\varepsilon_{Si} = 11.9$ & $\varepsilon_{SiO_2} = 3.9$)
Label max and min points.



c. (10 pts) Sketch the electrostatic potential.
Label max and min points.



d. (10 pts) Sketch the band diagram.
(E_G SiO_2 = 9 eV. $Ec(Si0_2) - Ec(Si)$ = 3eV)
(you will not be able to draw it to scale)



e. (10 pts) Calculate the built in voltage, V_{bi}.(A number in volts).

f. (50 pts) Calculate the total depletion width, $W = x_p + t_{ox} + x_n$. (a number in nm). You first have to derive the appropriate expression for W. No credit will be given for simply taking the W derived for a pn or pin junction. Pay attention to the 2 different dielectric constants.

(g) (30 pts) Calculate the capacitance in (F/cm^2).

7. The doping of the emitter of a BJT is higher than the doping of the base which is higher than the doping of the collector. The equations that we derived in class indicate that device performance improves as the emitter / base doping ratio increases. However at some point performance starts to degrade due to band gap narrowing and Auger recombination. Discuss how these 2 effects degrade device performance by describing their effect on the base transport factor, the emitter injection efficiency, and the forward current gain, β_F. Refer to equations to support your argument.

(a) (10 pts) Band gap narrowing

(b) Auger recombination

(b.1) (10 pts) First describe what Auger recombination is and illustrate the process on a band diagram.

(b.2) (10 pts) Why does Auger recombination increase as the emitter doping increases?

(b.3) (10 pts) Now describe how Auger recombination affects the figures of merit, α_T, γ, and β_F, and thus device performance.

8. As Si MOSFETS are scaled down 2 things occur that we described in class, drain induced barrier lowering (DIBL) and velocity saturation. Discuss how these effects alter device operation in saturation.

a. (10 pts) DIBL

b. (10 pts) Velocity saturation

9. (20 pts) Derive an expression for the maximum value for the MOSFET transition frequency as the gate length becomes very short with the device operating under velocity saturation.