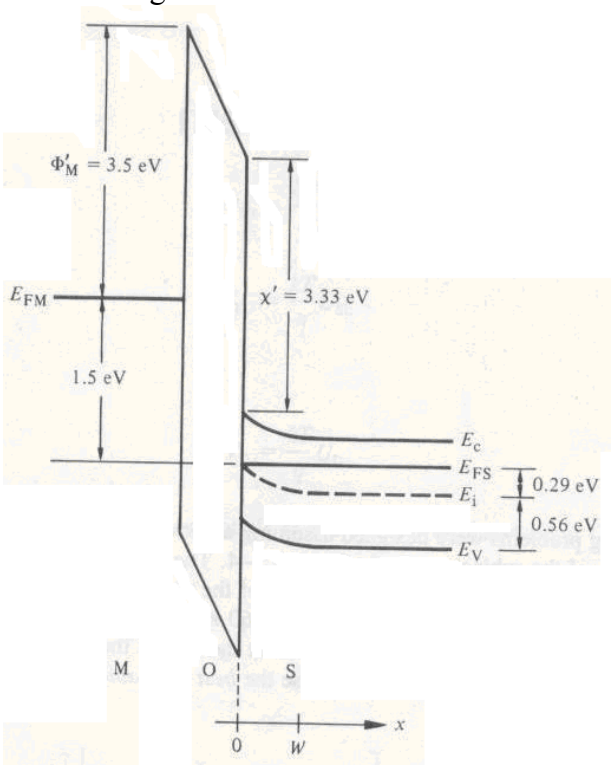
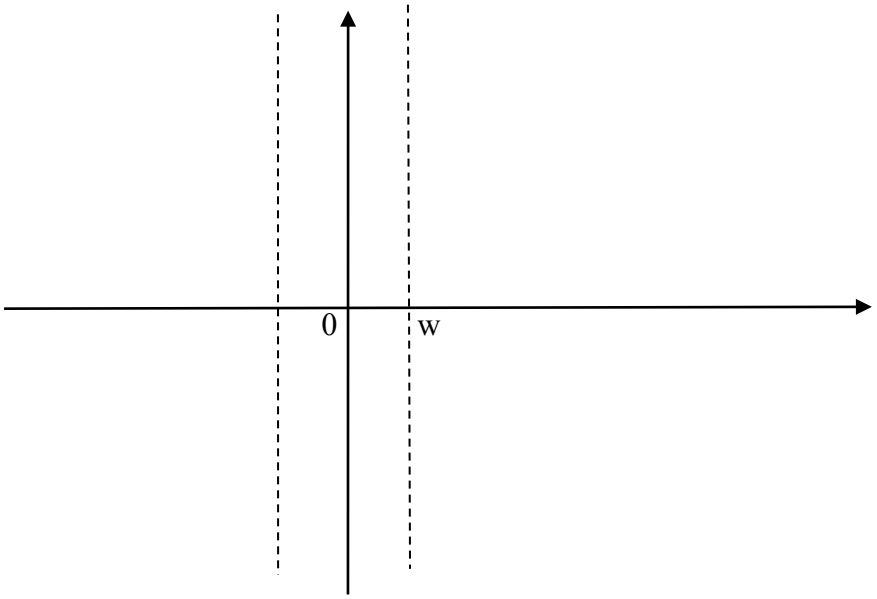
1. The MOS capacitor is maintained at 300 K. kT/q = 0.0259 V, $n_i = 10^{10}$ cm^{-3}, K_s = 11.9, K_o = 3.9, $\varepsilon_o = 8.85 \times 10^{-14}$ farad/cm, oxide thickness d = 0.2 μm, where K_s and K_o are relative dielectric constant of semiconductor and oxide, respectively, and ε_o is the absolute permittivity. No interface charge.



ϕ_s is the surface potential of the semiconductor at the oxide-semiconductor interface, positive pointing downward.

(a) (10 points) Sketch the electric field across the MOS capacitor, from metal to semiconductor.



(b) (5 points) ϕ_s = ?

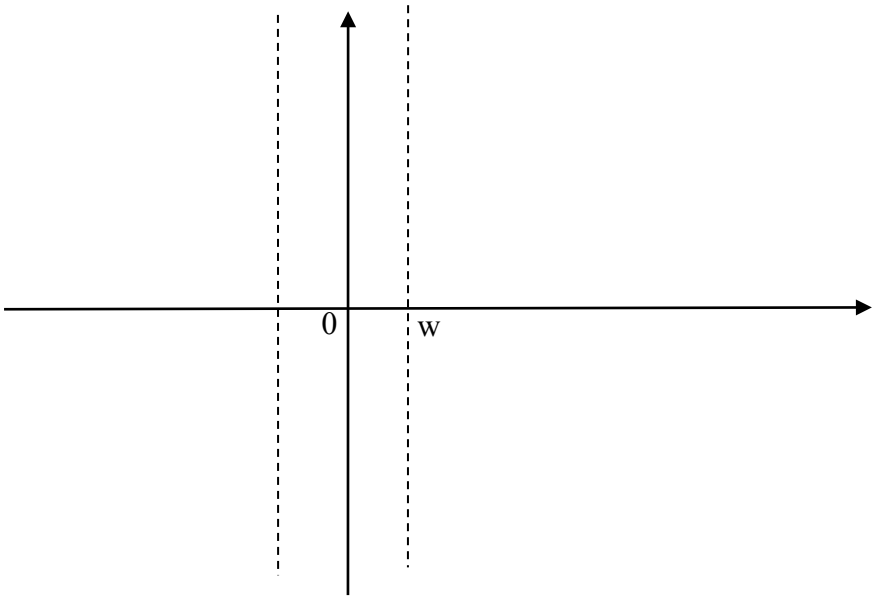
(d) (7 points) N_D = ?

(e) (5 point) $|\phi_{Fn}|$ = ? $\phi_{Fn} = (1/e)(E_F - E_i)$ where E_i is the intrinsic Fermi level.

(f) (5 point) V_G = ?

(g) (10 points) Metal-semiconductor work function difference ϕ_{ms} = ?

(h) (8 points) Sketch the block charge diagram corresponding to the state pictured in the energy band diagram. For reference purposes, include the maximum equilibrium depletion width W_{max} on your diagram.

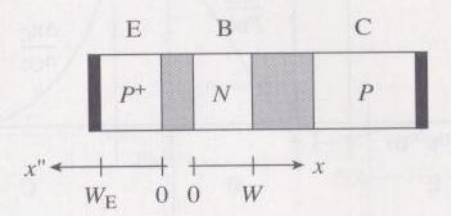


2. Multiple choice questions (10 points each)
   (a) If the substrate doping in an n-channel MOSFET is increased, does the threshold voltage (A) increase, (B) stay the same, or (C) decrease?

   (b) If the oxide thickness in an n-channel MOSFET is decreased, does the threshold voltage (A) increase, (B) stay the same, or (C) decrease?

   (c) If another metal with a larger work function is used as the gate for an *n*-channel MOSFET, does the threshold voltage (A) increase, (B) stay the same, or (C) decrease?

Consider the *pnp* BJT pictured on the right, where, like the base, the emitter width W_E << L_E, the minority carrier diffusion length in the emitter.



   (d) How is the collector current affected: (A) increase, (B) stay the same, or (C) decrease as W_E is systematically decreased?

   (e) How is the emitter efficiency γ affected: (A) increase, (B) stay the same, or (C) decrease as W_E is systematically decreased?