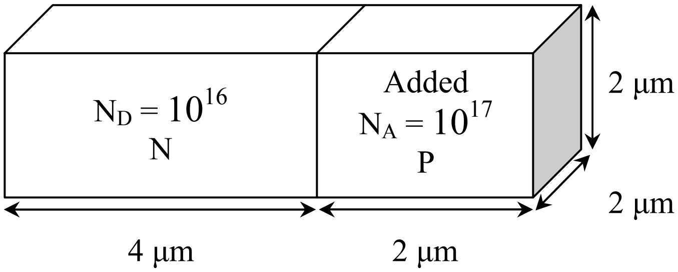
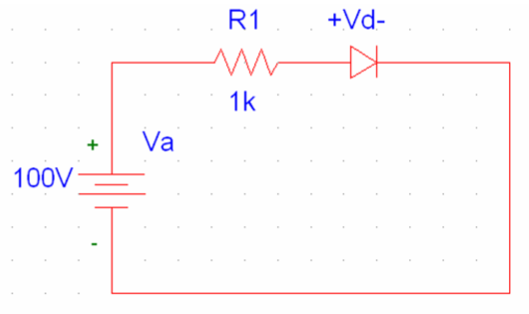
Ex 1) A P-N junction is formed by doping one side of an N-type piece of Si with 10^{17} cm^{-3} acceptors. The original Donor concentration was = 10^{16} cm^{-3}.
$\mu_n = 600$ & $\mu_p = 250$



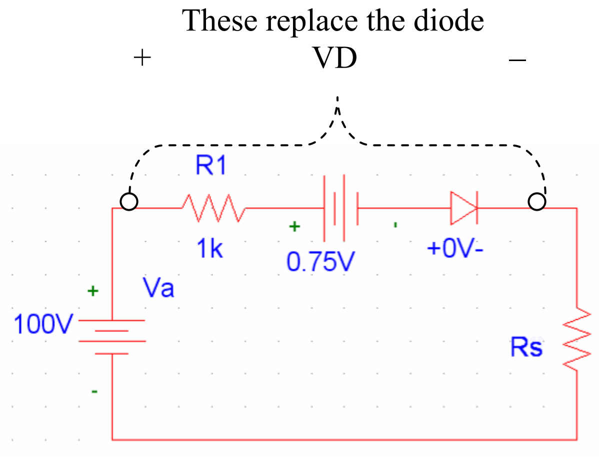
A) calculate the built-in potential.

N_{Dnet} = net donor concentration at the N-side
N_{Anet} = net acceptors concentration at the P-side
$V_{bi} = V_T \ln[N_{Dnet} * N_{Anet} / n_i^2]$
$N_{Dnet} = 10^{16}\ cm^{-3}$
$N_{Anet} = 10^{17} - 10^{16} = 9*10^{16}\ cm^{-3}$
➔ $Vbi = 0.025 \ln[9*10^{32}/10^{20}] = 0.75$ V

B) If this diode is used in the circuit shown, calculate I.



Replace the diode with the simple model →



then

$I = (100V - 0.75V)/(1K\Omega + R_S)$

$R_S = R_N + R_P$

$\rho_{N\text{-side}} = 1/q\ \mu_n\ n$, $n = N_D = 10^{16} \Rightarrow \rho_{N\text{-side}} = 1/1.6*10^{-19}*600*10^{16} = 1.04\ \Omega cm$

$\rho_{P\text{-side}} = 1/q\ \mu_p\ p$, $p = N_A - N_D = 9*10^{16} \Rightarrow$

$\rho_{P\text{-side}} = 1/1.6*10^{-19}*250*9*10^{16} = 2.5\ \Omega cm$

$R_S = (1.04*4*10^{-4})/(2*10^{-4}*2*10^{-4}) + (505*2*10^{-4})/(2*10^{-4}*2*10^{-4}) = 22.9\ k\Omega$

$I = 99.25/23.9\ k\Omega = 4.15*10^{-3}\ A = 0.415\ mA$

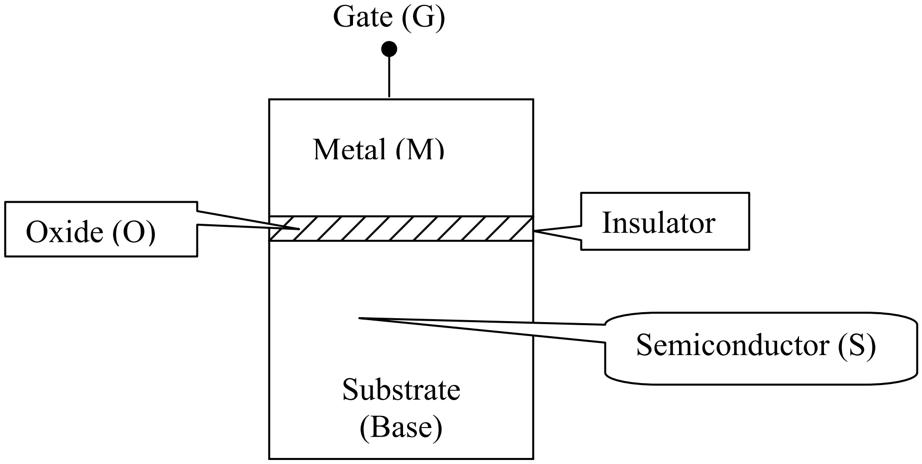
C) How much voltage we need to apply to make I = 1A?

$I = 1A = (V - 0.75) / 23.9\ k\Omega \Rightarrow V \approx 23.9\ kV$

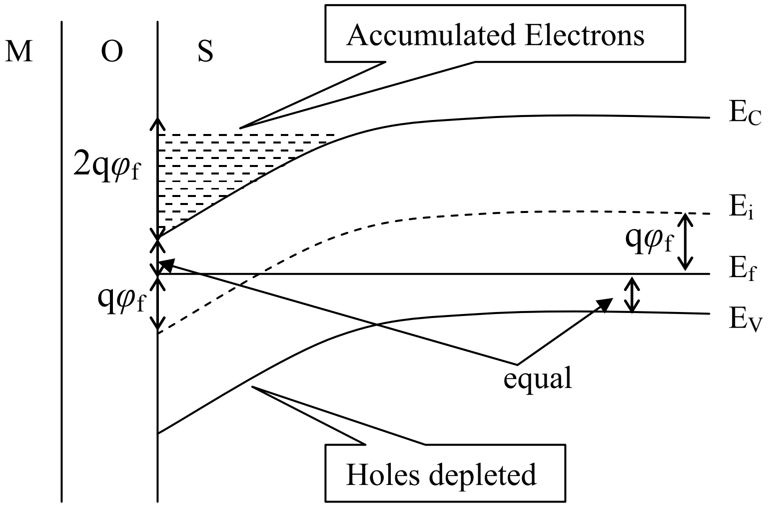
D) How much of this voltage will appear across the diode?

$V_D = V_{bi} + I*R_S = 22.9k$

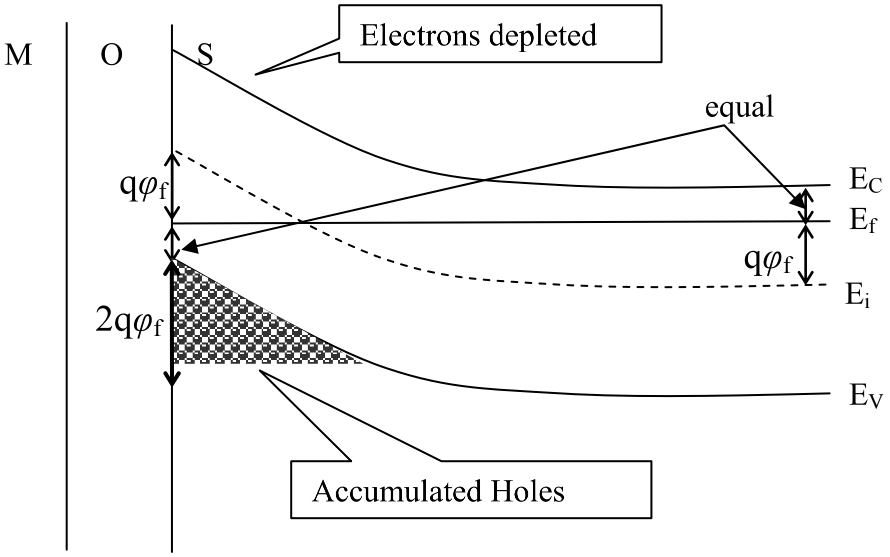
The Mos (Metal oxide semiconductor) structure:



- The gate voltage is used to invert the surface of semiconductor substrate
- The insulator ensures that no current can flow from gate to substrate (Hence the Fermi level is always constant and continuous)
- To strongly invert the surface of a P-type substrate, we need to bend the bands at the surface **downward** by $2q\varphi_f$ ➔ at strong inversion **n** (electron concentration) at the surface = **p** (hole concentration) away from the surface (or $[E_f - E_v]_{\text{away from the surface}} = [E_c - E_f]_{\text{at the surface}}$).



- To strongly invert the surface of an N-type substrate we need to bent the bands at the surface of the semiconductor **upward** by $2q\varphi_f$ ➔ at strong inversion **p** at the surface and **n** away from the surface
  (or $[E_f - E_v]_{\text{at the surface}} = [E_c - E_f]_{\text{away from the surface}}$).



- The voltage required to cause strong inversion of the semiconductor surface is called the threshold voltage $\mathbf{V_{th}}$.
- The MOS structure acts like a capacitor with a capacitance per unit area

  $$Cox = (\epsilon_0 \epsilon_{0xr})/t_{ox} \text{ (F/cm}^2\text{)}$$

  ϵ_0 = vacuum dielectric constant, ϵ_{0xr} relative dielectric constant of $SiO_2 \approx 4$
  t_{ox} = oxide thickness