Q1 Have you downloaded the textbook: Modern Semiconductor Devices for Integrated Circuits by Chenming Calvin Hu? Write down the web address of the textbook where one can freely download it from. [10 pts]

Yes

Link

https://www.chu.berkeley.edu/modern-semiconductor-devices-for-integrated-circuits-chenming-calvin-hu-2010/

Q2 Draw the band diagram (the relative positions of conduction band edge $E_C$, valence band edge $E_v$, Fermi level $E_F$) for the four following cases. Clearly note $E_C - E_F$, $E_F - E_V$, $E_i - E_F$, $E_G = E_C - E_V$. $E_i$ is the intrinsic Fermi level. Take $N_C$=$N_V$=$10^{25}$ m$^{-3}$, $E_G$=1.1 eV, $n_i$=$1.5\times10^{16}$ m$^{-3}$, $kT$=0.026 eV. [30 pts]

(Q1.1) p-type, $N_A$=$5\times10^{23}$ m$^{-3}$.

(Q1.2) p-type, $N_A$=$5\times10^{21}$ m$^{-3}$.

(Q1.3) n-type, $N_D$=$5\times10^{23}$ m$^{-3}$.

(Q1.4) n-type, $N_D$=$5\times10^{21}$ m$^{-3}$.

## Q1.1

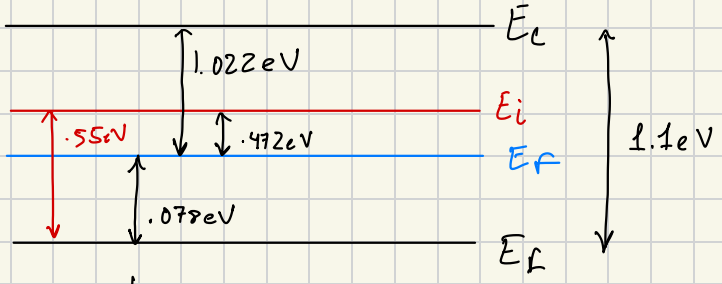
$E_c - E_v = 1.1\,eV = E_G$

equation 8.8 from textbook: $P = N_v e^{-(E_F - E_v)/kT}$

$P = N_a = N_v e^{(E_v - E_F)/kT}$

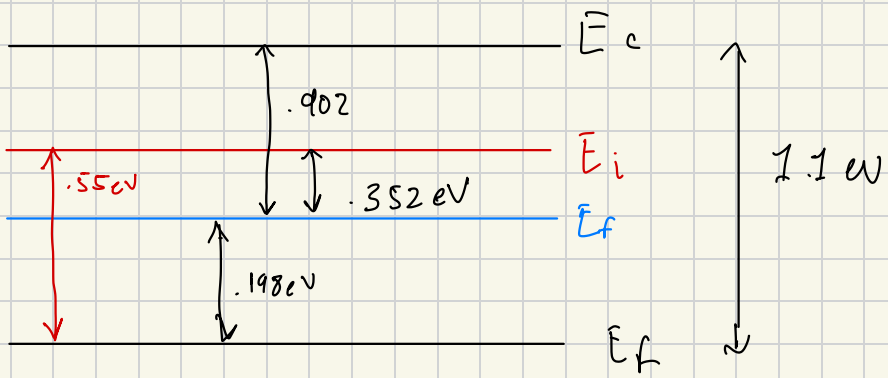
$\Rightarrow E_v - E_f = \Delta E_{VF} = kT \cdot \ln\left(\frac{N_a}{N_v}\right) = (.026\,eV)\left(\ln\left(\frac{5e23}{1e25}\right)\right)$

$= -.078\,eV$




## Q1.2

$P = N_v e^{-(E_f - E_v)/kT} \Rightarrow E_v - E_F = kT \ln\left(\frac{5e21}{1e25}\right) = -.198\,eV$

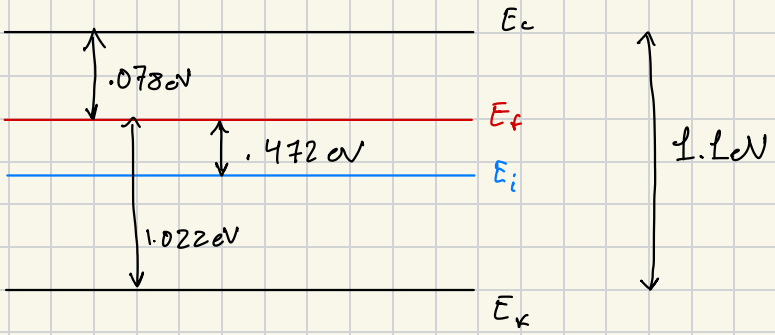


**Q1.3** $n = N_c e^{-(E_c - E_f)/kT}$ (1.8.5)

$n = N_D = N_c e^{-(E_c - E_f)/kT}$

$E_f - E_c = kT \ln\left(\frac{N_D}{N_c}\right)$

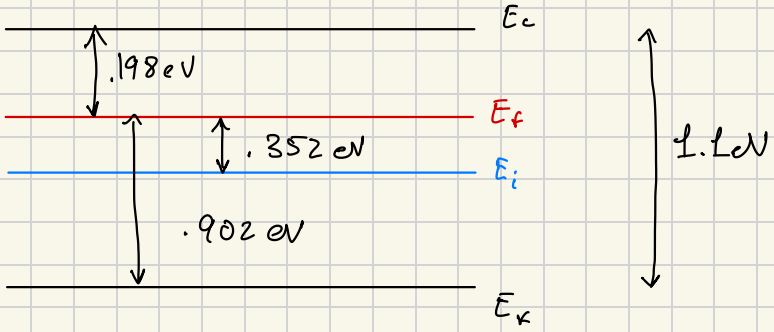
$(.026)\left(\ln\left(\frac{5E23}{1E25}\right)\right) = -.078\ eV$




**Q1.4**

$n = N_D = N_c e^{-(E_c - E_f)/kT}$

$E_f - E_c = (.026)\left(\ln\left(\frac{N_D}{N_c}\right)\right) \Rightarrow -.198\ eV$



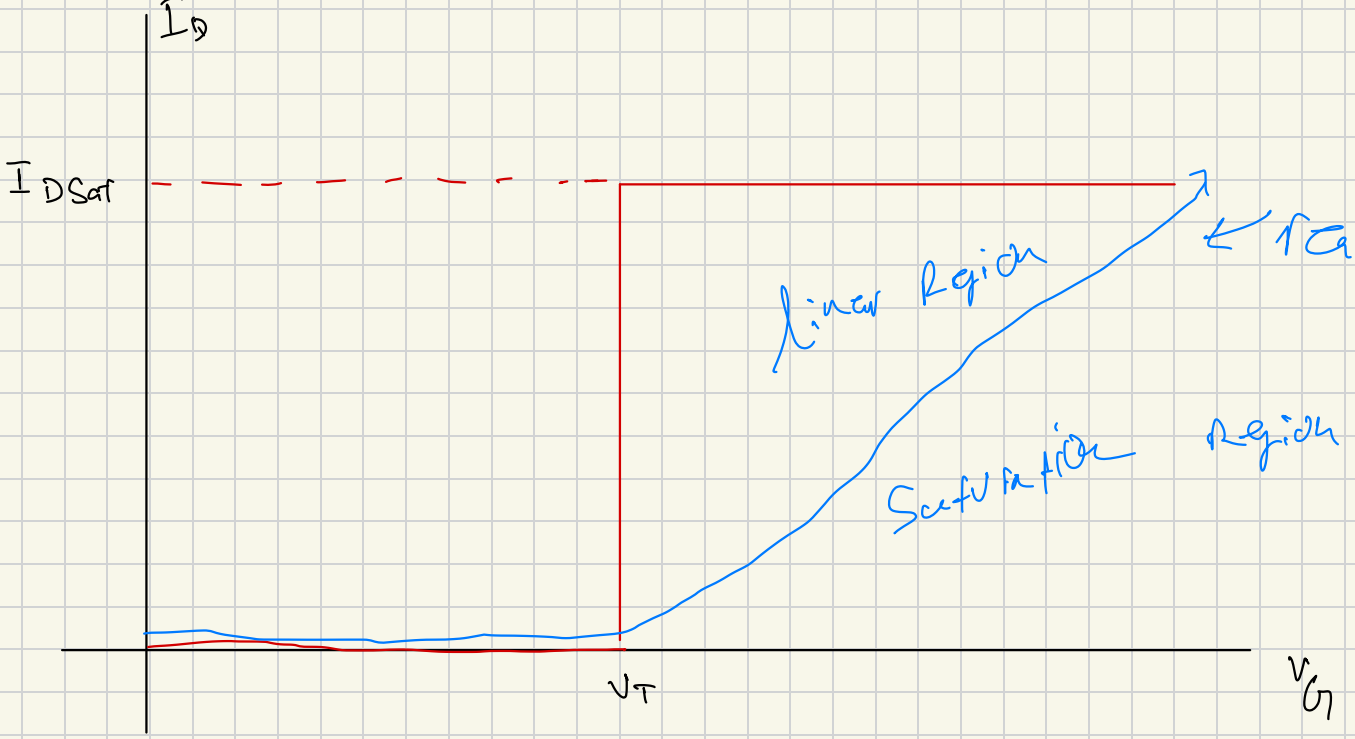
Q3 Explain in short why at absolute zero temperature silicon will not conduct any electric current. [10 pts]

Given That @ Zero Kelvin, There is No Thermal Energy, This implies that the Electrons are Bound To the Nucleus and cannot move around => No Free electrons.

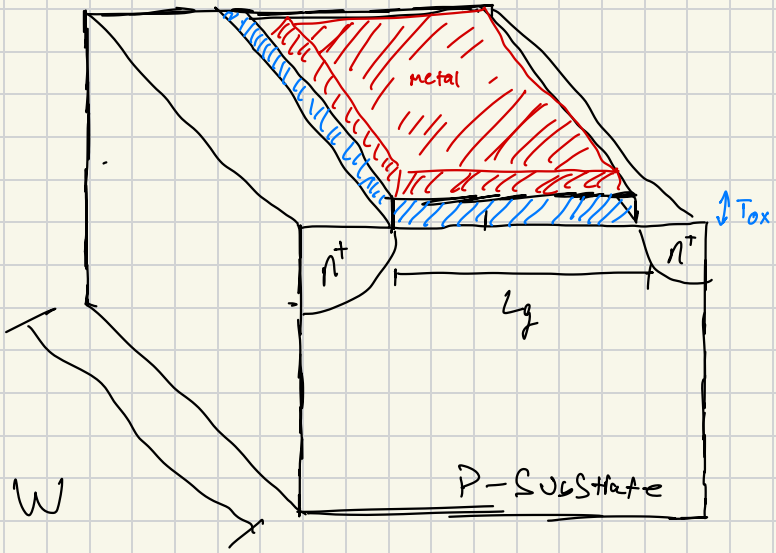
When a Δvoltage is applied across Pure Si Then NO free electrons are able to move mainly No current is able to flow.

Q4 What are the two main differences between an ideal switch and a real MOSFET based switch? Explain with $I - D$-$V_G$ characteristics. All variables have their usual meaning. [25 pts]

An ideal switch is said to only switch between NO current and maximum current with NO resistance. However, a MOSFET has a linear region of operation where there is leakage current. Observe the $I_D - V_g$ graph below

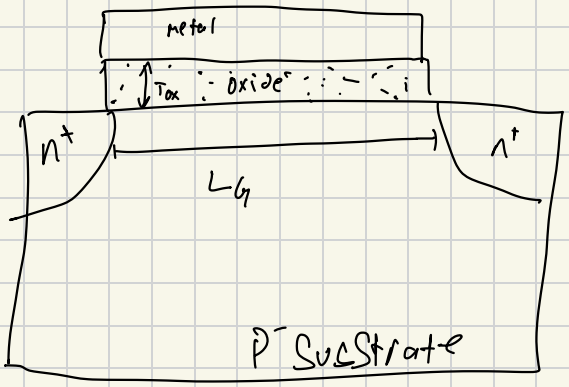


Q5 Draw the 3-D schematic diagram of a MOSFET and the 2-D cross-section of the same, indicating all the relevant dimensions $L_G$, $t_{ox}$ and $W$ and the terminals. All variables have their usual meaning. [25 pts]




MOSFET

3D




2D CROSS-Section