LOCATING THE FERMI ENERGY/CHEMICAL POTENTIAL IN SEMICONDUCTORS

● What Determines E_F ? ●

This example is designed to show that the Fermi level, E_F, is determined by the available electrons and states in the system. Figure 1–19 shows the energy states of an electron system at room temperature. Each energy state can hold either one electron or none, i.e., be either occupied or empty. It is known that there is only one electron in this system. Since there is only one electron in the system, the sum of the probabilities that each state is occupied must be equal to 1. By trial and error, convince yourself that only one specific E_F, somewhere above E_1 and below E_2, can satisfy this condition. Do not calculate this value. *Hint*: Ask yourself how many electrons will be in the system if E_F is, say, above E_3 and how many if E_F is below E_1.

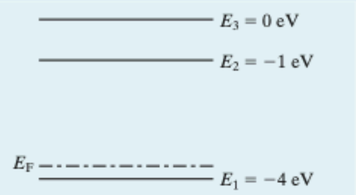
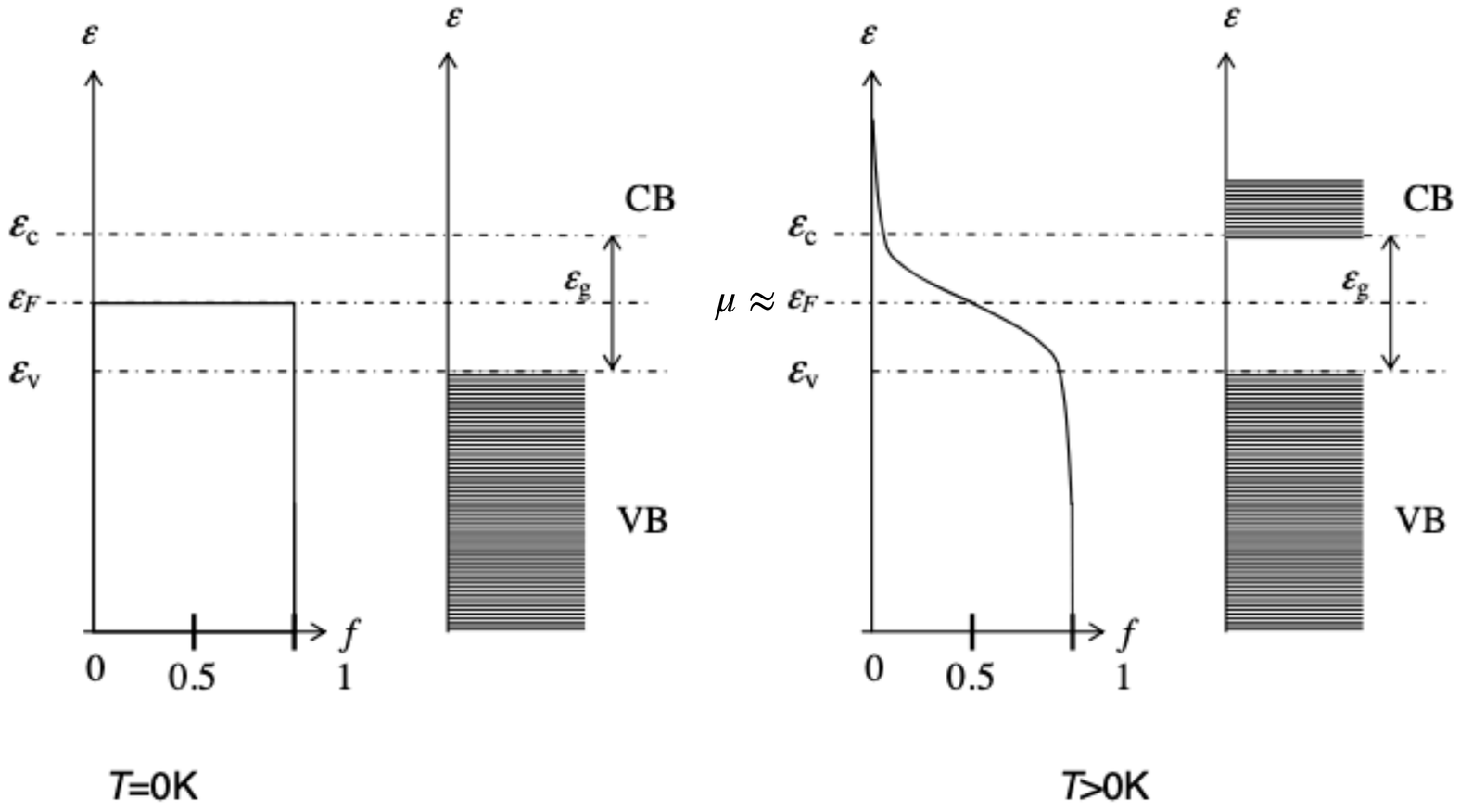


FIGURE 1–19 A simple electron system at room temperature for illustration of what determines the Fermi energy, E_F.

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

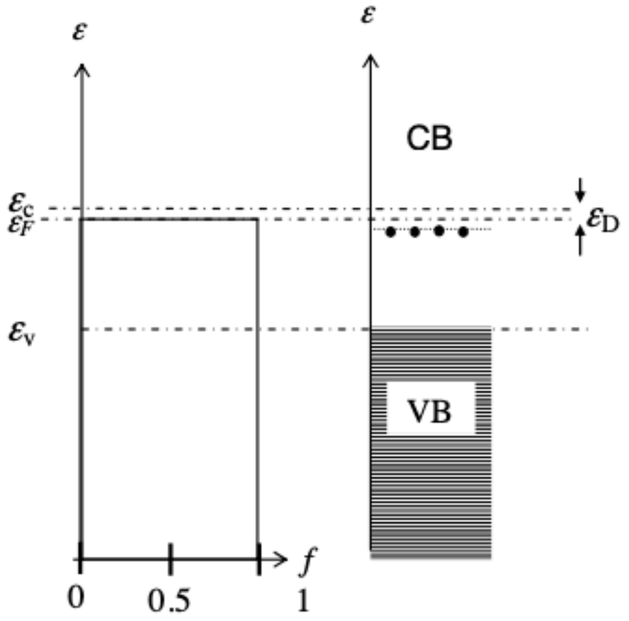
Intrinsic semiconductor



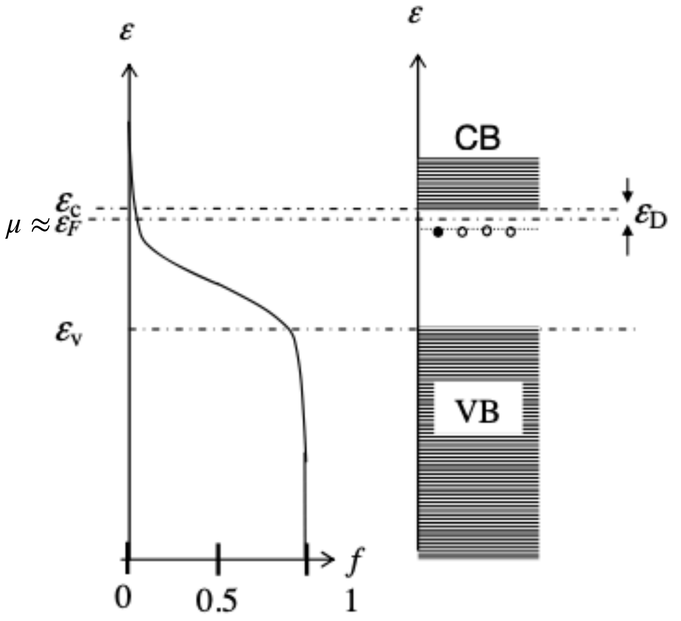
This picture and the following ones are adapted from:
lecture notes of Solid State Physics (SSP) - PHY550 at Queen Mary University of London
by A. Sapelkin, M. Baxendale, D.J. Dunstan

n-type doping

At 0K the highest occupied levels will be the donor levels, the lowest empty levels will be at the bottom of the conduction band, so the Fermi energy will lie between the donor levels and the bottom of the CB. Fermi energy said to be 'pinned' by doner concentration.

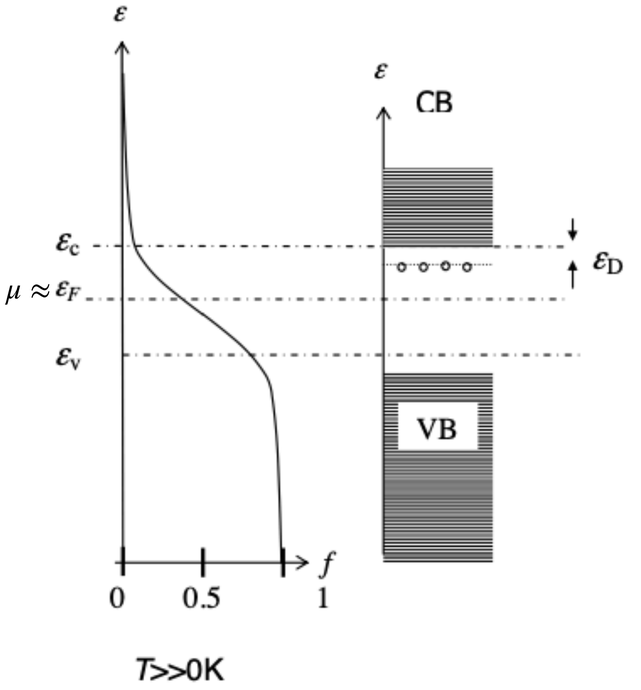


T=0K



T>0K

If the temperature is raised, electrons are excited from the donor levels into the CB (above left).



T>>0K

At very high temperature all donors are ionised and further electrons must come from the valence band, we are then back to the in the intrinsic regime so the Fermi energy is located at the mid-point of the band gap.

The Fermi Level and Carrier Concentrations

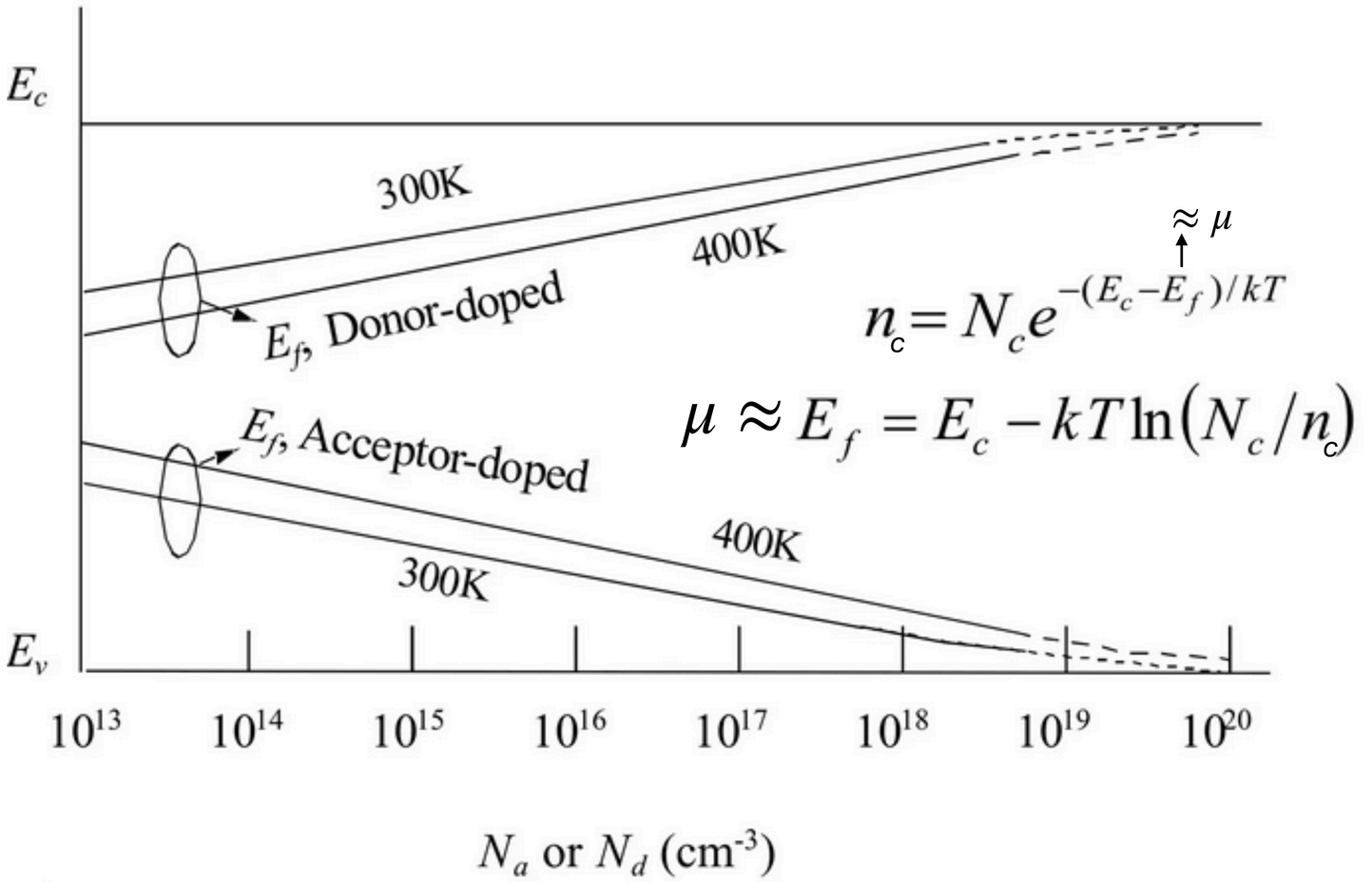


FIGURE 1–21 Location of Fermi level vs. dopant concentration in Si at 300 and 400 K.

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