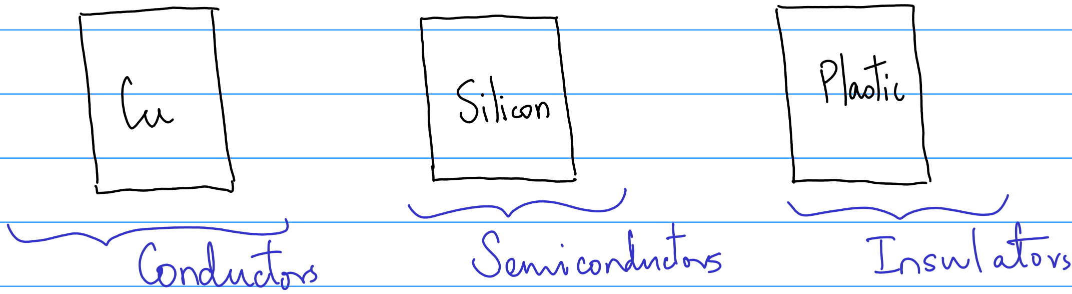
3.01.2022

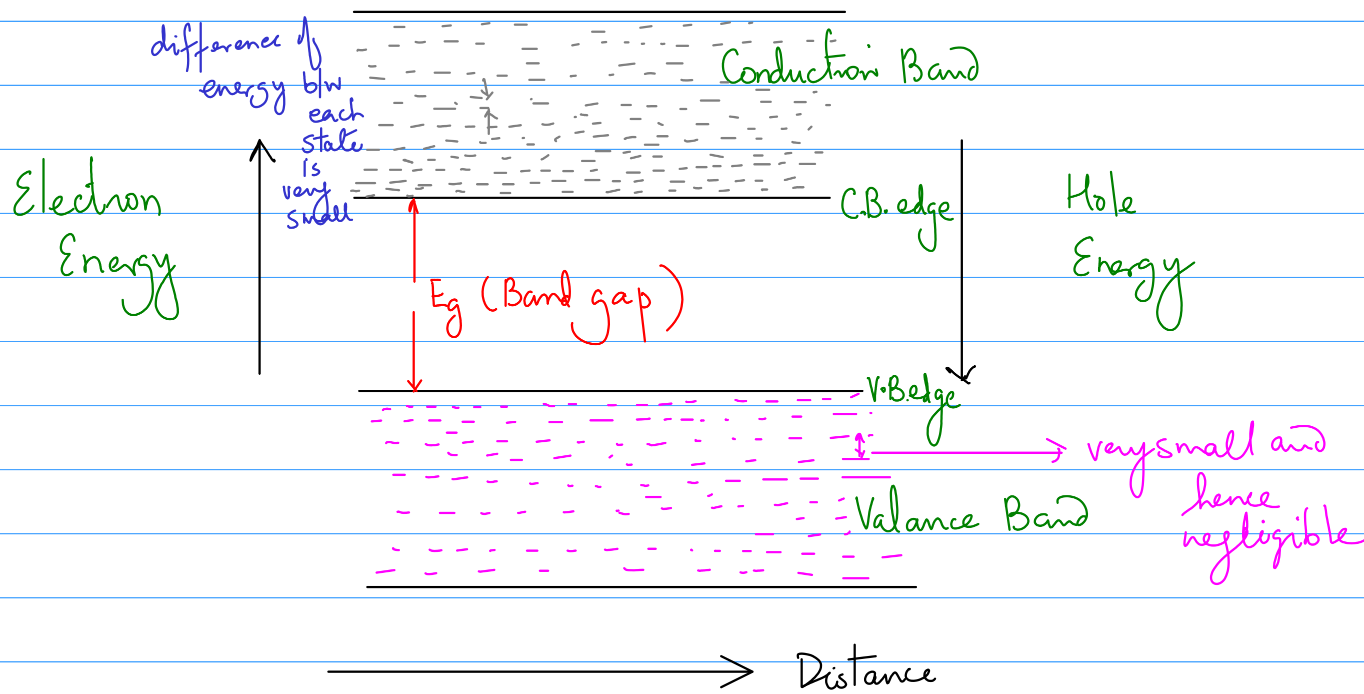
Semiconductors



In terms of Energy gap : E_g (semiconductors) ~ 1–3 eVs (typical)

E_g (Insulators) ~ > 3eV (typical)

Simplified Band Diagram of a Semiconductor :



In each energy band, we have discrete energy states, however, the energy separation b/w them is very small and hence assumed negligible. Therefore, We visualize each band is having continuum energy states.

Typically, at room temperature (300K)

$$E_g(\text{silicon}) = 1.12\,eV$$

$$E_g(Ge) = 0.66\,eV$$

$$E_g(GaAs) = 1.42\,eV$$

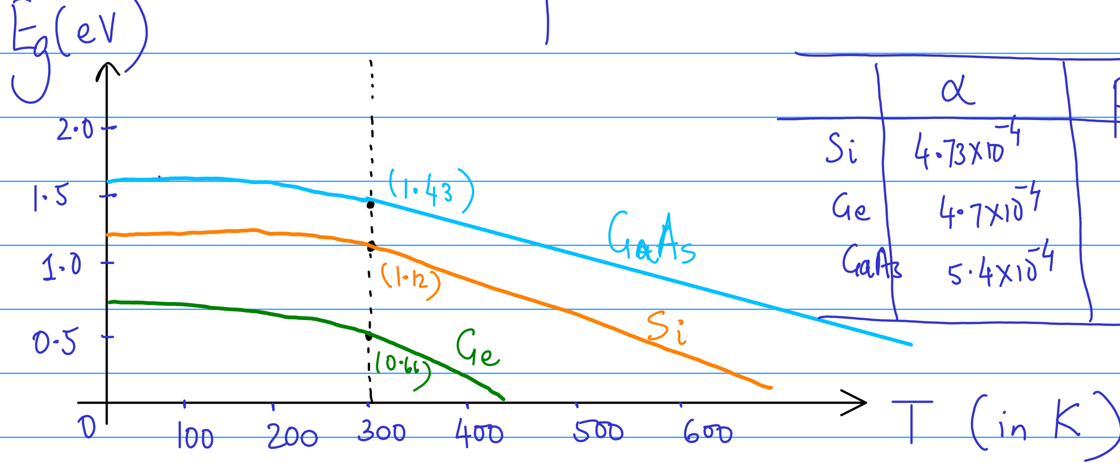
Band gap depend on temperature

$$E_g(T) = E_g(0) - \frac{\alpha T^2}{(T+\beta)}$$

where $E_g(0)$ = Band gap at $T = 0K$

α, β are the parameters

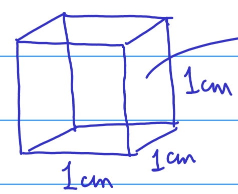
T = temperature in Kelvin.



	α	β
Si	4.73×10^{-4}	636
Ge	4.7×10^{-4}	235
GaAs	5.4×10^{-4}	204

Charge-carrier density in Conductors, Semiconductors & Insulators.

Charge-carrier density $\equiv$ No. of electrons/holes per unit volume (cm^{-3})

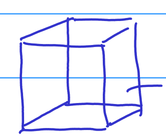


$\rightarrow$ Volume = $1\ cm^3$

In any solid, atomic density $\sim 10^{22}\ cm^{-3}$

Let take specific example:

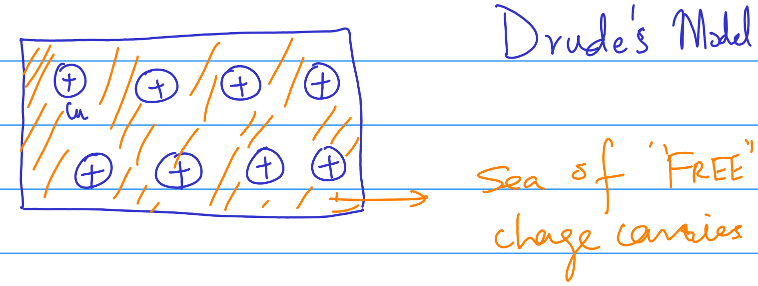
Copper : $Cu \rightleftharpoons Cu^{2+} + \underbrace{2e^-}_{\text{"FREE"}}$



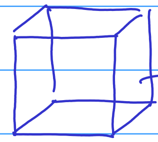
$1\ cm^3$ of Copper $\equiv 10^{22}$ atoms $= \underbrace{2 \times 10^{22}\ \text{electrons}}_{\text{"FREE"}}$

In metals (conductors), we have $\sim 10^{22}$ "FREE" electrons cm^{-3} which are available for the conduction of electrical energy.

Drude's Model



What about semiconductors? (say silicon)



$1\,cm^3$

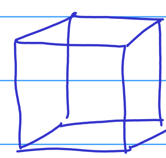
$\#$ atoms $= 10^{22}$

at $T = 0K$; "FREE" electrons/holes $\approx 0\ cm^{-3}$

$\boxed{\text{at } T = 300K \text{ (RT) "FREE" electron/hole} \sim 10^{10}\ cm^{-3}}$

Thermal Energy at RT $= k_B T \approx 25\,meV$

<u>Insulators</u>:



$1\,cm^3$ atom $\sim 10^{22}$

at RT(300K); "FREE" electron $\lessapprox 10^5\ cm^{-3}$