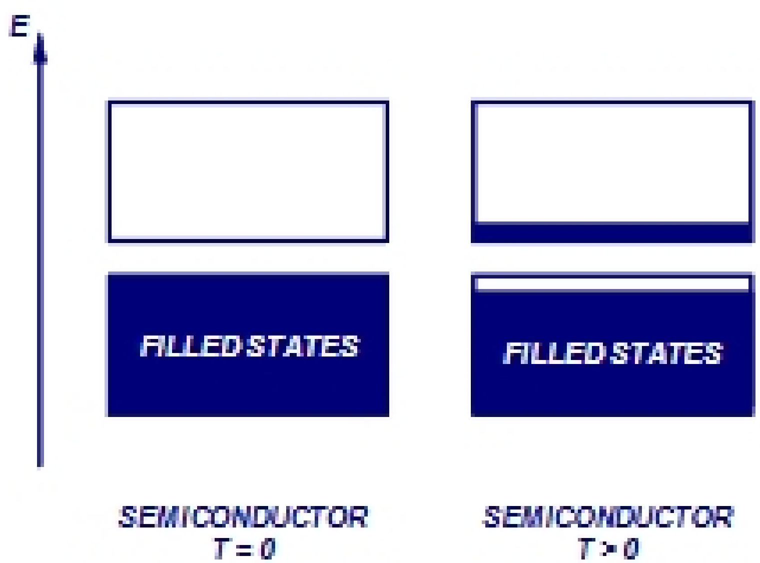
Density of States (DOS)

- Electrical current in semiconductors is carried by ELECTRONS in the conduction band and by HOLES in the valence band

  - The number of the electrons and holes VARIES as a function of TEMPERATURE
  - We want to find EXPRESSIONS for the number of carriers in the conduction and valence bands at any given temperature
  - To get there, we will first need to introduce the concept of the conduction- and valence-band **DENSITY OF STATES (DOS)**



DOS is essentially the NUMBER of quantum states that exist at a given energy per unit volume of material

Density of States (DOS)

- Electrons are allowed to move freely in the conduction band, but they are still confined to a three dimensional crystal
- To calculate the allowed energy levels that conduction electrons are allowed to occupy, we consider as a first step a free electron confined to a three dimensional potential well
- Assume that the semiconductor is a cube with side L. Recall that $\Psi = A\sin(k_x x) + B\cos(k_x x)$

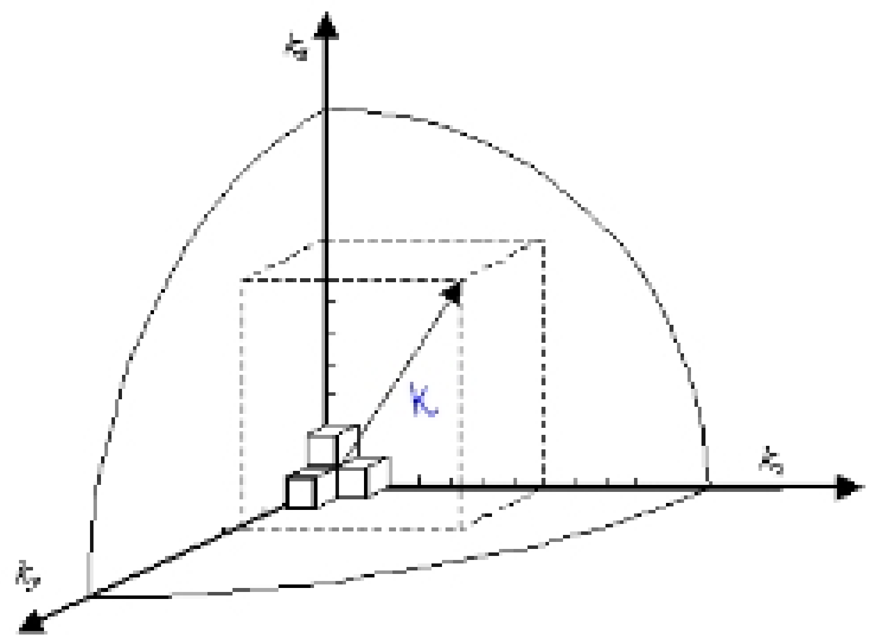
$$k_x = \frac{n\pi}{L} \quad n = 1, 2, 3 \ldots$$

$$k_y = \frac{m\pi}{L} \quad m = 1, 2, 3 \ldots$$

$$k_z = \frac{l\pi}{L} \quad l = 1, 2, 3 \ldots$$

Total number of solutions with unique values of k_x, k_y, k_z and magnitude still less than k

$$N = \frac{\frac{1}{8}\left(\frac{4}{3}\pi k^3\right)}{(\pi/L)^3} \, 2$$



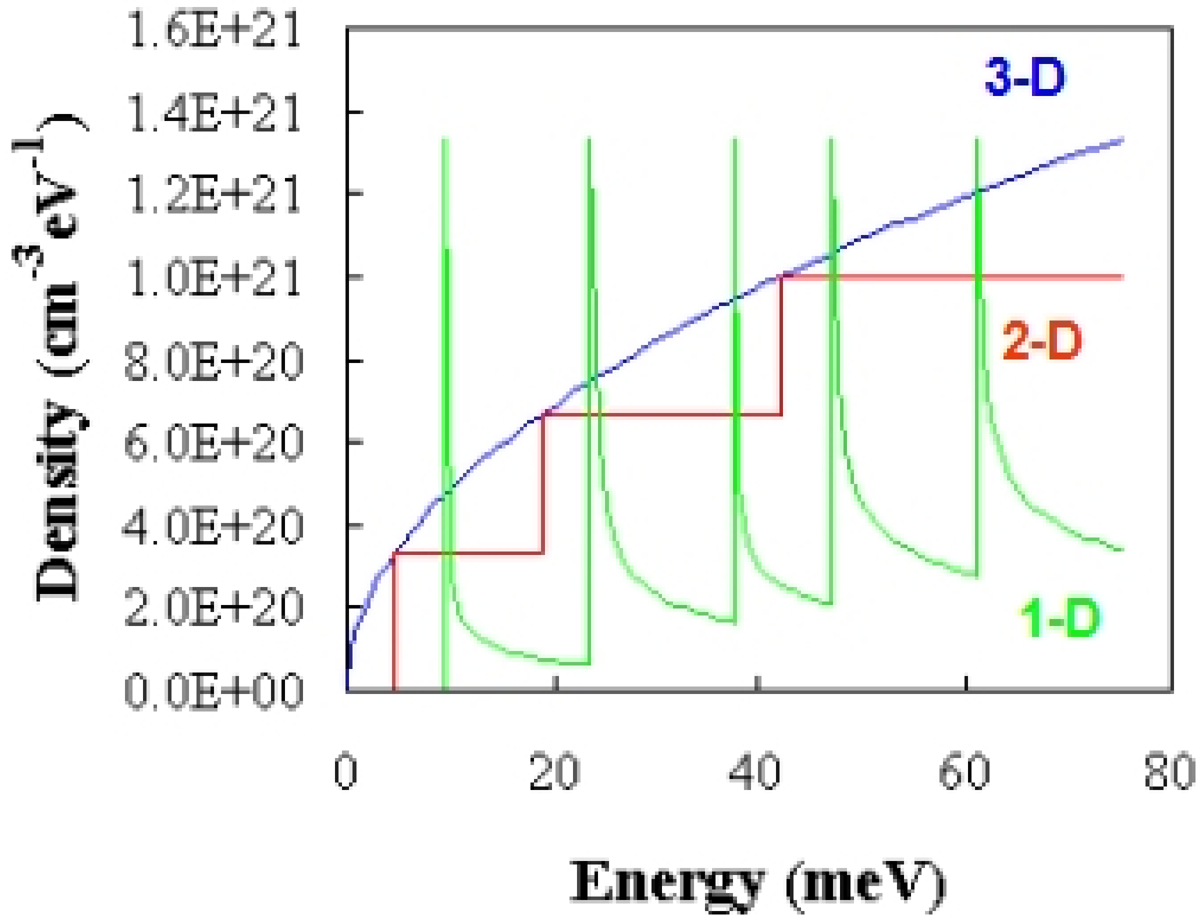
$$\rho(E) = \frac{1}{V}\frac{dN}{dE} = \frac{1}{(L)^3}\frac{dN}{dk}\cdot\frac{dk}{dE}$$

$$E = \frac{\hbar^2 k^2}{2m^*}$$

$$\frac{dE}{dk} = \frac{\hbar^2 k}{m^*}$$

$$= \frac{8\pi\sqrt{2}}{h^3} {m^*}^{3/2}\sqrt{E}$$ — DOS for 3D Semiconductor

One and Two dimensional DOS



Density of states per unit volume and energy for a 3-D semiconductor (blue curve), a 10nm quantum well with infinite barriers (red curve) and a 10 nm by 10 nm quantum wire with infinite barriers (green curve). $m^*/m0 = 0.8$