

Current in semiconductor

Dr Mohammad Abdur Rashid



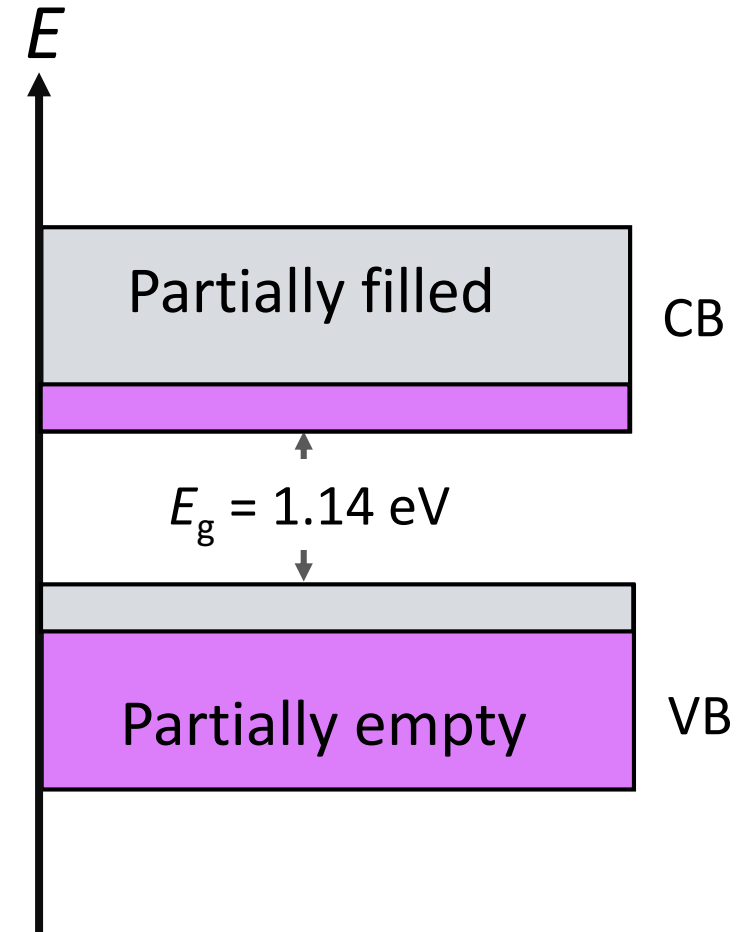
Current in semiconductor

Electric current is due to movement of charge carriers:

$$I = \sum_i qv_i$$

Semiconductor has:

- partially filled CB
- partially empty VB

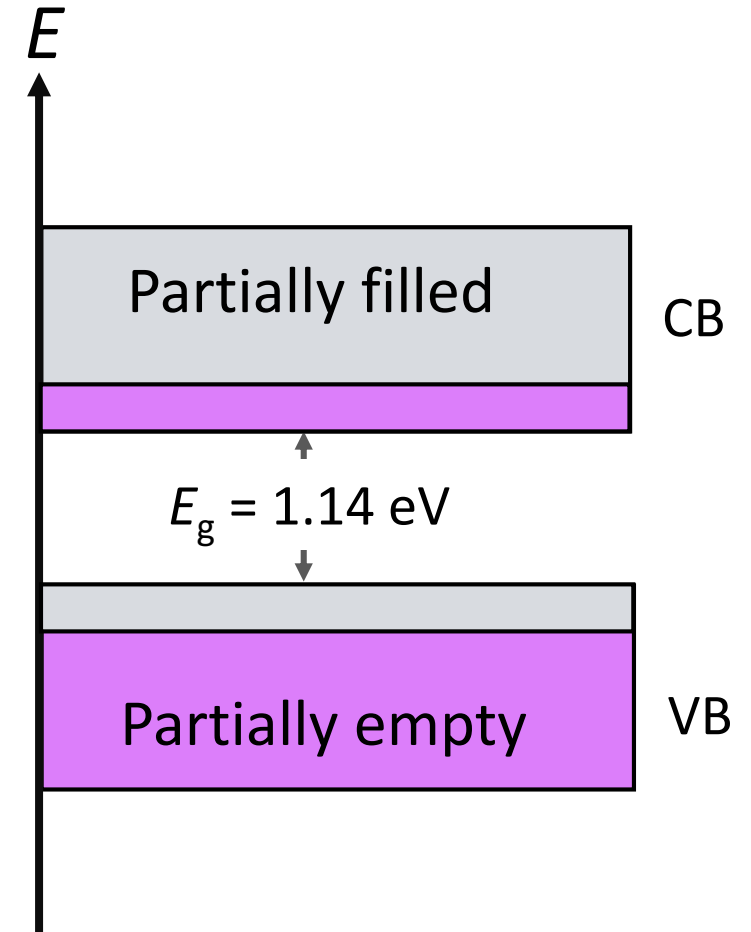


Current in semiconductor

Conduction band – almost empty,
relatively small number of electrons
move and conduct electricity

$$I_{\text{CB}} = \sum_{\text{all electrons in CB}} (-q)v_i$$

$$q = 1.6 \times 10^{-19} \text{ C}$$

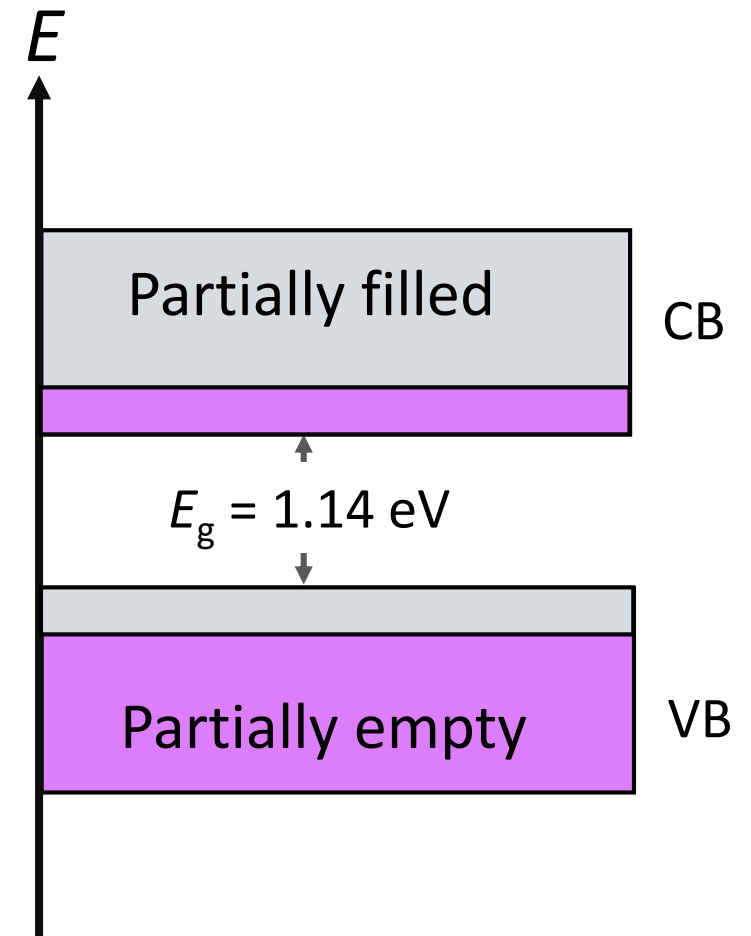


Current in semiconductor

Valance band – almost full, very large small number of electrons move and conduct electricity

$$I_{CB} = \sum_{\text{filled ststes in VB}} (-q)v_i$$

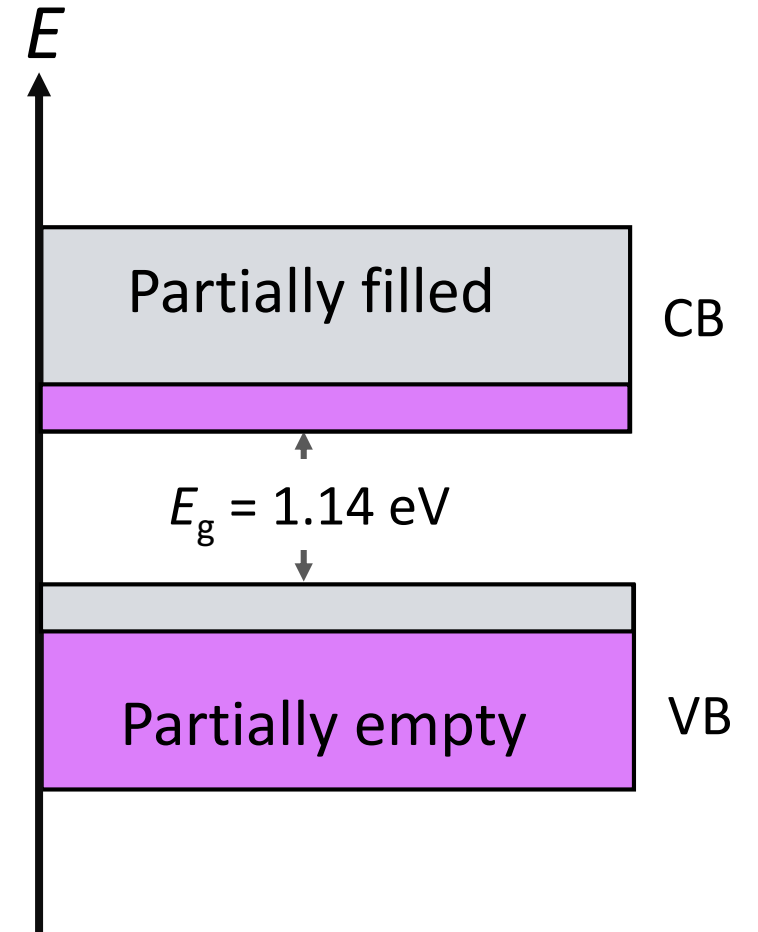
Simpler description is to treat the relatively small number of empty states as positively charged particles called Hole.



Current in semiconductor

Valance band:

$$\begin{aligned} I_{CB} &= \sum_{\substack{\text{filled states} \\ \text{in VB}}} (-q)v_i \\ &= \sum_{\substack{\text{all} \\ \text{states}}} (-q)v_i - \sum_{\substack{\text{empty} \\ \text{states}}} (-q)v_i \\ &= \sum_{\substack{\text{empty} \\ \text{states}}} (+q)v_i \end{aligned}$$



Current in semiconductor

- Any motion of free carriers leads to a current.
- In a semiconductor, there are two types of carriers:
 - Electron and hole
- Carrier motion may be caused by
 - Electric field : drift current
 - Non-uniform carrier concentration: diffusion
- Assume carriers move at an average velocity of v then the current is given by

$$I = \frac{Q}{t} = \frac{Q}{L/v}; \quad J = \frac{I}{A} = \frac{Q}{AL} v = \rho v = -qn v$$



Current in semiconductor

- In order to know how much current flows in a semiconductor, we need to know:
 - How many carriers are there in each band?
 - How fast are they moving?
- To answer the first question, we need to know
 - How many available states are there in the conduction band?
 - What is the probability to find an electron in a given state?



Current in semiconductor

- How many available states are there in the conduction band?

Density of states

- What is the probability to find an electron in a given state?

Fermi-Dirac probability function



Density of states

- Energy bands: A number of closely-spaced energy levels
- Density of states, $g(E)$:
 - $g(E)$ is the number of states per unit volume per energy
 - $g(E) dE$ is the number of states per unit volume between an infinitesimal energy range between E and dE

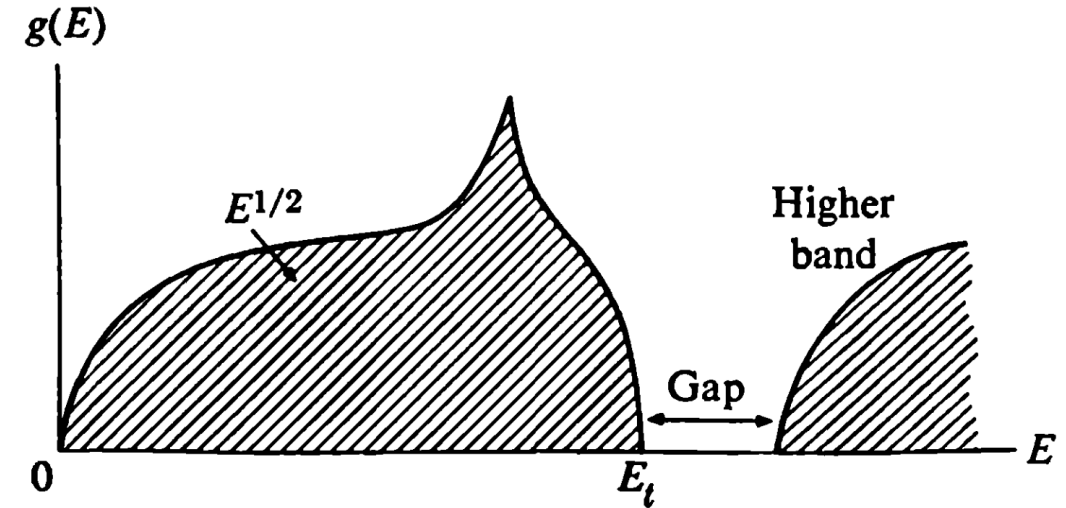
$$g(E) \equiv \frac{\text{number of states in } \Delta E}{\Delta E \times \text{volume}}$$



Density of states

$$g(E) = \frac{1}{2\pi^2} \left(\frac{2m^*}{\hbar^2} \right)^{3/2} E^{1/2}$$

m^* is the effective mass



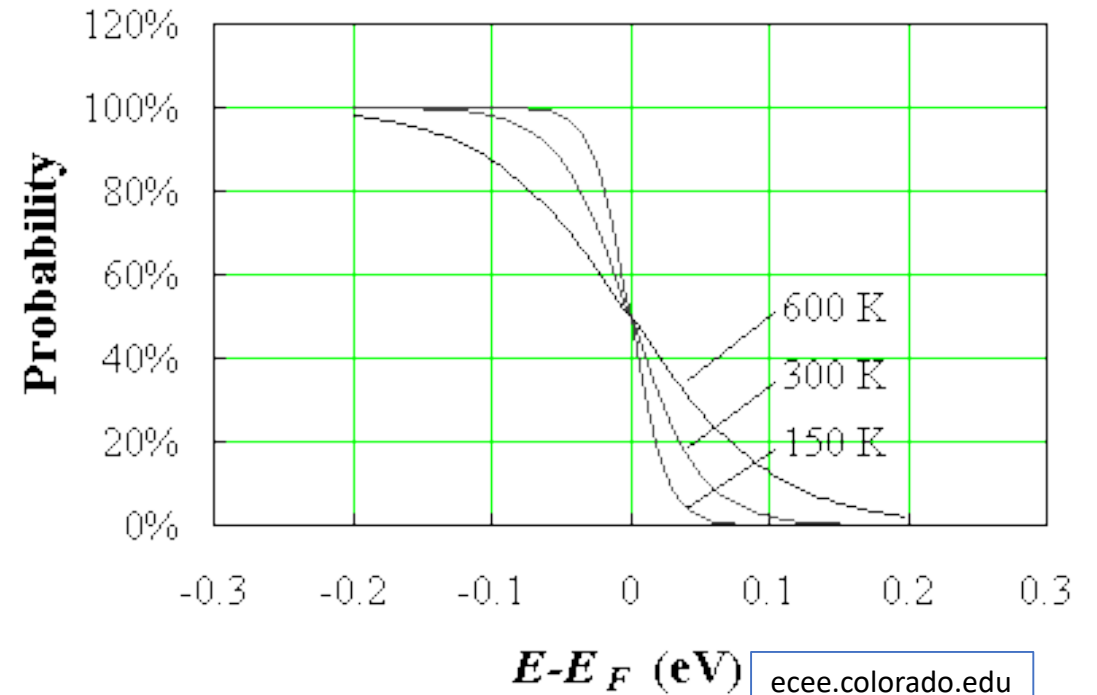
Elementary Solid State Physics – Ali Omar

Fermi-Dirac probability function

The Fermi-Dirac distribution f gives the probability that an orbital at energy E will be occupied by an ideal electron in thermal equilibrium.

$$f(E) = \frac{1}{e^{(E-E_F)/k_B T} + 1}$$

E_F is the Fermi-energy



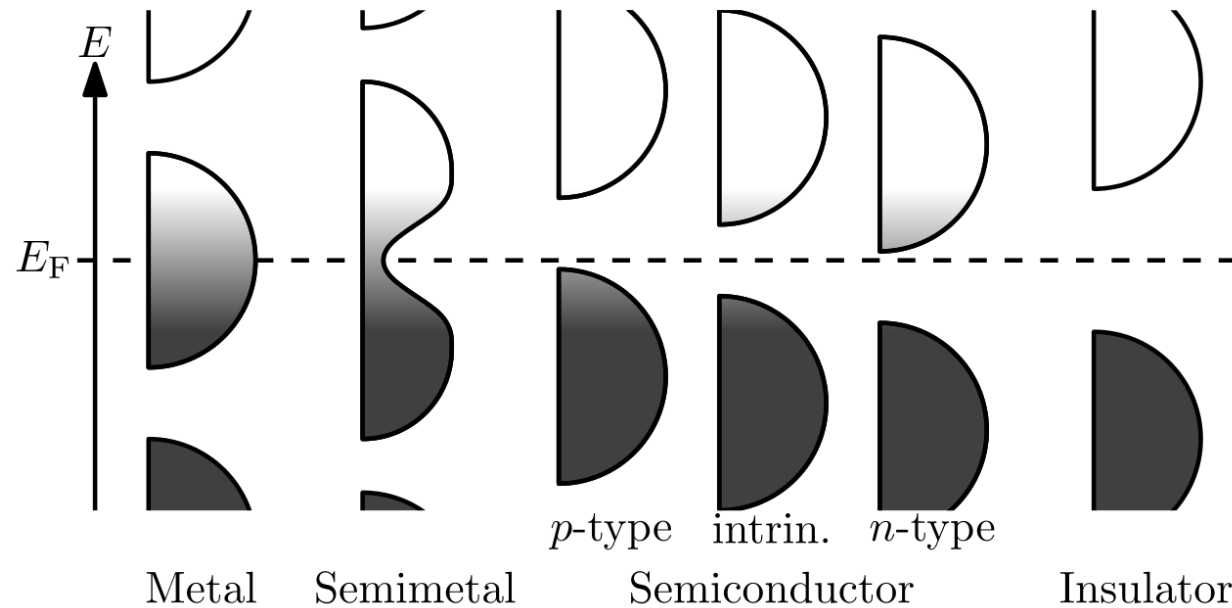
Electron Concentration

The electron concentration n in thermal nonequilibrium is expressed as

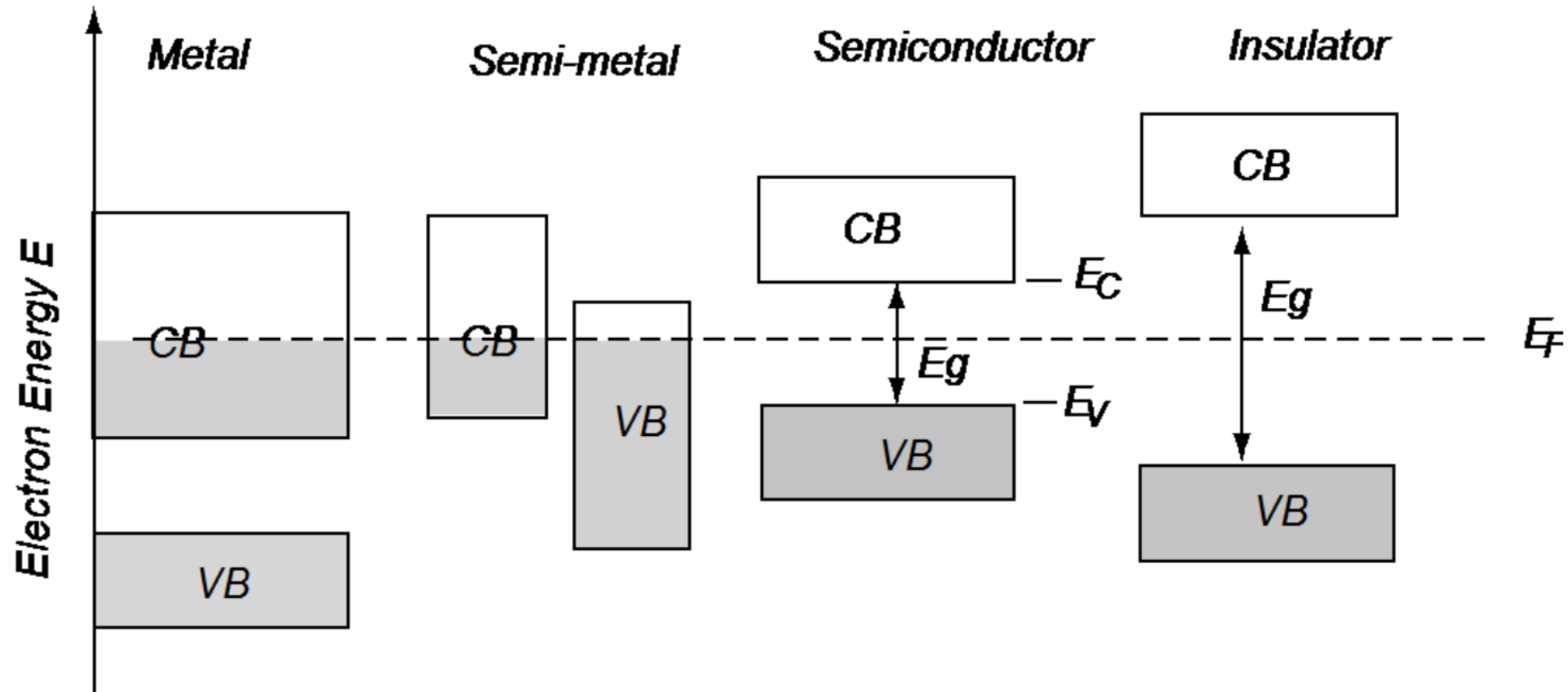
$$n = \int_0^{\infty} g(E) f(E) \, dE$$

Fermi energy

Fermi energy is often defined as the highest occupied energy level of a material at absolute zero temperature. In other words, all electrons in a body occupy energy states at or below that body's Fermi energy at 0 K.

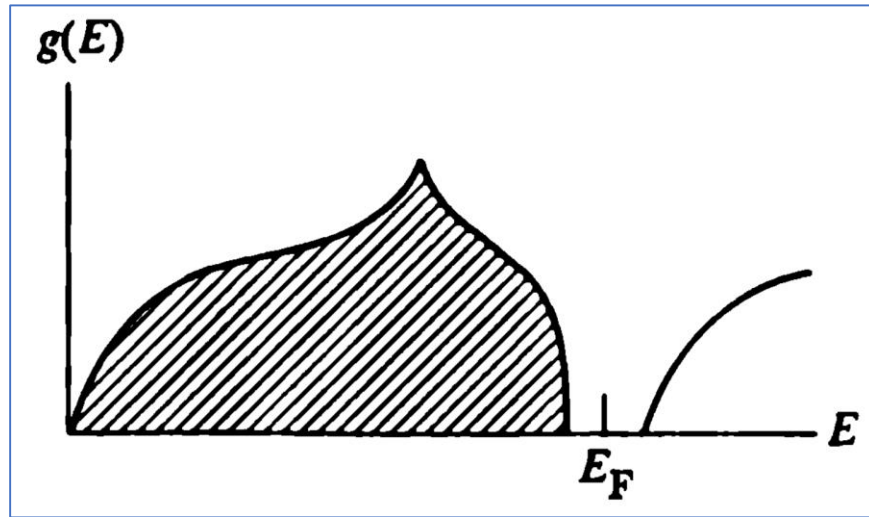


Energy level diagrams



Fermi energy in an insulator

$$n = \int_0^{\infty} g(E) f(E) dE$$



Elementary Solid State Physics – Ali Omar

$$n = \int_0^{E_F} g(E) dE$$

$$E_F = \frac{\hbar^2}{2m^*} (3\pi^2 n)^{2/3}$$

Thank You

**To receive notification of new video
please subscribe to our channel.**

You may also let us know your comments.

