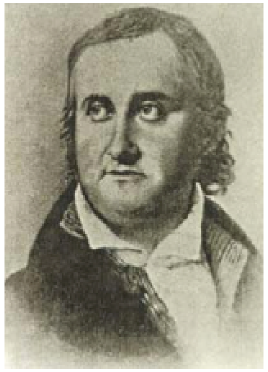
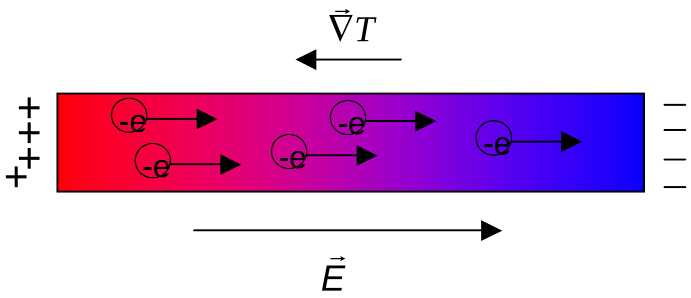
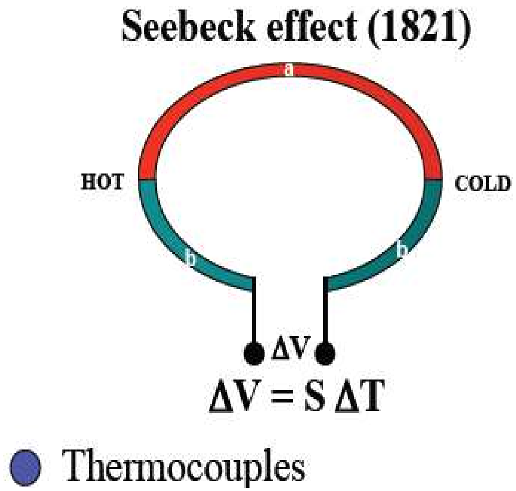


Thermopower (Seebeck Effect)

In 1821, Thomas Seebeck found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals, if the junctions of the metals were maintained at two different temperatures.

Free electron gas





Origines of thermopower :
diffusion, « phonon-drag »,
« magnon-drag »

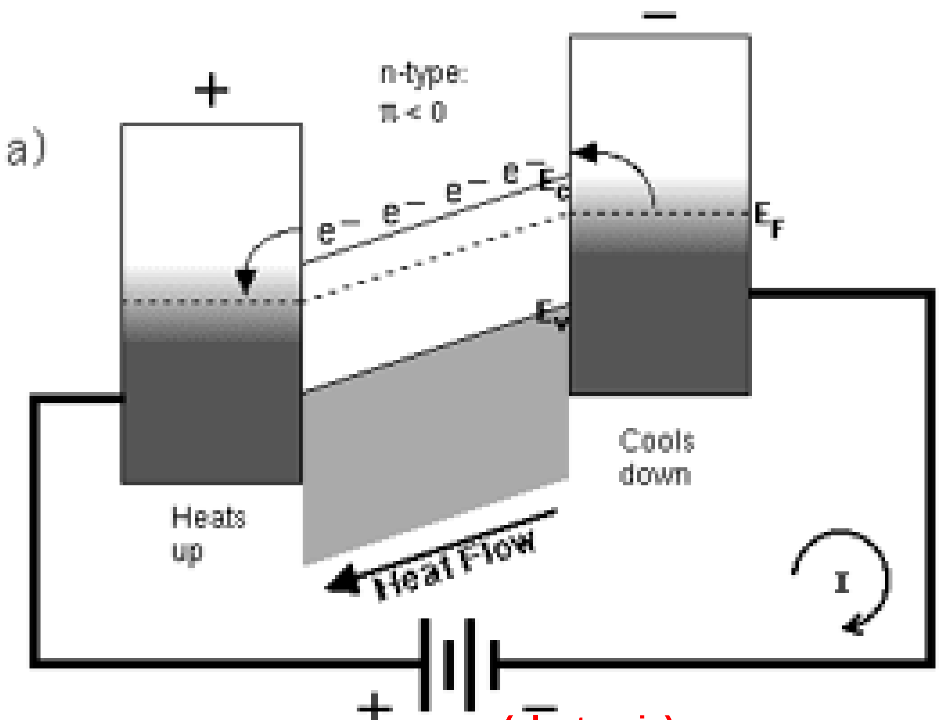
$S = dV / dT$;

S is the Seebeck Coefficient with units of Volts per Kelvin

S is positive when the direction of electric current is same as the direction of thermal current

Peltier Effect

- In 1834, a French watchmaker and part time physicist, Jean Peltier found that an electrical current would produce a temperature gradient at the junction of two dissimilar metals.



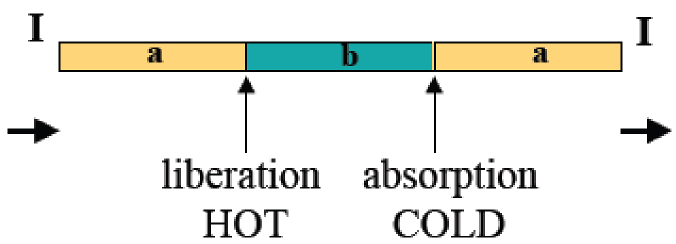
(electronic)

$\Pi < 0$; Negative Peltier coefficient

High energy electrons move from right to left.

Thermal current and electric current flow in opposite directions.

Peltier effect (1834)



$$Q = \Pi I$$

- Thermoelectric cooling

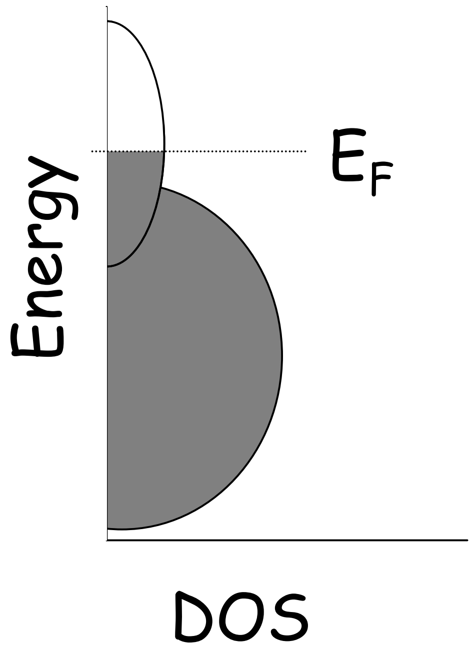
Explanation of Thermopower in metals

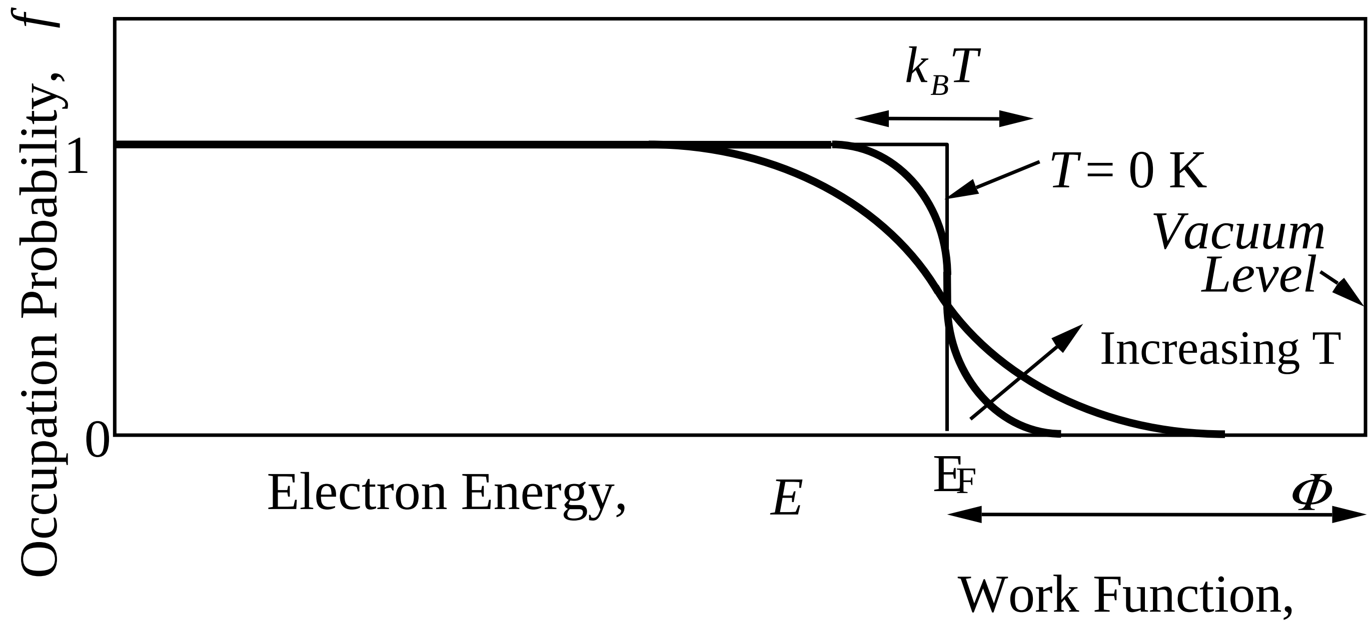
(Band Structure View Point)

Key role of Fermi-Dirac equilibrium distribution
for the probability of electron occupation of energy level *E* at temperature *T*

$$f(E) = \frac{1}{1 + \exp\left(\frac{E - E_F}{k_B T}\right)}$$

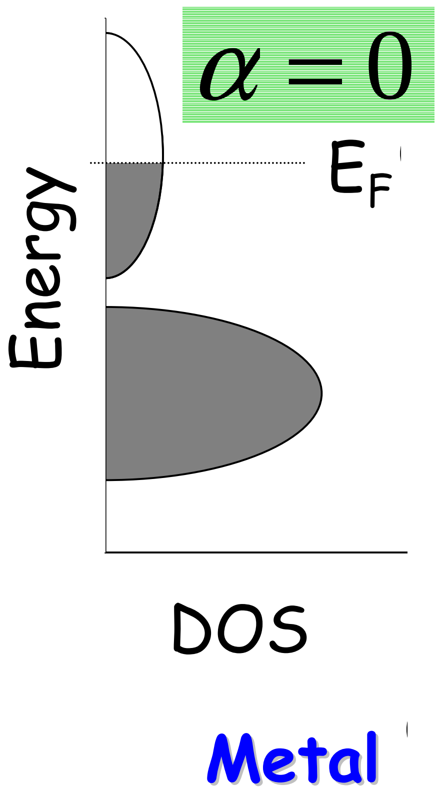
Effect of Temperature

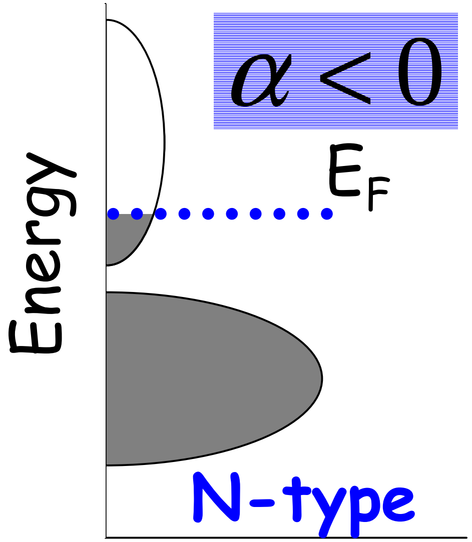


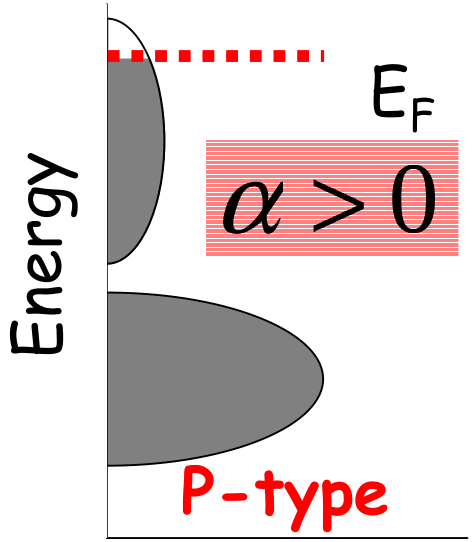


Thermopower in metals (Band Structure View Point)

$$D_e(E) = \frac{m}{\hbar^2 \pi^2} \sqrt{\frac{2mE}{\hbar^2}}$$ in 3D







Thermopower:

- From energy dependent conductivity.
- Mott formula:

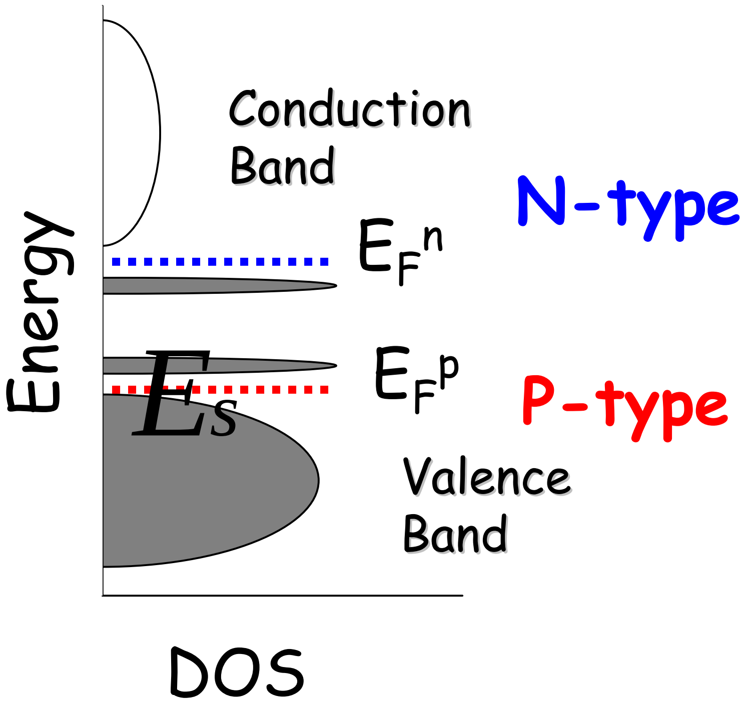
$$s = \left(\frac{\pi^2 k_B^2 T}{3e\sigma}\right) \frac{\partial \sigma}{\partial E} \Big|_{E=E_F}$$

- Note log derivative (not an extensive quantity – multiplicative factors in density of states (specific heat, entropy) or in σ do not change *S*.

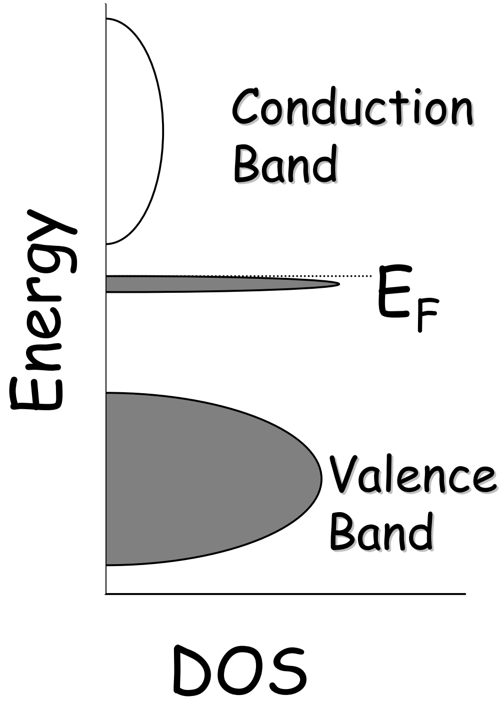
Density of States

-- Number of electron states available between energy *E* and *E*+*dE*

Thermopower in non-metals



Band gap Semiconductor



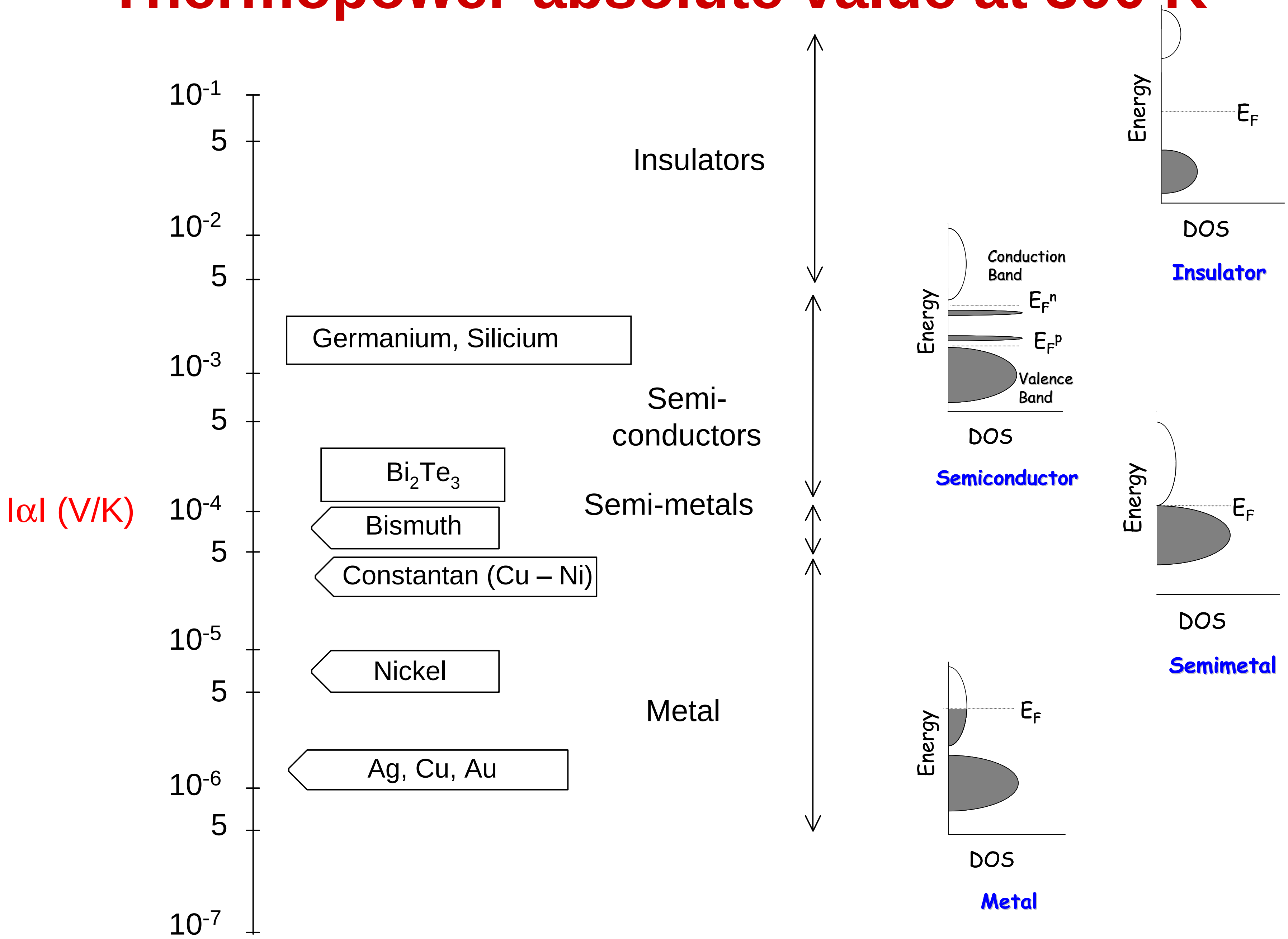
Hopping semiconductor

$$S_d = \frac{k_B}{e}\left(\frac{E_s}{k_B T} + B\right)$$

$$S_d = \frac{k_B}{e}\ln\left(\beta_s\beta_o\left\{\frac{1-\frac{n}{N}}{\frac{n}{N}}\right\}\right)$$

•*B is configurational entropy term*

Thermopower-absolute value at 300 K



Thermopower-temperature dependence