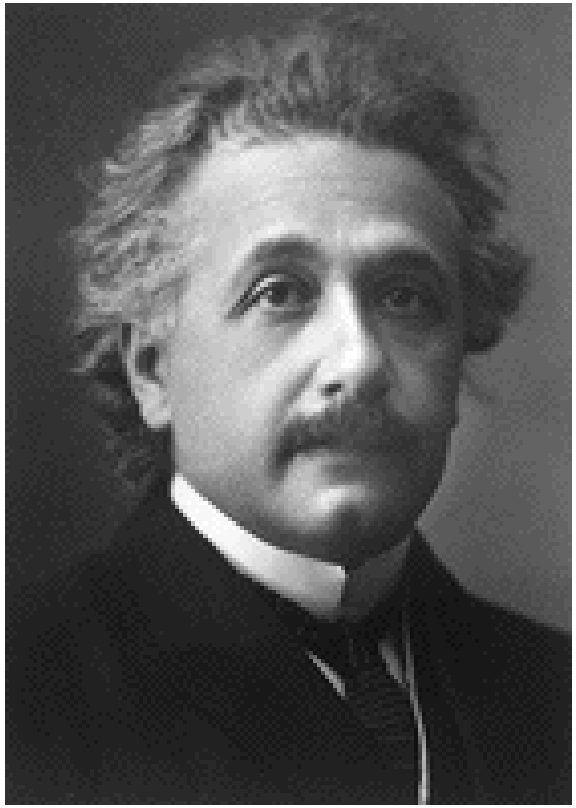
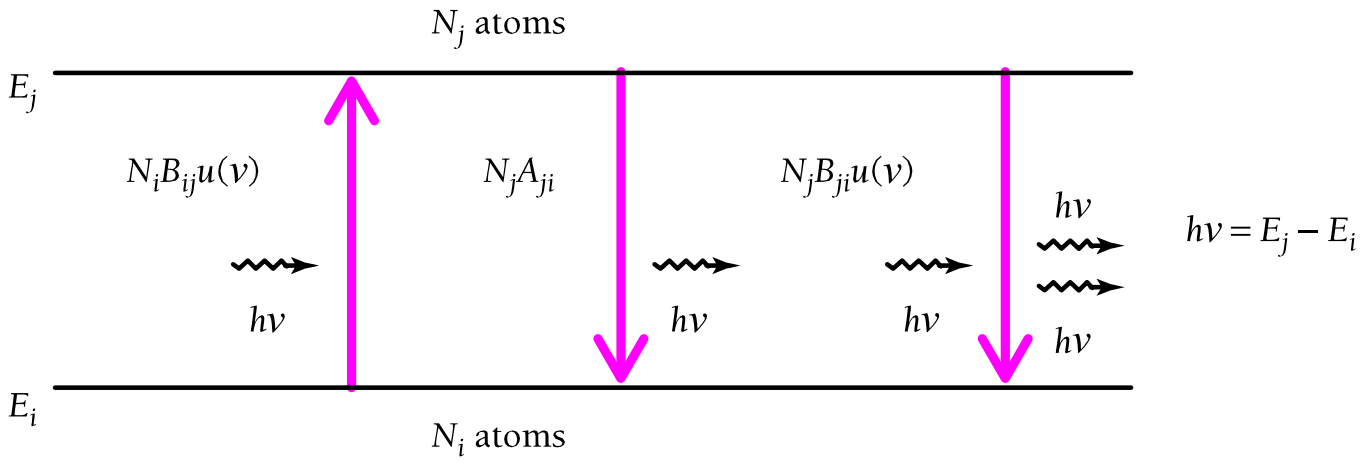
Einstein



Albert Einstein
(1879-1955)

"*Imagination is more important than knowledge.* For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand."

Stimulated Emission



At equilibrium

$$N_i B_{ij} u(\nu) = N_j \left[A_{ji} + B_{ji} u(\nu) \right]$$

Stimulated Emission

$$N_i B_{ij} u(\nu) = N_j \left[A_{ji} + B_{ji} u(\nu) \right]$$

$$u(\nu) = \frac{A_{ji} / B_{ji}}{\left(\frac{N_i}{N_j} \right) \left(\frac{B_{ij}}{B_{ji}} \right) - 1}$$

Boltzmann factors

$$\frac{N_i}{N_j} = e^{\left(E_j - E_i \right) / k_B T} = e^{h\nu / k_B T}$$

Planck's distribution

$$u(\nu) = \frac{8\pi h\nu^3 / c^3}{\left(\frac{B_{ij}}{B_{ji}} \right) e^{h\nu / k_B T} - 1}$$

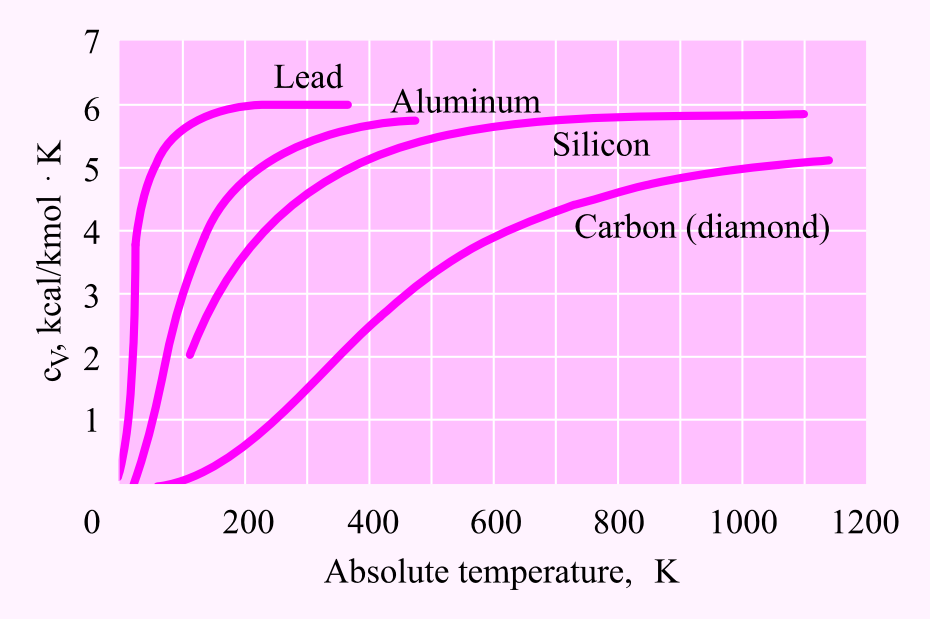
Emission's *A*, *B* Coefficients

$$B_{ij} = B_{ji} \equiv B$$

$$A \equiv A_{ji} = \frac{8\pi h\nu^3}{c^3} B_{ji}$$

Stimulated emission should exist!

Specific Heat of Solids



$$E = 3N_0 k_B T = 3RT$$

internal energy of 1kilomole of soild

N_0 : Avogadro's number

$$c_V = \left(\frac{dE}{dT}\right)_V$$

$$c_V = \frac{d(3RT)}{dT} = 3R$$ Dulong-Petit law

Einstein's Theory of Specific Heat of Solids

$$\bar{\varepsilon} = \frac{h\nu}{e^{h\nu/k_BT} - 1}$$

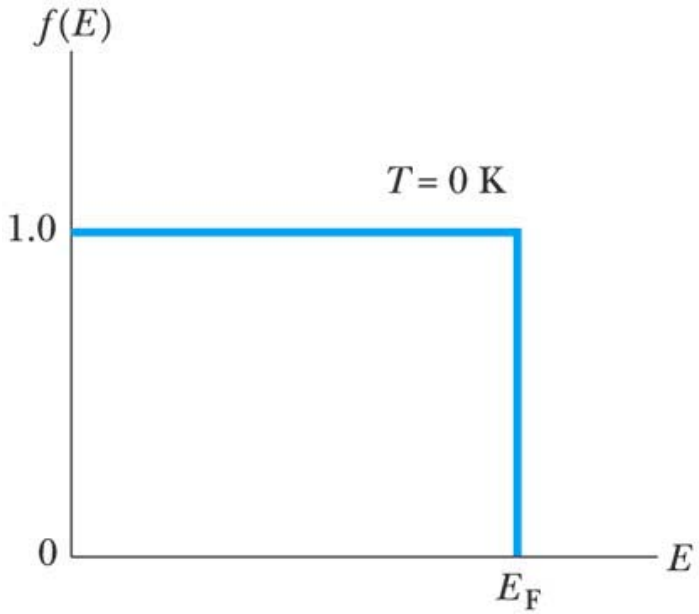
$$E = 3N_0\bar{\varepsilon}$$

$$c_V = \left(\frac{dE}{dT}\right)_V = 3R\left(\frac{h\nu}{k_BT}\right)^2 \frac{e^{h\nu/k_BT}}{\left(e^{h\nu/k_BT} - 1\right)^2}$$

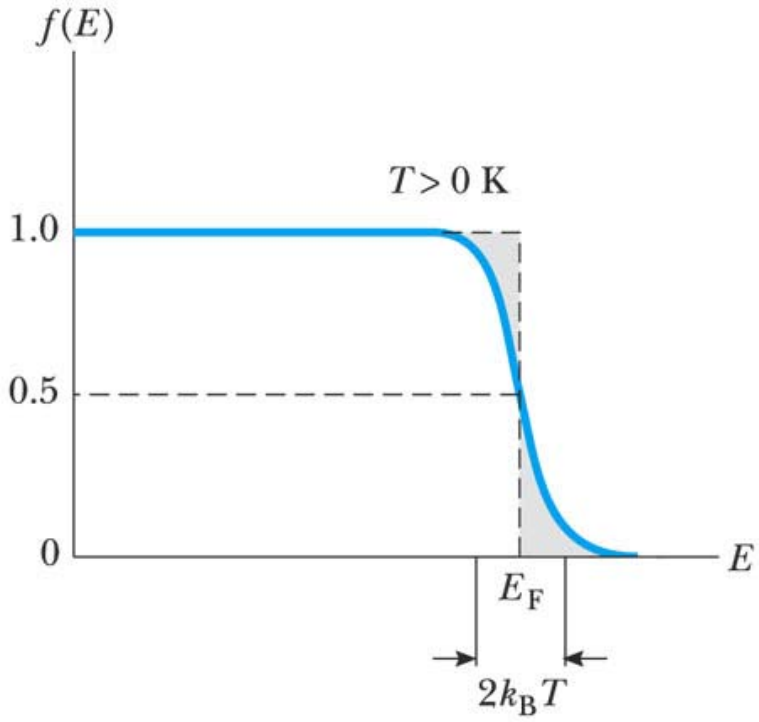
Coupled harmonic oscillators

Phonons

Fermi-Dirac Distribution



(a)



(b)

Density of States in 3D Structure (Metal)

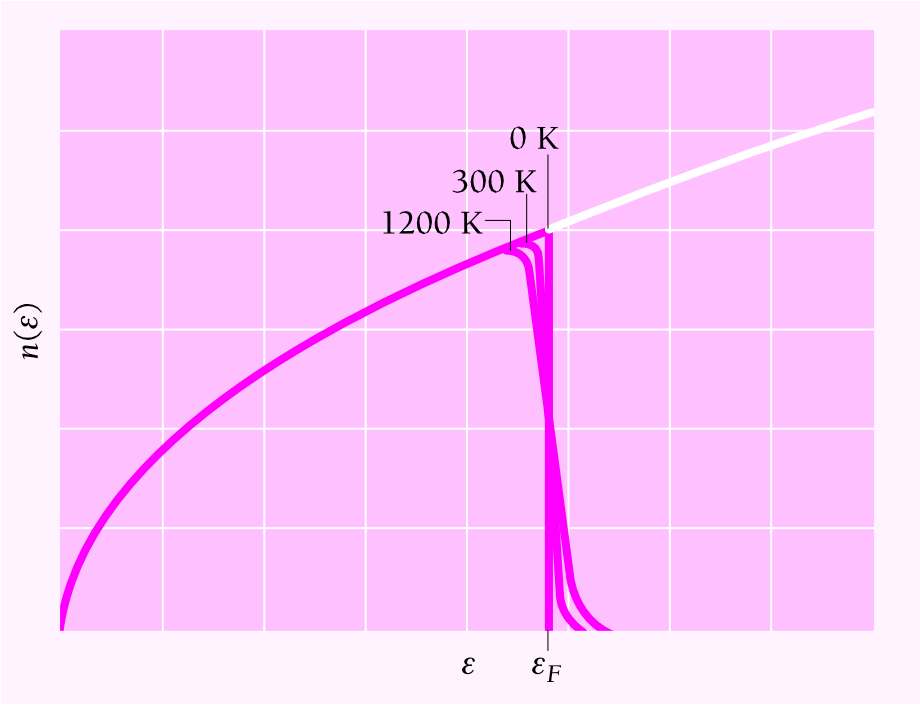
$$g(E)dE = D\sqrt{E}\,dE$$

$$D = \frac{8\sqrt{2}\pi m^{3/2}}{h^3}$$

$$n(E)dE = \frac{D\sqrt{E}\,dE}{e^{(E-E_F)/k_BT}+1}$$

$$\frac{N}{V} = \int_0^\infty n(E)dE = D\int_0^\infty \frac{\sqrt{E}\,dE}{e^{(E-E_F)/k_BT}+1}$$

Fermi Energy in Metal



$$\text{At } T = 0K$$

$$\frac{N}{V} = D\int_0^{E_F} \sqrt{E}\,dE = \frac{2}{3}DE_F^{3/2}$$

$$E_F(0) = \frac{h^2}{2m}\left(\frac{3N}{8\pi V}\right)^{2/3}$$

표 9.2 페르미 에너지 eV

금속		페르미 에너지, eV
Lithium	Li	4.72
Sodium	Na	3.12
Aluminum	Al	11.8
Potassium	K	2.14
Cesium	Cs	1.53
Copper	Cu	7.04
Zinc	Zn	11.0
Silver	Ag	5.51
Gold	Au	5.54