Lect. 1 - Drude model

$$\sigma_0 = \frac{ne^2\tau}{m}$$

$$\mathbf{v}_d = -\frac{e\tau}{m}\mathbf{E} = -\mu\mathbf{E}$$

$$R_H = \frac{E_y}{j_x B} = -\frac{1}{ne}$$

$$\omega_c = \frac{eB}{m}$$

$$W = -K\frac{\mathrm{d}T}{\mathrm{d}x}$$

$$\kappa = \frac{1}{3}c_v l v$$

$$L = \frac{\kappa}{\sigma T}$$

$$Q = -\frac{1}{3}\frac{c_v}{ne}$$

Lect. 2 - Sommerfeld theory

$$f_{FD} = \frac{1}{e^{(\varepsilon-\mu)/k_B T} + 1}$$

$$\psi_{\mathbf{k}}(\mathbf{r}) = \frac{1}{\sqrt{V}}e^{i\mathbf{k}\cdot\mathbf{r}}$$

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

$$D(\varepsilon)d\varepsilon = 2\frac{V}{8\pi^3}4\pi k^2 dk$$

$$U = \int_0^\infty \varepsilon D(\varepsilon)f(\varepsilon)d\varepsilon$$

$$\int_0^\infty A(\varepsilon)f(\varepsilon)d\varepsilon = \int_0^\mu A(\varepsilon)d\varepsilon + \frac{\pi^2}{6}(k_B T)^2 A'(\mu)$$

$$c_{v,\mathrm{el}} = \frac{\partial u}{\partial T} = \frac{\pi^2}{3}g(\varepsilon_F)k_B^2 T = \frac{\pi^2}{2}nk_B\left(\frac{k_B T}{\varepsilon_F}\right) = \gamma T$$

Lect. 5 - Reciprocal lattice

$$\mathbf{b}_1 = 2\pi\frac{\mathbf{a}_2\times\mathbf{a}_3}{\mathbf{a}_1\cdot(\mathbf{a}_2\times\mathbf{a}_3)}$$

$$\mathbf{G} = h\mathbf{b}_1 + k\mathbf{b}_2 + l\mathbf{b}_3$$

$$d(hkl) = \frac{2\pi}{|G(hkl)|}$$

$$S_{\mathbf{G}} = \sum_{j=1}^{n} f_j e^{i\mathbf{G}\cdot\mathbf{d}_j}$$

$$\sin^2\theta = \frac{\lambda^2}{4a^2}\left(h^2 + k^2 + l^2\right)$$

Lect. 6 - Bloch's theorem

$$\psi(\mathbf{r}+\mathbf{R}) = e^{i\mathbf{k}\cdot\mathbf{R}}\psi(\mathbf{r})$$

$$\mathbf{v}_n(\mathbf{k}) = \frac{1}{\hbar}\nabla_{\mathbf{k}}\varepsilon_n(\mathbf{k}) = \frac{1}{\hbar}\frac{\partial\varepsilon_n}{\partial\mathbf{k}}$$

$$\frac{1}{m^*} = \frac{1}{\hbar^2}\frac{\partial^2\varepsilon}{\partial k^2}$$

$$\frac{d\mathbf{k}}{dt} = \frac{\mathbf{F}}{\hbar}$$

$$g_n(\varepsilon) = \frac{1}{4\pi^3}\int_{S_n(\varepsilon)}\frac{dS}{|\nabla_{\mathbf{k}}\varepsilon_n(\mathbf{k})|}$$

Lect. 7 - NFE, Tightbinding

$$\psi_{\mathbf{k}}(\mathbf{r}) = \sum_{\mathbf{G}} C_{\mathbf{k}-\mathbf{G}}\exp\{i(\mathbf{k}-\mathbf{G})\cdot\mathbf{r}\}$$

$$C_{\mathbf{k}-\mathbf{G}} = \frac{\sum_{\mathbf{G}'} U_{\mathbf{G}'-\mathbf{G}}C_{\mathbf{k}-\mathbf{G}'}}{\varepsilon - \varepsilon^0_{\mathbf{k}-\mathbf{G}}}$$

Lect. 9 - Band structure

$$\hbar\frac{d\mathbf{k}}{dt} = -e(\mathbf{v}_g\times\mathbf{B})$$

$$\Delta\left(\frac{1}{B}\right) = \frac{2\pi e}{\hbar}\cdot\frac{1}{A_e}$$

$$\varepsilon = \left(n+\frac{1}{2}\right)\hbar\omega_c + \frac{\hbar^2 k_z^2}{2m}$$

Lect. 10 - Classification of solids

$$\phi(r) = 4\epsilon\left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^6\right]$$

$$u^{\mathrm{coul}}(r) = -\alpha\frac{e^2}{r}$$

Lect. 12 - Lattice vibrations

$$\omega(K) = \sqrt{\frac{4C}{M}}\left|\sin\frac{Ka}{2}\right|$$

Lect. 13 - Lattice vibrations II

$$n_s(\mathbf{K}) = \frac{1}{e^{\hbar\omega_s(\mathbf{K})/k_BT} - 1}$$

$$u = \frac{1}{V}\sum_{\mathbf{K}s}\frac{\hbar\omega_s(\mathbf{K})}{e^{\hbar\omega_s(\mathbf{K})/k_BT} - 1}$$

$$c_v = \frac{\partial u}{\partial T} = 3nk_B$$

$$g_D(\omega)\mathrm{d}\omega = 3\frac{1}{(2\pi)^3}4\pi K^2\mathrm{d}K$$

Lect. 14 - Defects in crystals

$$n_v = N_0 e^{-U_0/k_BT}$$

Lect. 16 - Semiconductors

$$g_c(\varepsilon) = \frac{1}{2\pi^2}\left(\frac{2m_e}{\hbar^2}\right)^{3/2}(\varepsilon-\varepsilon_c)^{1/2}$$

$$n_c(T) = \int_{\varepsilon_c}^{\infty}\frac{1}{e^{(\varepsilon-\mu)/k_BT}+1}g_c(\varepsilon)\mathrm{d}\varepsilon$$

$$N_c(T) \approx \frac{1}{4}\left(\frac{2m_ek_BT}{\pi\hbar^2}\right)^{3/2}$$

$$\sigma = n_c e\mu_e + p_v e\mu_h$$

$$n_cp_v = n_i^2 = N_cP_ve^{-\varepsilon_g/k_BT}$$

Lect. 17 - Magnetism

$$\chi = -\frac{e^2\mu_0ZN}{6m}\left\langle r^2\right\rangle$$

$$g \approx 1 + \frac{J(J+1)+S(S+1)-L(L+1)}{2J(J+1)}$$

$$\bar{\mu} = -g\mu_B\mathbf{J}$$

$$U = -\bar{\mu}\cdot\mathbf{B} = m_Jg\mu_BB$$

$$M = \frac{\mu_BN}{V}\tanh\left(\frac{\mu_BB}{k_BT}\right)$$

$$\chi = \frac{g^2J(J+1)}{3}\frac{\mu_0\mu_B^2n}{k_BT}$$

$$\chi = \mu_0\mu_B^2D(\varepsilon_F)$$

$$T_c = \frac{\mu_0\mu_B^2\lambda n}{k_B}$$

Lect. 18 - Superconductivity

$$\frac{c_s-c_n}{c_n} = 1.43$$

$$\nabla\times\mathbf{j_s} = -\frac{n_se^2}{m}\mathbf{B}$$

$$\frac{\Delta(0)}{k_BT_c} = 1.76$$

$$T_c \sim \theta_De^{-1/N_0V_0}$$

Units etc.

- $\mu_0 = 4\pi\cdot10^{-7}$ [N/A^2]
- [T] = [N/Am]
- k_BT has unit [J] = [Nm]
- μ_B has unit [Nm/T] = [Am^2]
- B has unit [T]
- H and M have unit [A/m]