Condensed Matter Theory. Spring semester 2013.
List of exam topics.

1. Specific heat of electrons and phonons.

$$c_{\mathrm{e}} \propto T\,, \qquad c_{\mathrm{ph}} \propto T^3$$

2. Irreducible representations of groups and degeneracies in the electron band structure.

$$\text{degeneracy} = \dim \Gamma$$

3. Hartree–Fock exchange energy for interacting electrons.

$$\delta E = -\frac{\mathcal{V}}{2} \iint \frac{d^3k}{(2\pi)^3} \frac{d^3k'}{(2\pi)^3} n_k n_{k'} V_{k-k'}$$

4. Time-ordered Green's functions for noninteracting and interacting electrons. Self energy.

$$G^c(t_1 - t_2; x_1, x_2) = -iT\langle a(t_1, x_1) a^+(t_2, x_2)\rangle\,,$$

$$G^c_{\mathrm{free}}(\omega, k) = \frac{1}{\omega - (\varepsilon_k - \mu) + i\delta\,\mathrm{sign}\,\omega}\,,$$

$$G^c_{\mathrm{int}}(\omega, k) = \frac{1}{\omega - (\varepsilon_k - \mu) - \Sigma(\omega, k) + i\delta\,\mathrm{sign}\,\omega}$$

5. Thomas–Fermi and Lindhard screening of Coulomb interaction.

$$\phi(R) = \frac{Q}{R}\, e^{-\kappa R}\,, \qquad \kappa = (4\pi e^2 \nu_0)^{1/2}\,, \qquad \phi(q) = \frac{Q}{\frac{q^2}{4\pi} - e^2\,\chi(q)}$$

6. Fermi liquid theory

$$E/\mathcal{V} = \int \frac{d^3k}{(2\pi)^3}\, \varepsilon_k^{(0)}\, \delta n_k + \frac{1}{2} \iint \frac{d^3k}{(2\pi)^3}\, \frac{d^3k'}{(2\pi)^3} f_{kk'}\, \delta n_k \delta n_{k'}$$

7. BCS theory: superconducting quasiparticles and their spectrum.

$$\gamma^+_{k\uparrow} = u_k a^+_{k\uparrow} + v_k a_{-k\downarrow}\,, \qquad \tilde{\varepsilon}_k = \pm\sqrt{(\varepsilon_k - \mu)^2 + |\Delta|^2}$$

8. BCS theory: relation between superconducting transition temperature and the gap at zero temperature.

$$T_c/\Delta_0 \sim 0.57$$