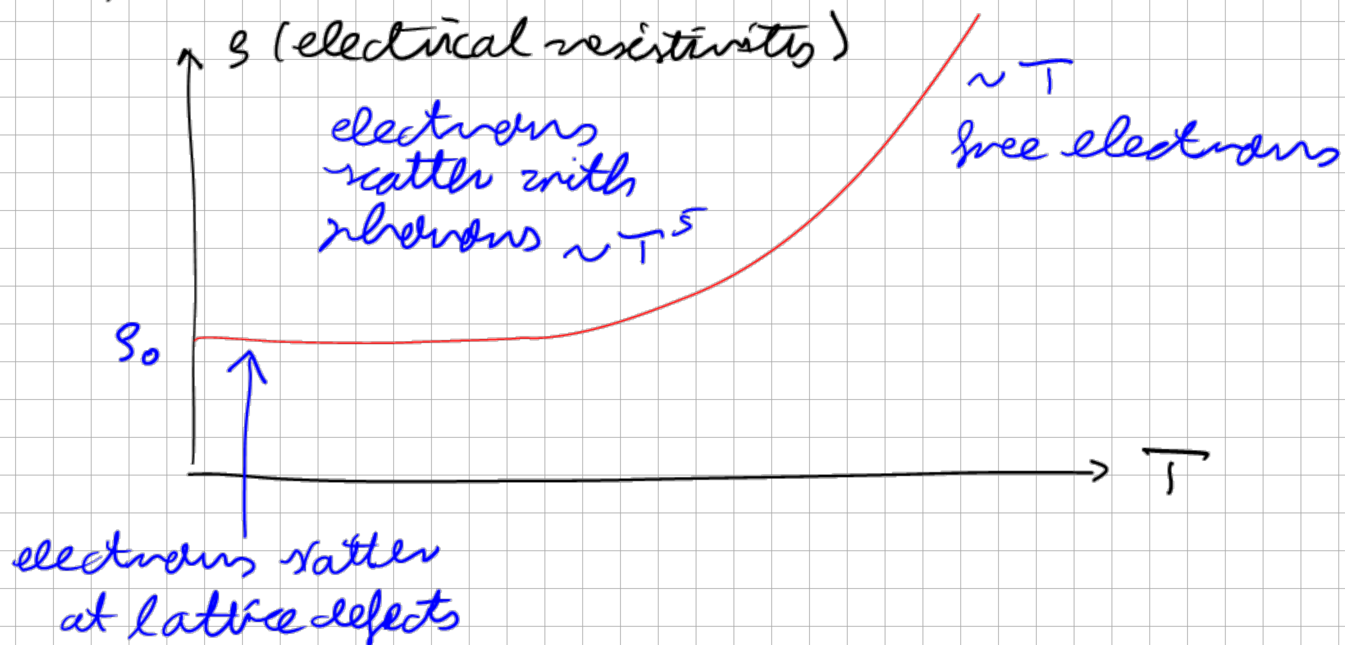
Chapter 1: Introduction

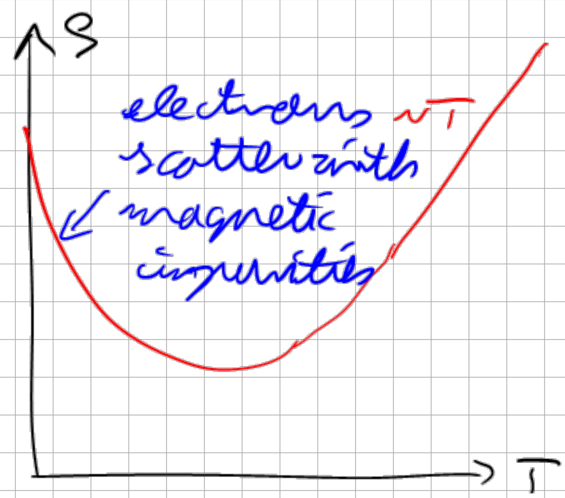
- focus: electric properties
- mention briefly some facts on magnetic / thermodynamic properties

1.1 Critical Temperature:

Heike Kammerlingh Onnes (1908): liquidation of Helium, becomes liquid 4.2 K



Sideremark:



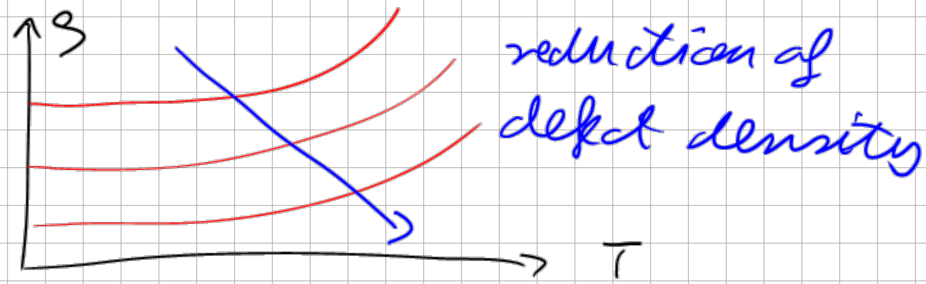
Kondo effect

Rule of Mathiessen: $\rho(T) = \rho_0 + \Delta\rho(T)$

Original aim of Onnes:

$\lim_{T \downarrow 0} \rho(T) \longrightarrow 0$?

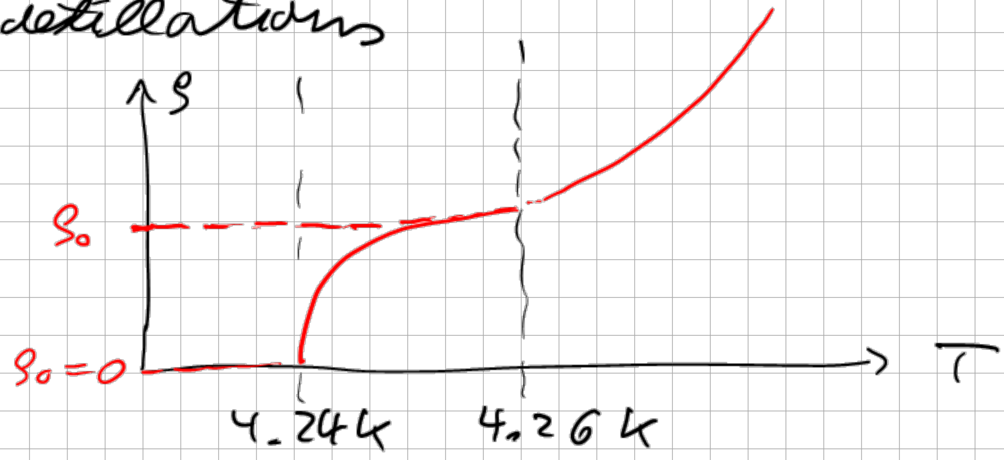
↑ lattice defects are gone



Material: metal which could be produced with highest degree of purity
→ mercury (Hg): successive distillations

$T_c(Hg) = 4.2\,K$

→ 1913 nobel prize



1.2 Superconducting Material:

Which materials are NOT superconducting:

1) Elements with spin order:
   a.) ferromagnet: iron (Fe), nickel (Ni), cobalt (Co)
   b) antiferromagnets: MnO_2
   c) ferrimagnets: Fe_3O_4
2) Elements with strong paramagnetism:
   Rh, Pd, Pt
3) Elements with a high conductivity:

copper Cu, silver Ag, gold Au

4) semiconductors like Si, Ge

$T_c^{Si}(120\,kbar) = 6.7\,K$, $T_c^{Ge}(115\,kbar) = 5.35\,K$

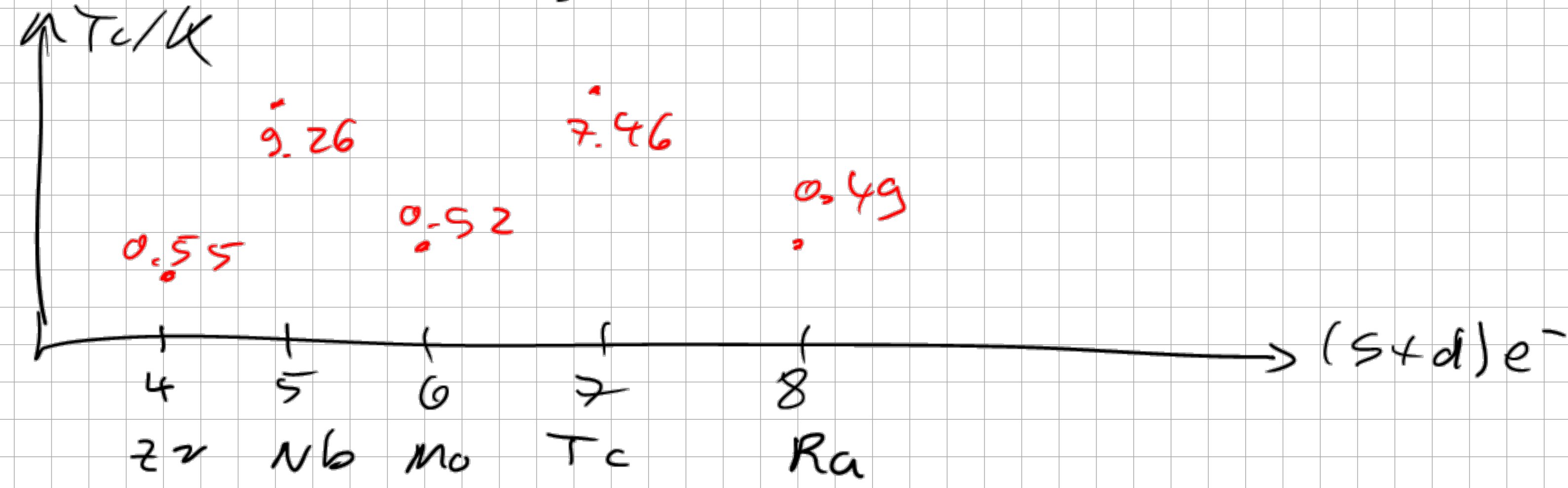
Many metals are superconducting:

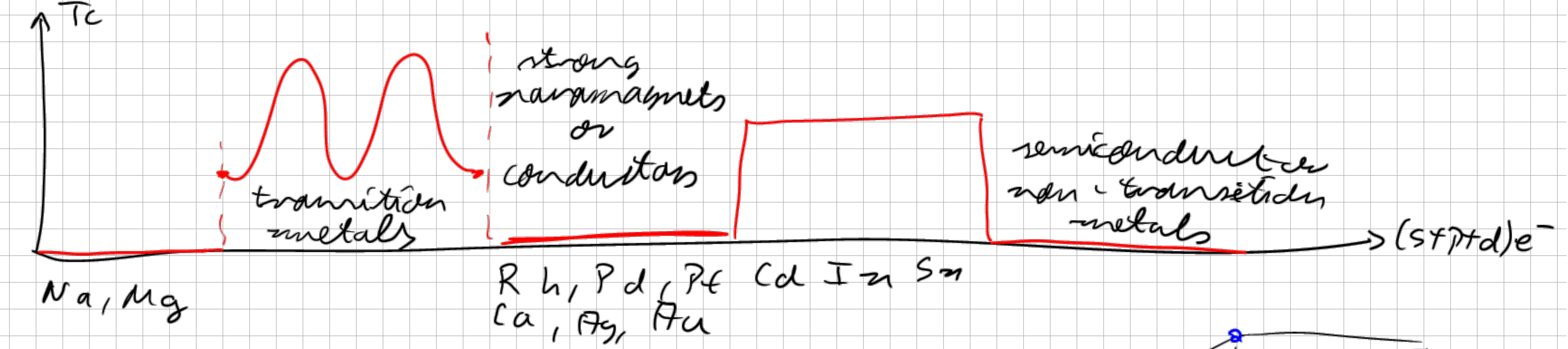
- low T_c: $T_c^{W} = 10^{-2}\,K$
- high T_c: $T_c^{Nb} = 9.26\,K$

Periodic table:

- non-transition metals of group IV, V, VI: only superconducting at very high pressures
- transition metals: it depends on the number of valence electrons

Example: second row of transition metals





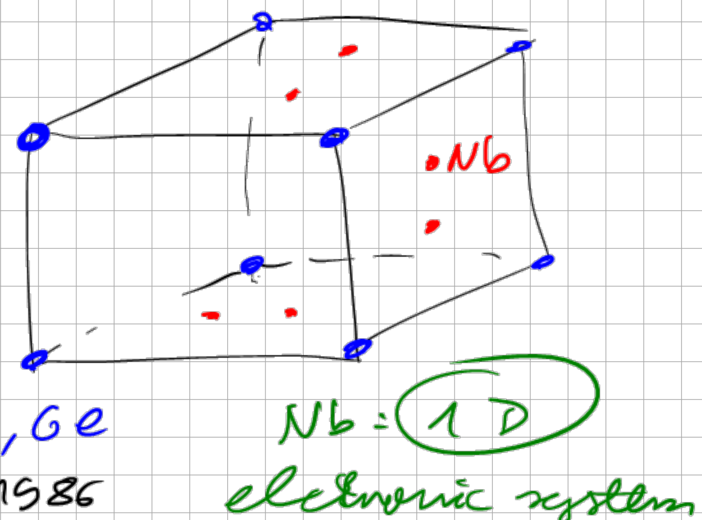
Highest T_c for conventional superconductors:

Intermetallic superconductor

β-wolfram A15 structure

$T_c(Nb_3Sn) = 18.05$ K

$T_c(Nb_3Ge) = 22.7$ K world-record until 1986

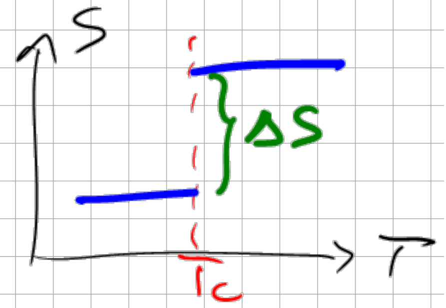


1986 Bednorz, Müller: perovskite

$(LaBa)_2CuO_4$	$YBa_2Cu_3O_7$	$Bi_2SrCaCu_2O_8$	$TlBa_{\circ}Ca_{\circ}Cu_{\circ}O_{\circ}$
$T_c = 35$ K	83 K	110 K	125 K

Not discuss high T_c superconductors: theory still lacking

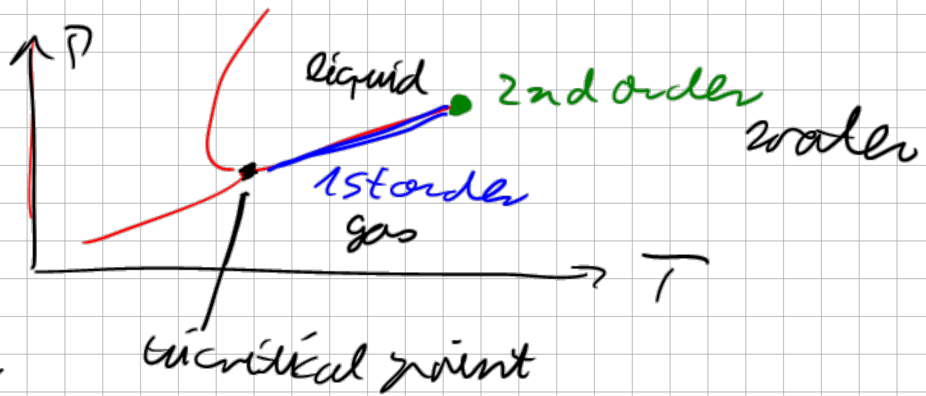
1.3 Phase Transitions:



1.3.1 First-order phase transition:

discontinuity of entropy S: latent heat $\Delta Q = \Delta S\, T_c$

1. example: liquid – solid.
2. " : superconductor – normalconductor (non-vanishing magnetic field)

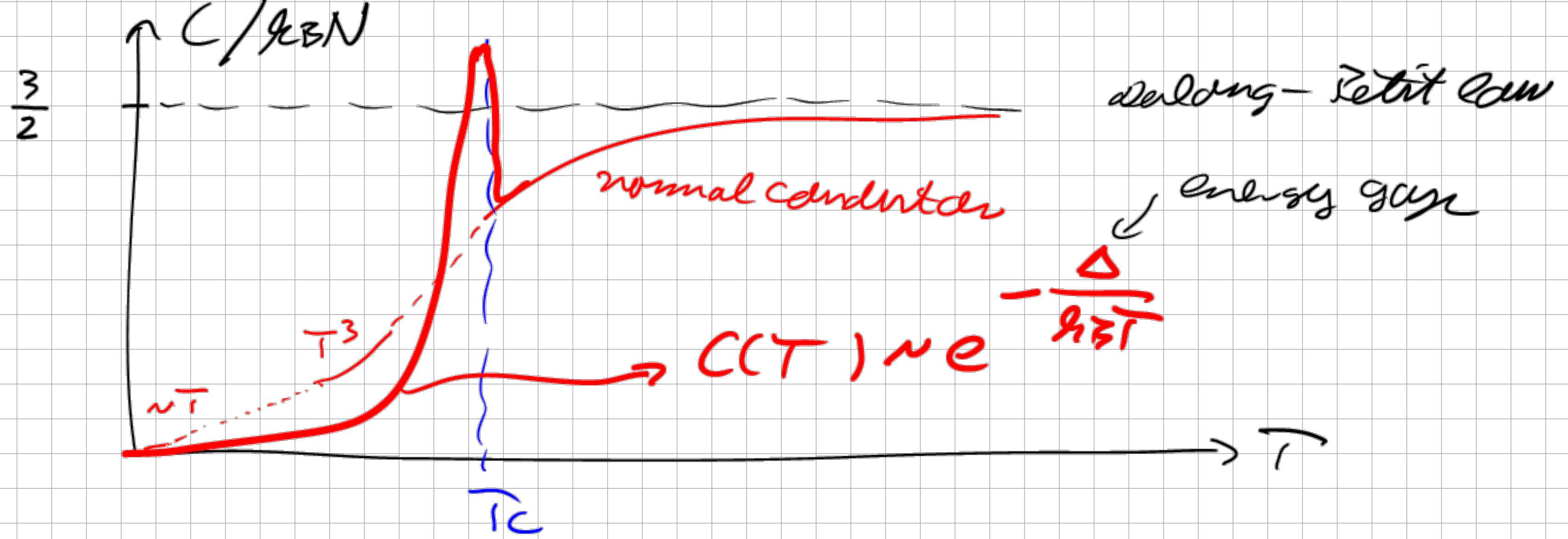


1.3.2 Second-order phase transition:

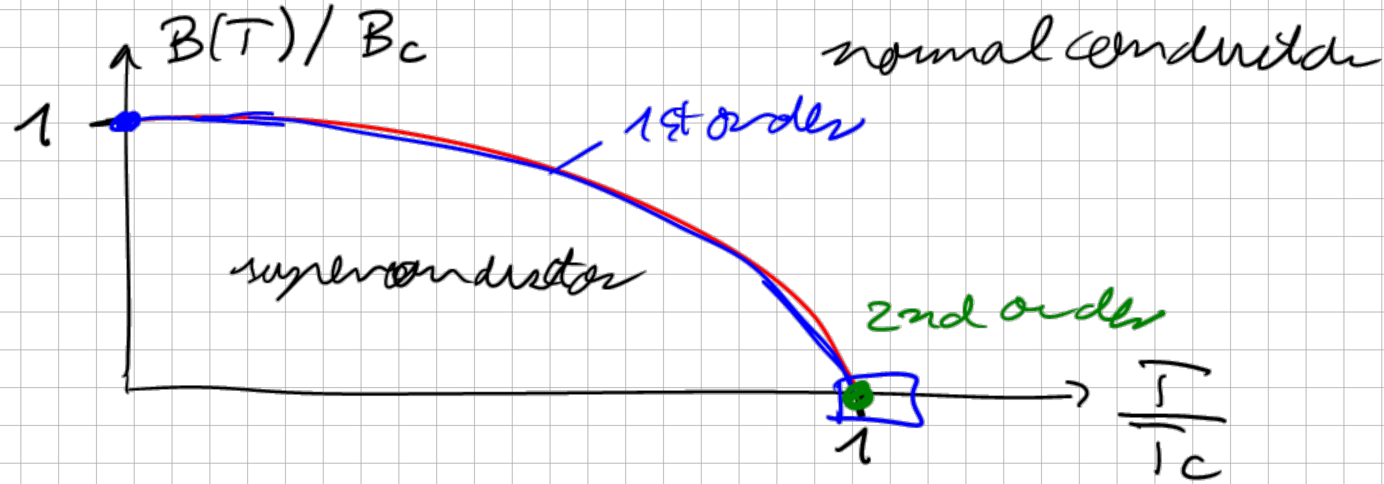
discontinuity at second derivative of thermodynamic potential

1. example: paramagnet – ferromagnet
→ magnetic susceptibility

2. example: superconductor - normal conductor (vanishing magnetic field)
→ heat capacity



1.3.3 Phase diagram:



Rule formula: $\frac{B(T)}{B(T=0)} = 1 - \left(\frac{T}{T_c}\right)^2$

universality for conventional superconductors

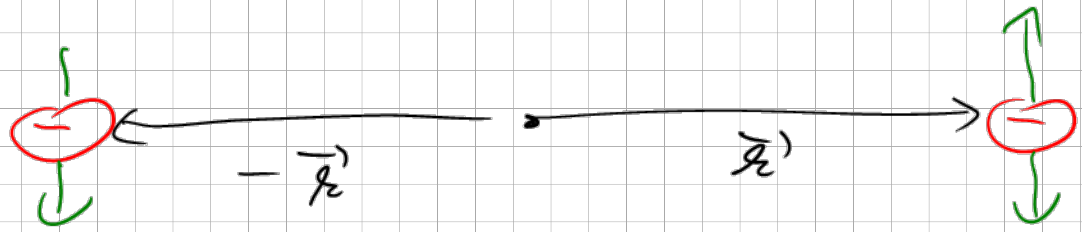
superconductors	Nb	Nb_3Sn	high T_c's
$B_c(0)$	0.2 T	25 T	∼ 100 T

earth magnetic field 30 μT

1.4 BCS Theory:

microscopic theory

John Bardeen, Leon Cooper, John Schrieffer

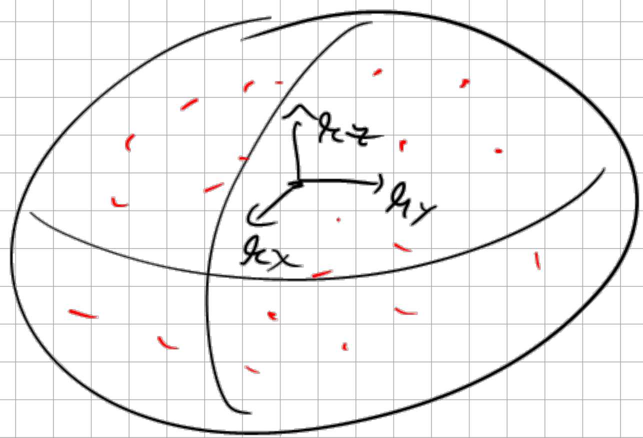


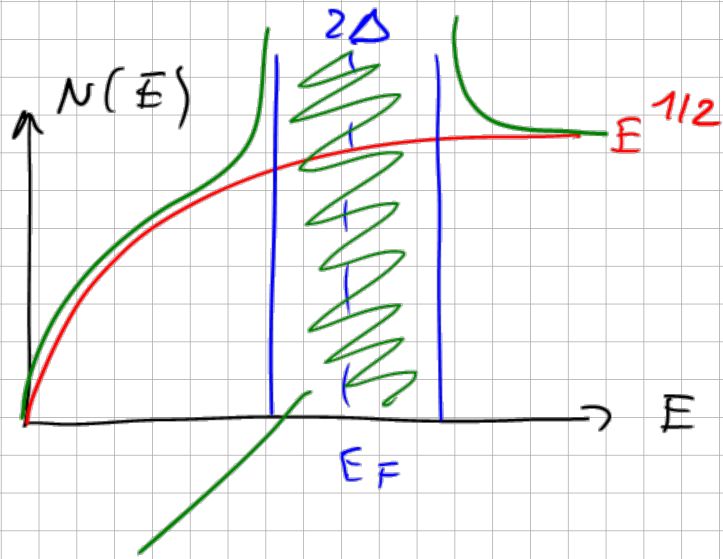
Cooper pair

pairing in momentum space

spatial distance: 1000 Å, 1 Å = 0.5 nm

Fermi sphere





no free electrons in this gap around E_F