Super-conductivity

1911 - Kamerlingh Ones

1986 - Bednorz & Müller high T_c.

remember: $\rho = \frac{m_e \langle v \rangle}{n e^2 \lambda}$

λ: mean free path length.

quantum: vibrations in crystal lattice

* resistivity $\to 0$ $\sigma \to \infty$
* Meissner effect - repels fields.
  - perfect case of Lenz' law
* supercurrents - flow without any voltage (E-field).

spin statistics

e^- $S = 1/2$ fermion

$2e^-$: $S = S_1 + S_2$

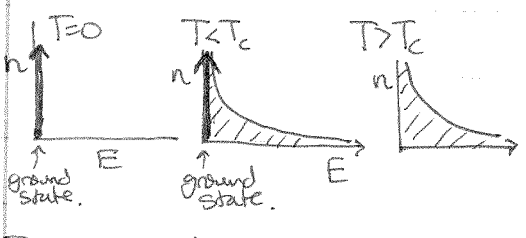
$(m_{s_1} = \frac{1}{2}) + (m_{s_2} = \frac{-1}{2}) = (m_s = 0)$

$S = S_1 + S_2 = 1$ (sym).

$\to$ or $|S_1 - S_2| = \boxed{0}$ $\leftarrow$ antisymmetric.

$L = 0$ symmetric

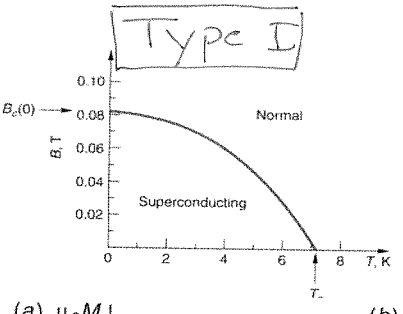
spin-0 Boson!

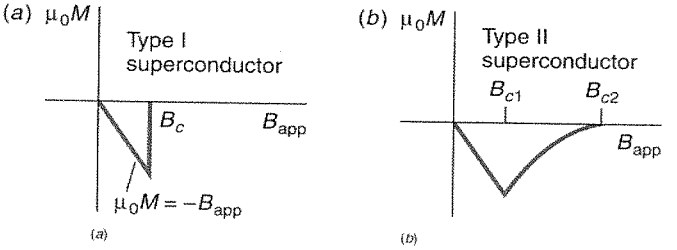


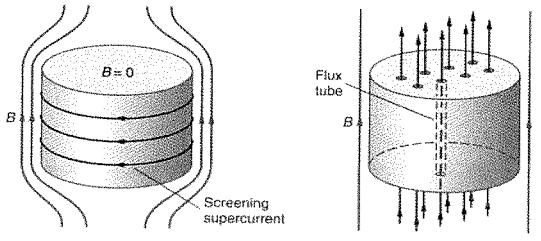
BCS theory

1) electron attracts ions of the lattice
2) creates a vibration wave, called a phonon
3) a second electron absorbs the phonon, recovering E, p.

- this interaction attracts 2 electrons, binding them into a spin-0 Cooper-pair, similar to molecular bonds.
- all Cooper pairs can occupy the same ground state.







* flux tubes, vortices

$\Phi_0 = B \cdot A = \frac{h}{2e}$

quantization of magnetic field

- Superconducting energy gap $E_g = 3.5\ kT_c$.
- all Cooper pairs have same momentum
  - scatter has no effect.
- disrupted by random thermal photons.

Josephson Junction

- junction between normal metal & superconductor

dc: $I = I_{max} \sin(\phi_2 - \phi_1)$ $\quad \psi = e^{i\phi}$

ac: $f = \frac{2eV}{h}$ dc in → ac out.
or vice versa.

measure: $\frac{e}{h}$

- SQUID can measure single quanta of flux 10^{-14} T, interference of supercurrents.