Superconductivity. BCS-theory

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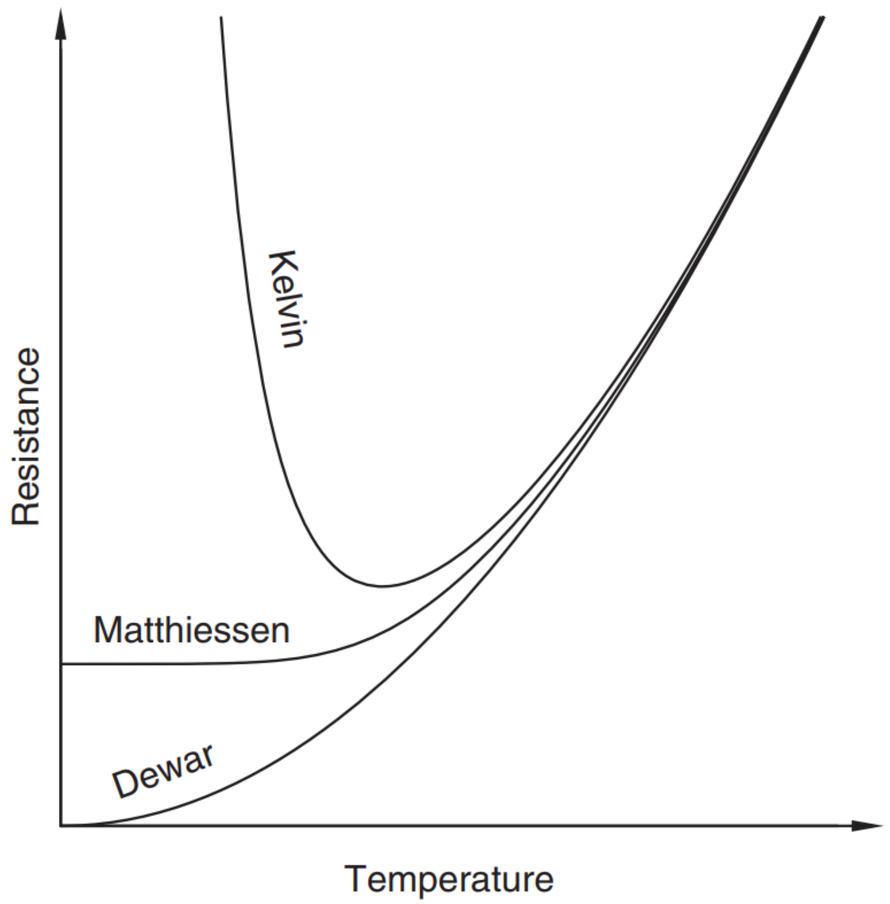
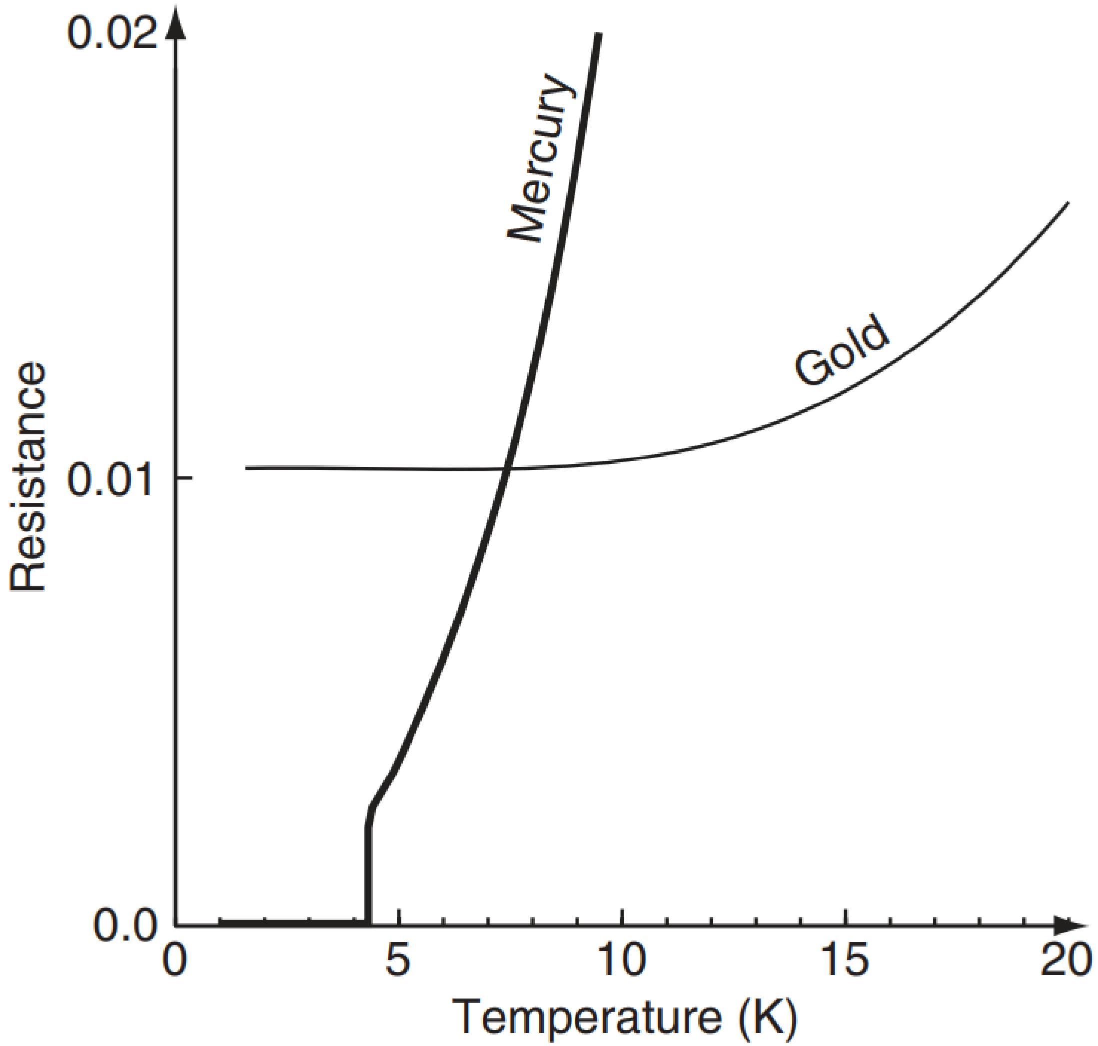
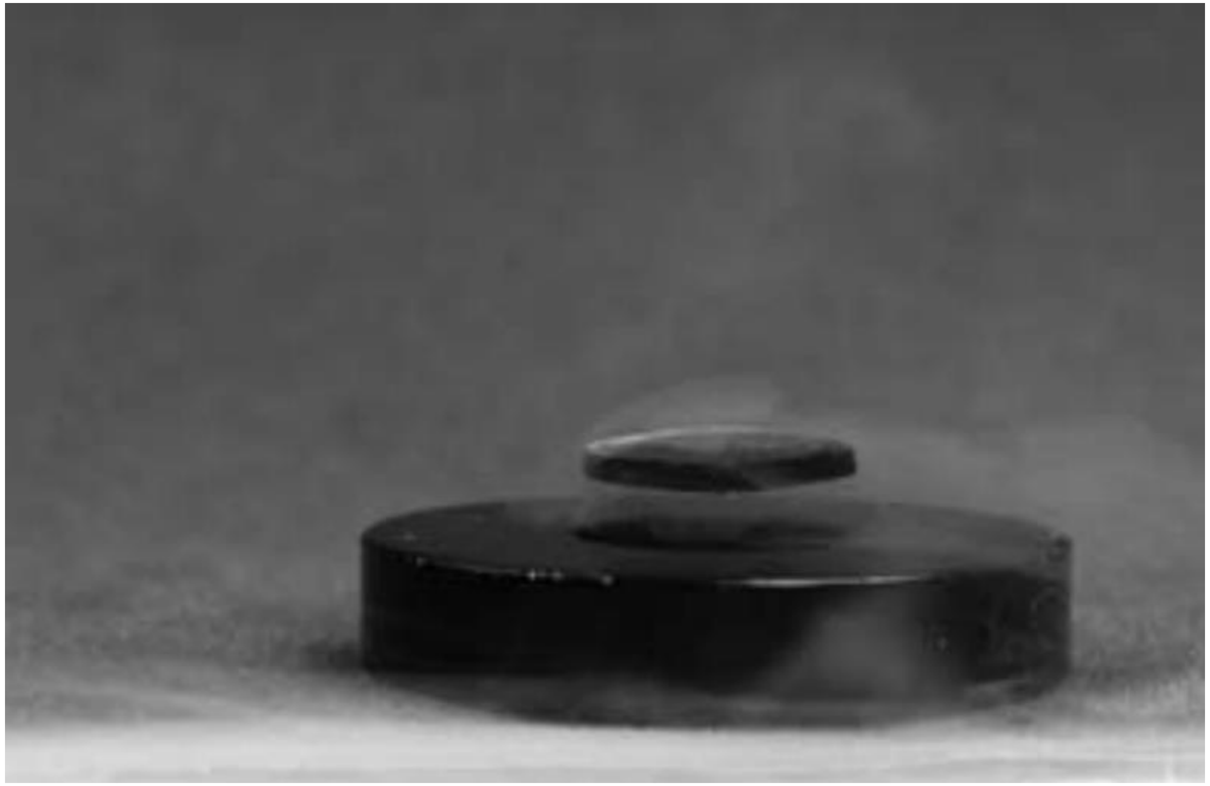
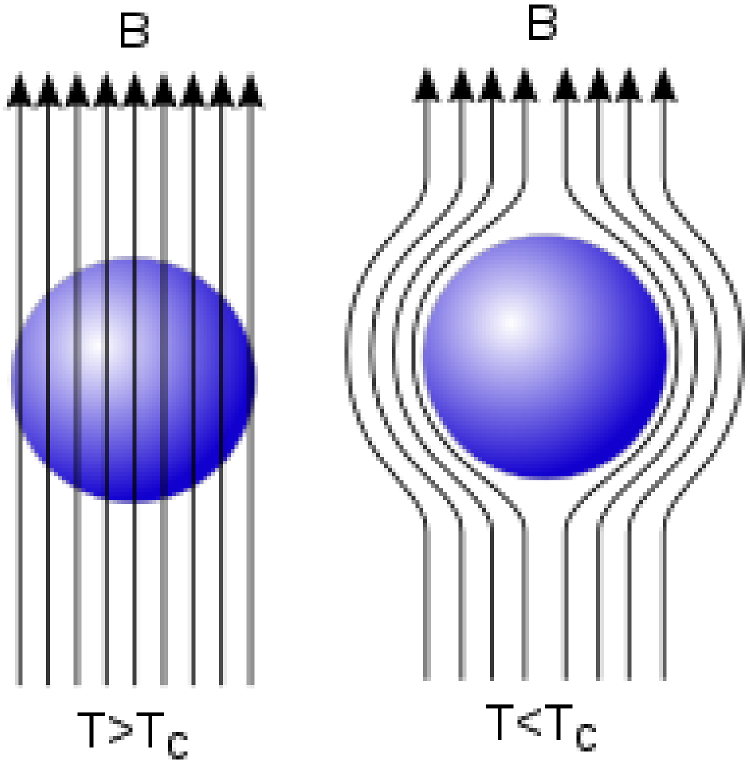
Resistance


Resistance
Kelvin
Matthiessen
Dewar
Temperature


0.02
0.01
0.0
Resistance
Mercury
Gold
0
5
10
15
20
Temperature (K)

Magnetic field



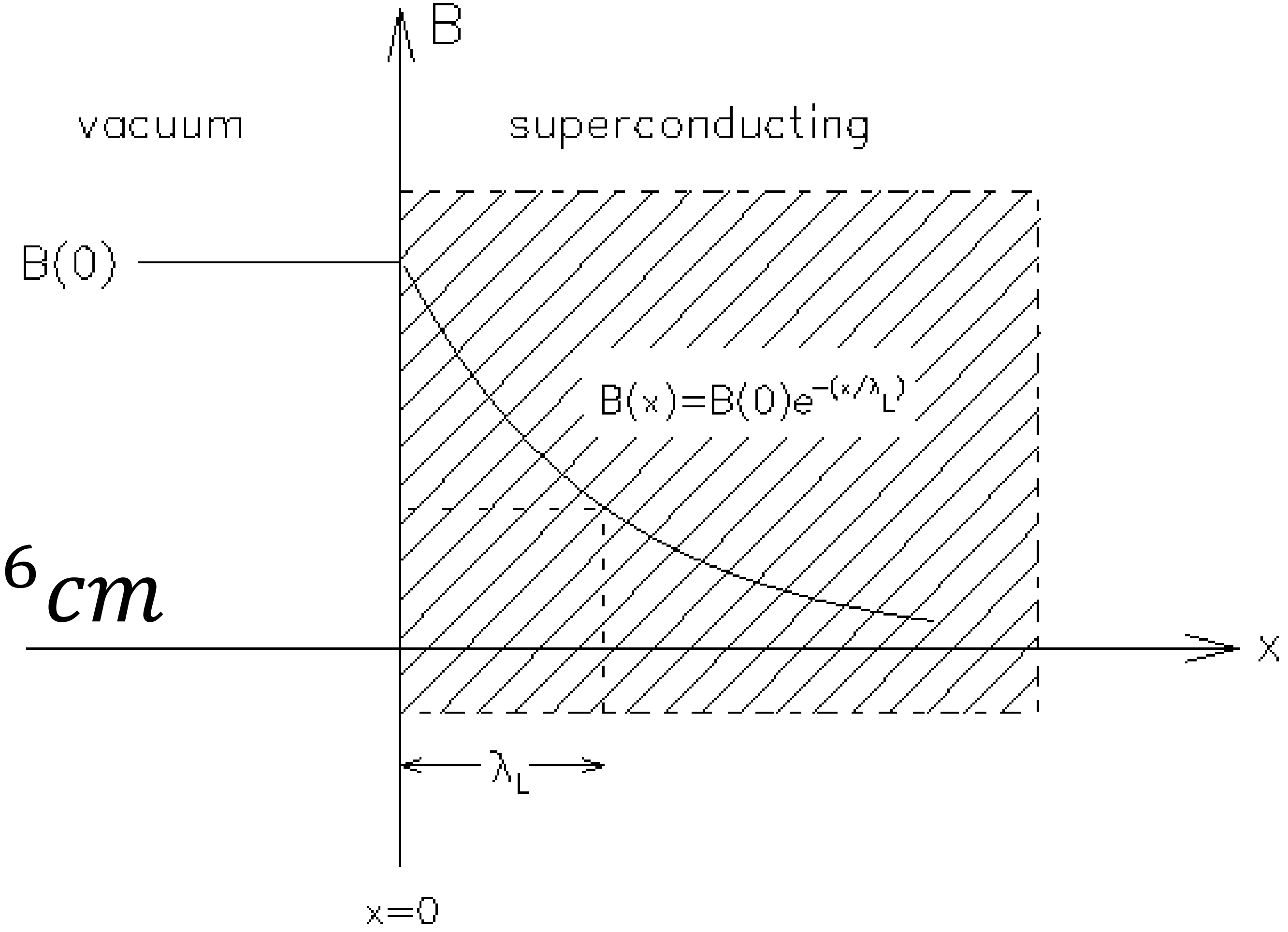


Electron fluid

- $q = q_s + q_n$
- q_n - normal electron density
- q_s - superfluid electron density
- $\frac{q_s}{q_n} = 0 \; at \; T = T_c$
- $\frac{q_s}{q_n} = 1 \; at \; T = 0$

London penetration depth

- $j_s = -\frac{1}{\Lambda_c} A$
- $\Lambda_c = {}^{m}/_{q_s e^2}$
- $\nabla \cdot A = 0$
- $\lambda_L = \sqrt{{\Lambda_c}^2 / 4\pi} \approx 10^{-6} cm$



Quantum mechanical description

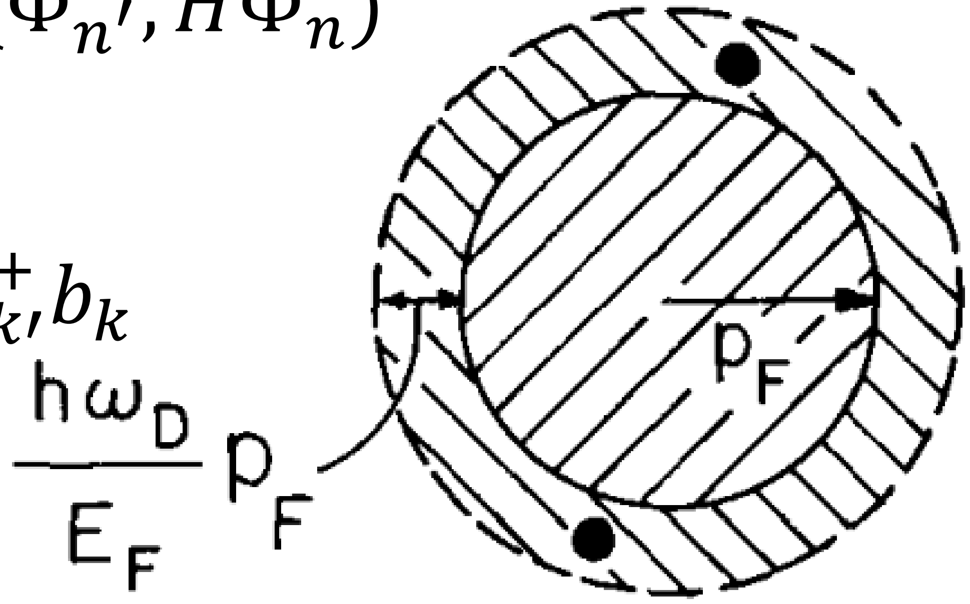
- $\frac{q_s(r)}{q_n} = |\psi(r)|^2$
- ΔF – free energy difference between the superconducting and normal states
- $\Delta F = \int \left\{ \frac{\hbar^2}{2\bar{m}} \left| \left(\nabla + \frac{\bar{e}}{c} A(r) \right) \psi(r) \right|^2 - a(T)|\psi(r)|^2 + \frac{b(T)}{2} |\psi(r)|^4 \right\} d^3r$
- $a(T_c) = 0$
- $\xi \sim 10^{-4} cm$ – coherence length associated with the superconducting state

Quasi-particle description

- Quasi-particles with m and v_F
- ψ_0 ground state is represented by a particular superposition of normal state configurations Φ_n
- $\Delta p \sim \hbar/\xi \sim 10^{-4} p_F$

The pairing concept

- $\Psi_0 = \sum_n a_n \Phi_n$
- $E_0 = (\Psi_0, H\psi_0) = \sum_{n,n'} a_{n'}^* a_n (\Phi_{n'}, H\Phi_n)$
- $E_B \cong \hbar\omega_D Exp[-\frac{2}{N(0)V}]$
- $H_{red} = \sum_{ks} \varepsilon_k n_{ks} - \sum_{kk'} V_{k'k} b_{k'}^+ b_k$



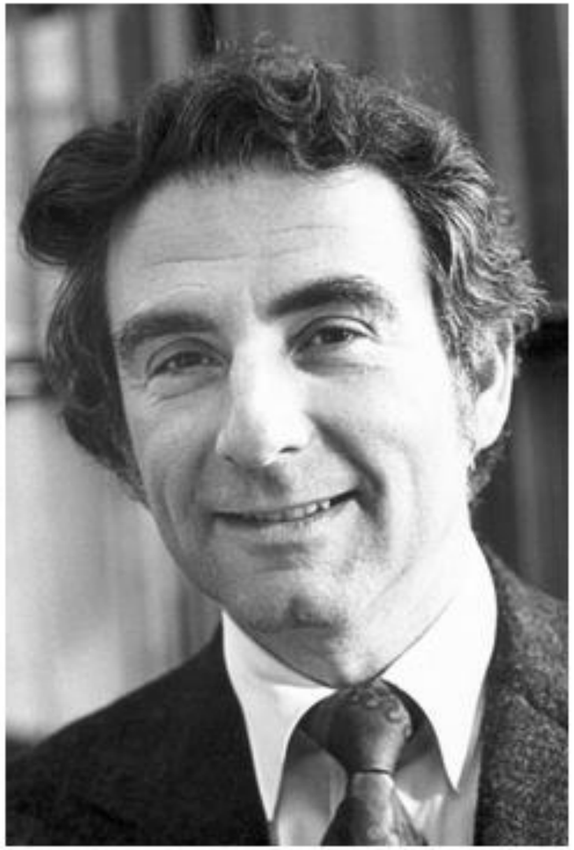
The ground state

- $\Psi_0 = \pi(u_k + v_k b_k)|0>$, where $u_k = \sqrt{1 - v_k^2}$
- $v_k^2 = \frac{1}{2}[1 - \frac{\varepsilon_k - \mu}{E_k}]$
- $E_k = \sqrt{(\varepsilon_k - \mu)^2 + \Delta_k^2}$
- $\Delta_k = -\sum V_{k'k} \frac{\Delta_{k'}}{2E_{k'}}$
- $\Delta = \hbar\omega_D Exp[-\frac{1}{N(0)V}]$ and $\Delta F = \frac{1}{2} N(0)\Delta^2$

Photo from the Nobel Foundation archive.

John Bardeen

Prize share: 1/3



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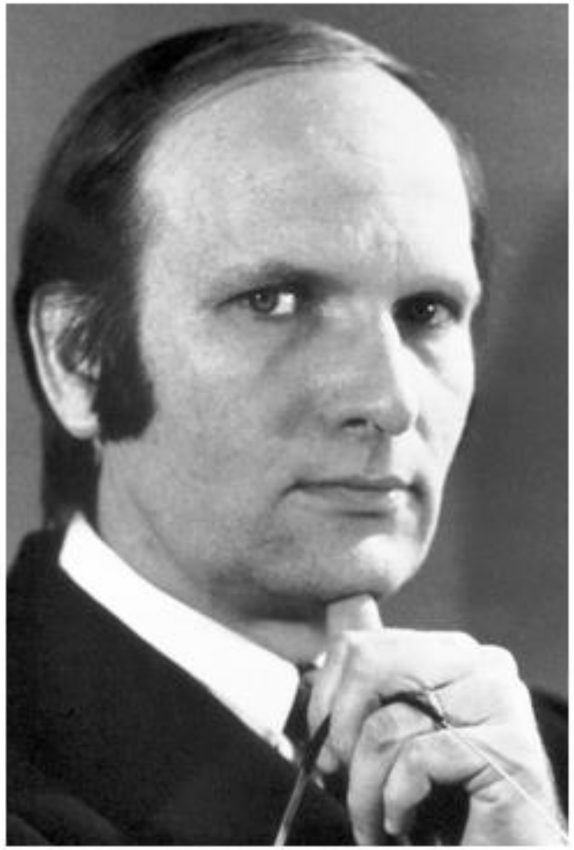
Leon Neil Cooper

Prize share: 1/3



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John Robert Schrieffer

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References

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