

Title: Spontaneous Broken Symmetry 5A

Date: Nov 29, 2007 10:00 AM

URL: <http://pirsa.org/07110023>

Abstract:

F^- ne electrons

J_s

Γ^- reflections

$$f_s = \pi_s$$

F⁻ re electrons

$$j_s = n_s e v_s$$

Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

Extra kin. energy induced by \vec{j}_s which is induced by $\vec{h} \neq 0$

Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

Extra kinetic energy induced by \vec{j}_s which is induced

0, $h(\hat{x})$ in the metal
specified by $b \cdot c$.

Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

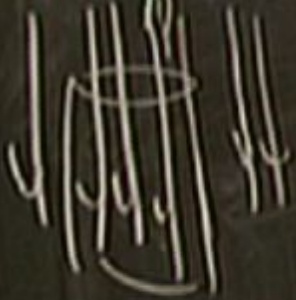
Extra kinetic energy induced by \vec{j}_s which is induced by $\vec{h} \neq 0$, $h(\vec{x})$ in the metal specified by $b < c$ outside the metal



Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

Extra kin. energy induced by \vec{j}_s which is induced by $\vec{h} \neq 0$, $h(\hat{x})$ in the metal specified by $b \cdot c$ outside the metal



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Extra kinetic energy induced by \vec{j}_s which is induced by $\vec{h} \neq 0$, $h(\hat{x})$ in the metal specified by $b \cdot c$ outside the metal



Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

Extra ^{density} momentum induced by \vec{j}_s which is induced by $\vec{h} \neq 0$, $h(\hat{x})$ in the metal specified by $b < c$ outside the metal

$$= \frac{1}{2} m n_s v_s^2$$

Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

Extra kin energy ^{density} induced by \vec{j}_s which is induced by $\vec{h} \neq 0$, $h(\hat{x})$ in the metal specified by $b \ll c$ outside the metal



$$= \frac{1}{2} m n_s v_s^2$$



Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

$$v_s = \frac{j_s}{n_s e}$$

Electron energy density induced by \vec{j}_s which is induced by $\vec{h} \neq 0$, $h(\vec{x})$ in the metal specified by b.c. outside the metal



$$= \frac{1}{2} m n_s v_s^2 = \frac{1}{2} m \frac{j_s^2}{n_s^2 e^2}$$

Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

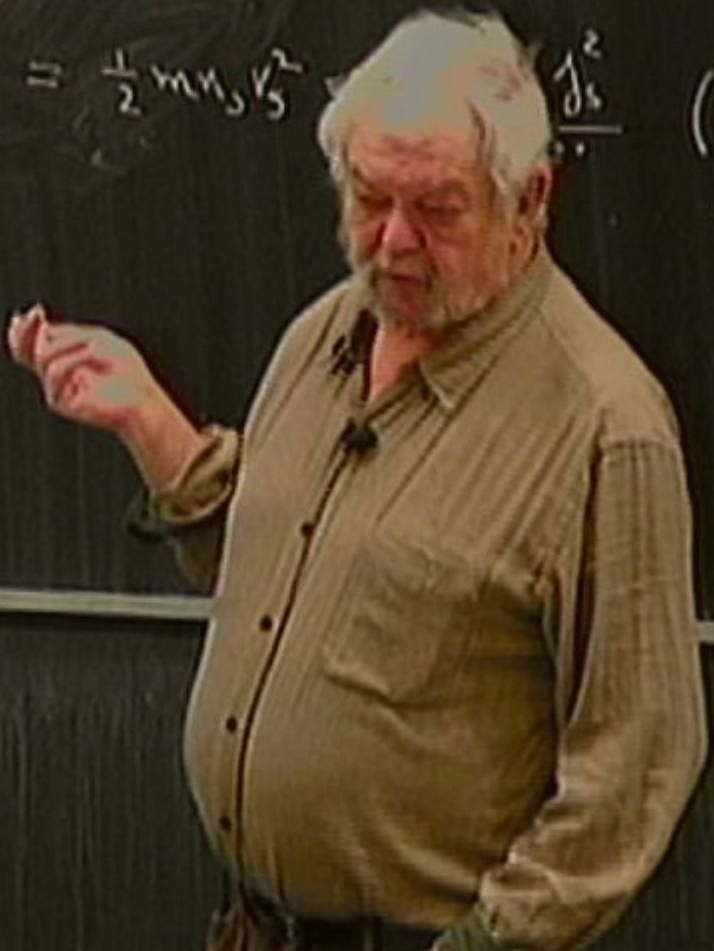
$$v_s = \frac{j_s}{n_s e}$$

Extra kin energy ^{density} induced by \vec{j}_s which is induced by $\vec{h} \neq 0$, $h(\hat{x})$ in the metal specified by $b \cdot c$ outside the metal



$$= \frac{1}{2} m n_s v_s^2 = \frac{1}{2} \frac{j_s^2}{n_s e^2}$$

(hypothesis is that j_s is not scattered i.e. it is resistanceless)



Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

$$v_s = \frac{j_s}{n_s e}$$

Extra kin energy ^{density} induced by \vec{j}_s which is induced by $\vec{h} \neq 0$, $h(\vec{x})$ in the metal specified by $b \ll c$ through the metal



$$= \frac{1}{2} m n_s v_s^2 = \frac{1}{2} m \frac{j_s^2}{n_s e^2}$$

(hypothetical
 j_s is not
 i.e. it is not
)

Free electrons

$$\vec{j}_s = n_s e \vec{v}_s$$

$$v_s = \frac{j_s}{n_s e}$$

Extra kin energy ^{density} induced by \vec{j}_s which is induced by $\vec{h} \neq 0$, $h(\vec{x})$ in the metal specified by b.c. outside the metal

$$= \frac{1}{2} m n_s v_s^2 = \frac{1}{2} m \frac{j_s^2}{n_s^2 e^2}$$

$$\nabla \times \vec{h} = \frac{1}{8\pi} \vec{j}_s$$

(hypothesis is that j_s is not scattered i.e. it is resistanceless)

Free electrons

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$$\nabla \times h = \frac{1}{8\pi} j_s$$

(hypothesis is that j_s is not scattered
i.e. it is resistanceless)

Variational base for the eq. for h .

$$F = \int \frac{h^2}{8\pi}$$

Variational base for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{m_s c^2} \int \int \nabla^2$$

$$= \int \frac{h^2}{8\pi} + \frac{m}{4\pi m_s c^2} \int \nabla \times h \int^2$$

Variational base for the eq. for h.

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{m_s c^2} \int \int \dot{s}^2$$

$$= \int \left[\frac{h^2}{8\pi} + \frac{m}{4\pi m_s c^2} (\nabla \times h)^2 \right]$$

Variational base for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{m_s c^2} \int \int \nabla^2$$

$$= \frac{1}{8\pi} \int \int \nabla^2 h^2 + \frac{m}{4\pi m_s c^2} \int \int (\nabla \times h)^2 = 0 \quad ; \quad \nabla \times \nabla \cdot \vec{h} = \vec{h}$$

Variational base for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m g_s}{m_s c^2} \int \delta s^2$$

$$= \int \left(\frac{m}{4\pi m_s c^2} \nabla \times \vec{h} \right)^2 = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

Variational basis for the eq. for h .

$$F = \int \frac{h^2}{4\pi} + \frac{4\pi m g}{\alpha_3 c^2} \int \delta^2$$

$$= \int \left(\frac{1}{4\pi} \delta \left[\int \frac{h^2}{4\pi} + \frac{m}{4\pi \alpha_3 c^2} \nabla \times h \right]^2 \right) = 0 \quad ; \quad \nabla \times \nabla \cdot \vec{h} + \nabla^2 \vec{h} = 0$$

Variational base for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m g_s}{m_s c^2} \int \delta^2$$

$$= \int \left(\frac{1}{8\pi} \left[\dot{h}^2 + \frac{m}{4\pi m_s c^2} \nabla \times h \right]^2 \right) = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\frac{m}{4\pi m_s c^2}$$

Variational base for the eq. for h .

$$F = \int \frac{h^2}{4\pi} + \frac{4\pi m g_s}{\alpha_s c^2} \int \delta^2$$

$$= \int \left(\frac{1}{4\pi} \left[\left(\frac{\partial h}{\partial t} \right)^2 + \frac{m}{4\pi \alpha_s c^2} \nabla \times h \right]^2 \right) = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi \alpha_s c^2}$$

Variational base for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{m_0 c^2} \int \delta^2$$

$$= \int \left(\frac{1}{8\pi} \left[\nabla \vec{h} \right]^2 + \frac{m}{4\pi m_0 c^2} \left[\nabla \times \vec{h} \right]^2 \right) = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi m_0 c^2}$$

Variational calc for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{\mu_0 c^2} \int \delta^2$$

$$= \int \left(\frac{h^2}{8\pi} + \frac{m}{4\pi\mu_0 c^2} (\nabla \times \vec{h})^2 \right) = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi\mu_0 c^2}$$



$$\left(\frac{d^2}{dx^2} - \lambda_L^2 \right) h_z = 0$$

$$h_z = e^{-\lambda_L x}$$

x into wire

Variational calc for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{\hbar^2 c^2} \int \psi^2$$

$$= \int \left(\frac{h^2}{8\pi} + \frac{m}{4\pi\hbar^2 c^2} (\nabla \times \vec{h})^2 \right) = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi\hbar^2 c^2}$$



$$\left(\frac{d^2}{dx^2} - \lambda_L^2 \right) h_z = 0$$

$$h_z = e^{-\lambda_L x}$$

x into wall

Variational calc. for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{m_0 c^2} \int \delta^2$$

$$= \int \left(\frac{h^2}{8\pi} + \frac{m}{4\pi m_0 c^2} \nabla \times h \right)^2 = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi m_0 c^2}$$

$$= 0(a^{-2})$$

a = interatomic dist.



$$\left(\frac{d^2}{dx^2} - \lambda_L^2 \right) h_2 = 0$$

$$h_2 = e^{-\lambda_L x}$$

x into metal

Variational basis for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{\alpha_2 c^2} \int_S h^2$$

$$= \int \left(\frac{h^2}{8\pi} + \frac{m}{4\pi\alpha_2 c^2} \nabla \times h \right)^2 = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi\alpha_2 c^2}$$



$$\left(\frac{d^2}{dx^2} - \lambda_L^2 \right) h_z = 0$$

$$h_z = e^{-\lambda_L x}$$

x into wire

$$j = O(a^{-3}) \quad a = \text{interwire dist.}$$

$$\lambda_L^2 / a^2 = \frac{(m/a^2)}{(c^2/a)}$$

Variational calc for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{\alpha_s c^2} \int d^3s$$

$$= \frac{1}{8\pi} \int \left(\nabla \vec{h} \right)^2 + \frac{m}{4\pi \alpha_s c^2} \left(\nabla \times \vec{h} \right)^2 = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi \alpha_s c^2} \quad ; \quad \int \vec{h} \quad \left(\frac{d^2}{dx^2} - \lambda_L^2 \right) h_2 = 0 \quad h_2 = e^{-\lambda_L x}$$

x into middle

$$\alpha_s = O(a^{-3}) \quad a = \text{interference dist.}$$

$$\lambda_L^2 / a^2 = \frac{(m/a^2)}{(c^2/a)} = O(1)$$

Variational ansatz for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{a_s c^2} \int d^3s$$

$$= \int \left(\frac{1}{8\pi} (\nabla h)^2 + \frac{m}{4\pi a_s c^2} h^2 \right) = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi a_s c^2} \quad ; \quad \left(\frac{d^2}{dx^2} - \lambda_L^2 \right) h_2 = 0 \quad h_2 = e^{-\lambda_L x}$$

x into middle

$a_s < 0 (a^{-3})$ a : interatomic distance

$$\lambda_L^2 / a^2 = \frac{(m/a^2)}{(c^2/a)} = \mathcal{O}(\dots) \text{ atomic scale characteristic}$$

Variational ansatz for the eq. for h .

$$F = \int \frac{h^2}{8\pi} + \frac{4\pi m}{a_0 e^2} \int \delta^2$$

$$= \int \left(\frac{h^2}{8\pi} + \frac{m}{4\pi a_0 e^2} \nabla \times h \right)^2 = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi a_0 e^2} \quad ; \quad \int \delta^2 \quad \left(\frac{d^2}{dx^2} - \lambda_L^2 \right) h_2 = 0 \quad h_2 = e^{-\lambda_L x}$$

$\lambda_L^2 < O(a^{-1})$ a : interatomic dist.

λ into units

$$\lambda_L^2 / a^2 = \frac{(m/a^2)}{(e^2/a)} = O(1) \quad ; \quad \lambda_L^2 \text{ is atomic in character}$$

Variational basis for the eq. for h .

$$F = \int \frac{h^2}{2\pi} + \frac{4\pi m}{\mu_0 \epsilon^2} \int \mathcal{L}^2$$

$$= \int \left(\frac{h^2}{2\pi} + \frac{m}{4\pi \mu_0 \epsilon^2} \left[\nabla \times \vec{h} \right]^2 \right) = 0 \quad ; \quad \nabla \times \nabla \times \vec{h} + \lambda_L^2 \vec{h} = 0$$

$$\lambda_L^2 = \frac{m}{4\pi \mu_0 \epsilon^2}$$



$$\left(\frac{d^2}{dx^2} - \lambda_L^2 \right) h_z = 0$$

$$h_z = e^{-\lambda_L x}$$

x into wire

$$\mu_0 < O(a^{-3}) \quad a = \text{interatomic dist.}$$

$$\lambda_L^2 / a^2 = \frac{(m/a^2)}{(e^2/a)} = O(1) \quad ; \quad \lambda_L \gg \text{atomic characteristic}$$

BCS theory

BCS theory



Fermi sphere

BCS theory

$T=0$

$n(k) = 1$

$\vec{k} < k_F$



Fermi sphere

BCS theory



Fermisphere

$$\underline{T=0}$$

$$n(k) = 1$$

$$|\vec{k}| < k_F$$

$$\frac{V k_F^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$

BCS theory



Fermi sphere

$$\frac{T=0}{\mu(k)=1} \quad \vec{k} < k_F$$

$$2 \frac{V k_F^3}{(2\pi)^3} \frac{4\pi}{3} = N$$

BCS theory



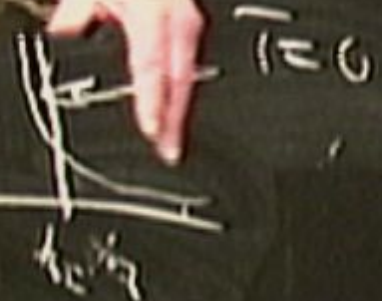
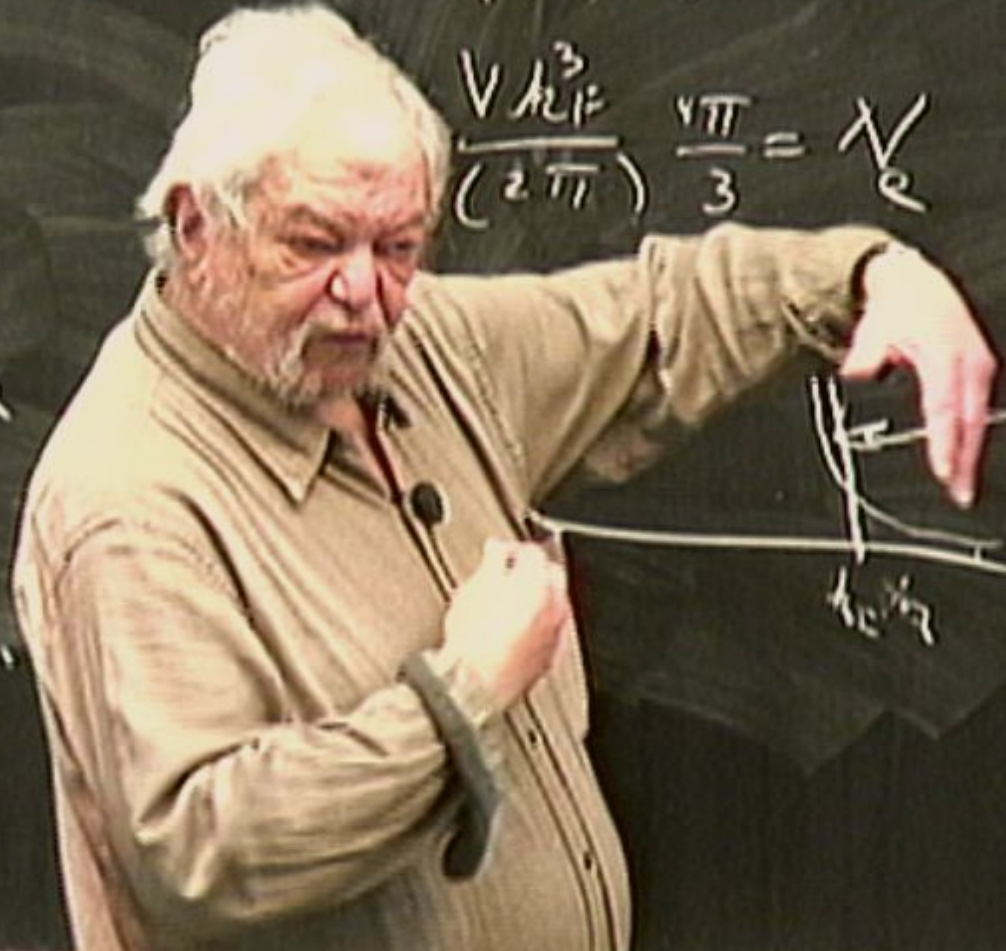
Fermisphere

$$T=0$$

$$n(k) = 1$$

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$$\frac{V k_F^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$



BCS theory

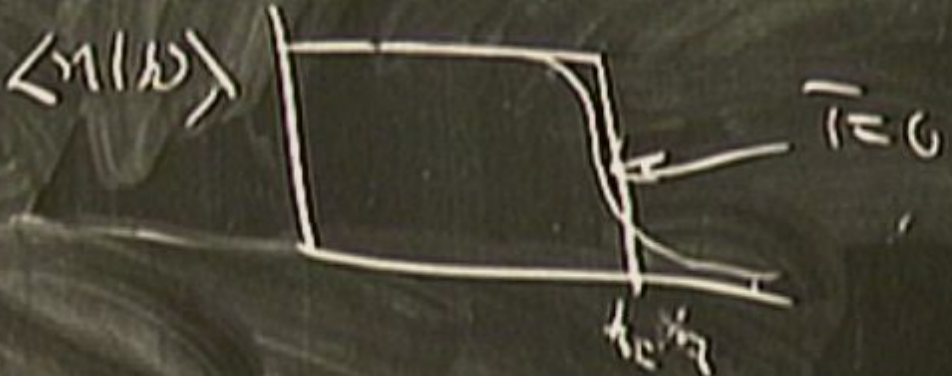


Fermisphere

$T=0$

$n(k) = 1 \quad \vec{k} < k_F$

$2 \frac{V k_F^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$



BCS theory

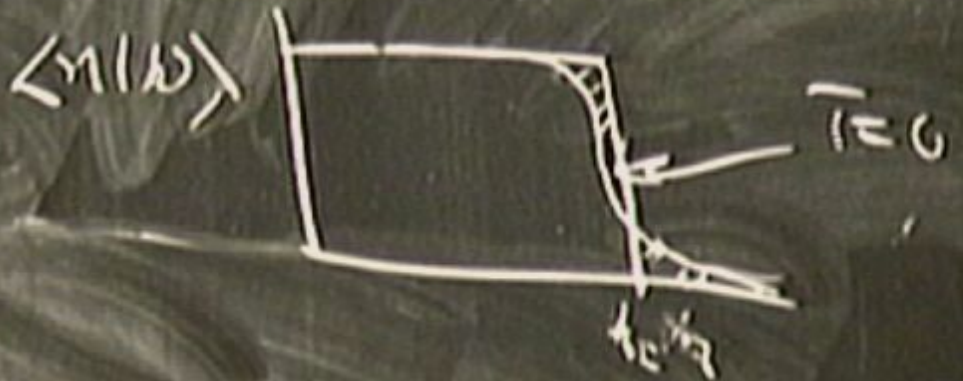


Fermisphere

$$T=0$$

$$n(\mathbf{k}) = 1 \quad \text{for } |\mathbf{k}| < k_F$$

$$2 \frac{V k_F^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$



BCS theory

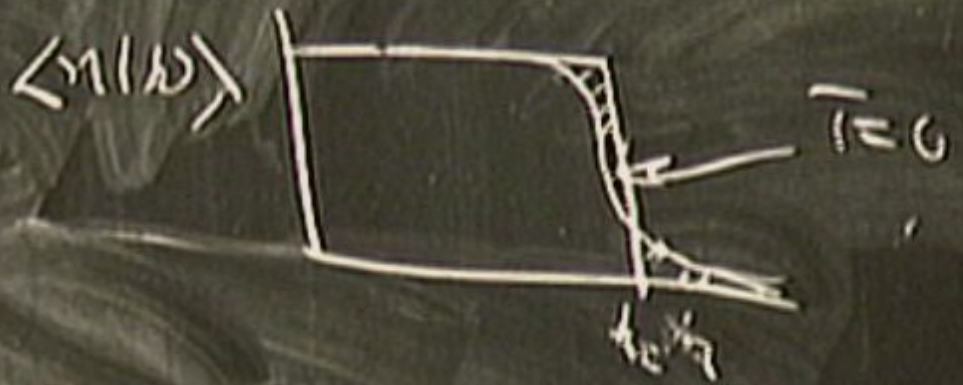


Fermisphere

$T=0$

$n(k) = 1 \quad \vec{k} < k_F$

$2 \frac{V k_F^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$



BCS theory



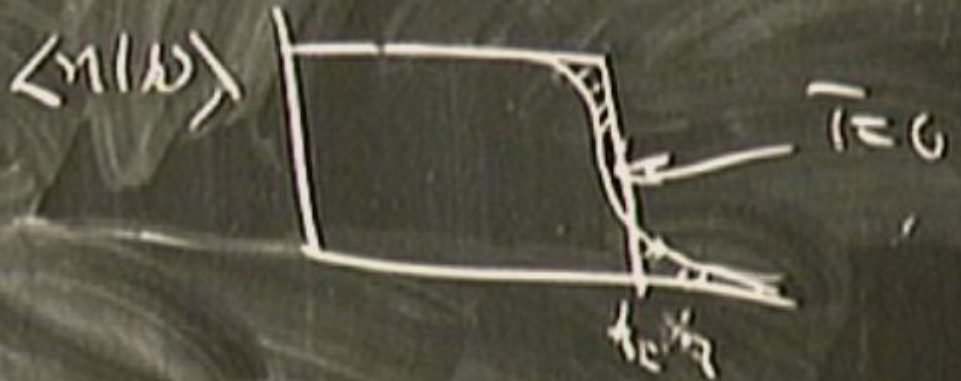
Fermisphere

$$T=0$$

$$n(k) = 1$$

$$|\vec{k}| < k_F$$

$$2 \frac{V k_F^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$



BCS theory



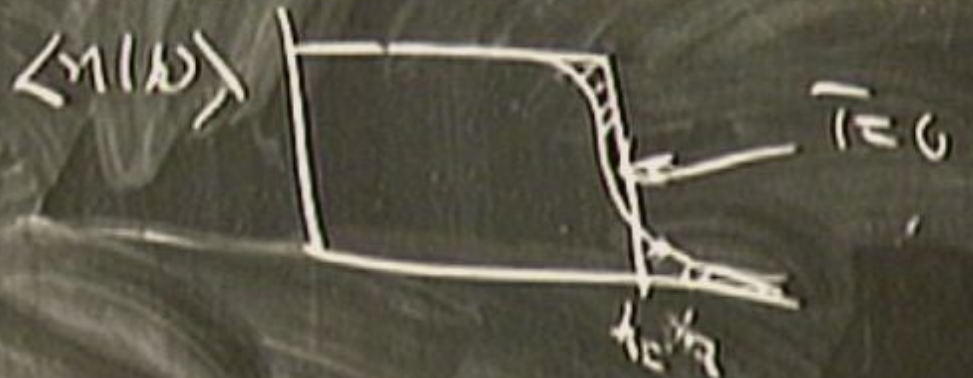
Fermi sphere

$$T=0$$

$$n(k) = 1$$

$$|\vec{k}| < k_F$$

$$2 \frac{V k_F^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$



BCS theory



Fermisphäre

x x

$$\frac{\hbar^2}{mR^2}$$

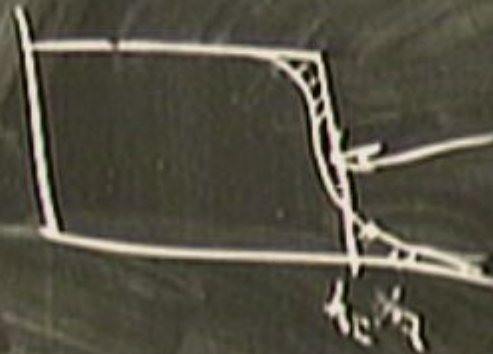
$$T=0$$

$$n(k) = 1$$

$$|\vec{k}| < k_F$$

$$2 \frac{\sqrt{4}^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$

$\langle n(\omega) \rangle$



$T=0$

BCS theory

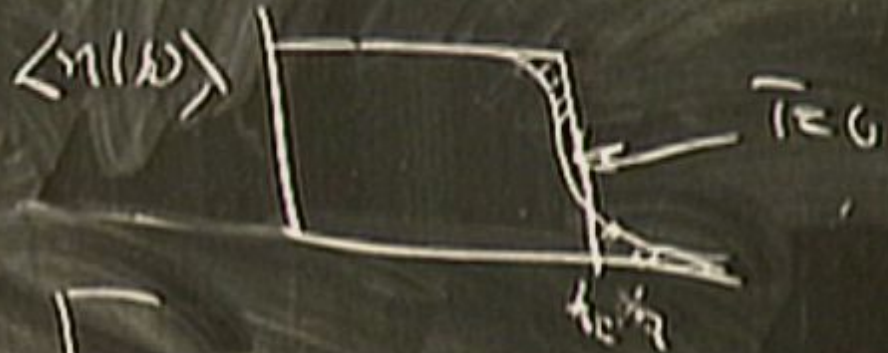


$$T=0$$

$$n(k) = 1 \quad \vec{k} < k_F$$

$$2 \frac{V N_F^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$

sphere



BCS theory



Fermisphere

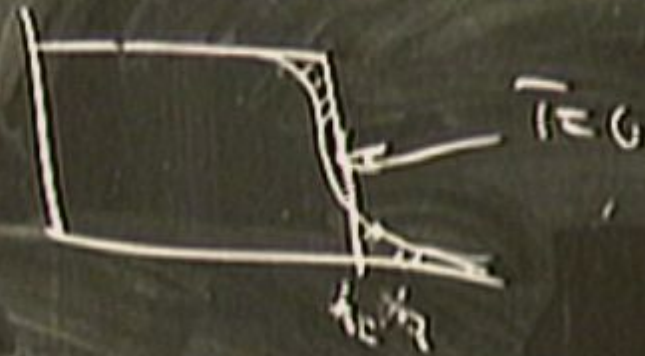
$$T=0$$

$$n(k) = 1$$

$$|\vec{k}| < k_F$$

$$2 \frac{V N k_F^3}{(2\pi)^3} \frac{\sqrt{\pi}}{3} = N \rho$$

$\langle n(k) \rangle$



$$\frac{J}{mR^2} < v$$



BCS theory



Fermisphere

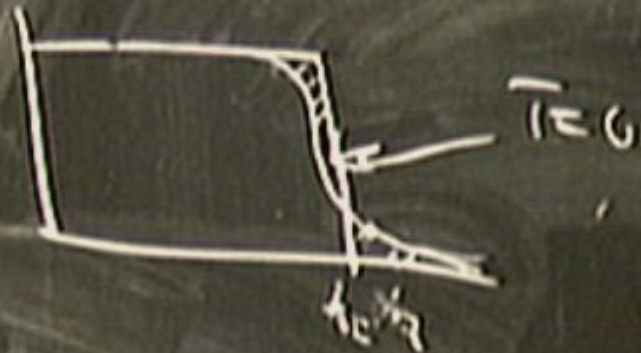
$$T=0$$

$$n(k) = 1$$

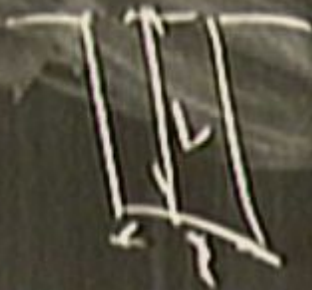
$$|\vec{k}| < k_F$$

$$2 \frac{V N_{\vec{k}}^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$

$\langle n(k) \rangle$



$$\frac{J}{mR^2} < |V|$$



BCS theory

$$T=0$$

$$n(k) = 1$$

$$|\mathbf{k}| < k_F$$

$$2 \frac{V N_{k_F}^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$



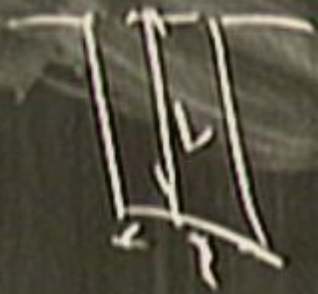
Fermi sphere

$\langle n(k) \rangle$



$T=0$

$$\frac{m v_F^3}{m R^3} \langle |v| \rangle$$



BCS theory



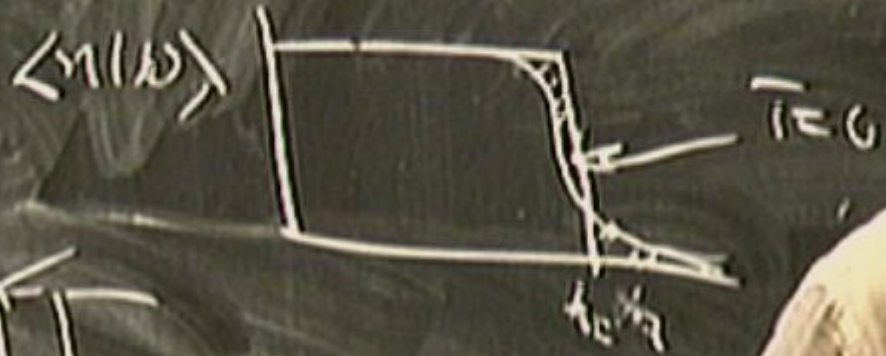
Fermisphere

$T=0$

$n(k) = 1$

$|\vec{k}| < k_F$

$2 \frac{V N_F^3}{(2\pi)^3} \frac{\sqrt{\pi}}{3} = N_e$



BCS theory



Fermi sphere

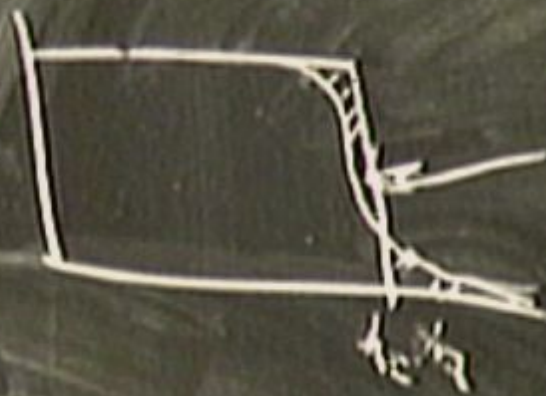
$$\bar{T} = 0$$

$$n(k) = 1$$

$$|\vec{k}| < k_{\text{F}}$$

$$2 \frac{V k_{\text{F}}^3}{(2\pi)^3} \frac{4\pi}{3} = N_e$$

$\langle n(k) \rangle$



$T=0$



BCS theory



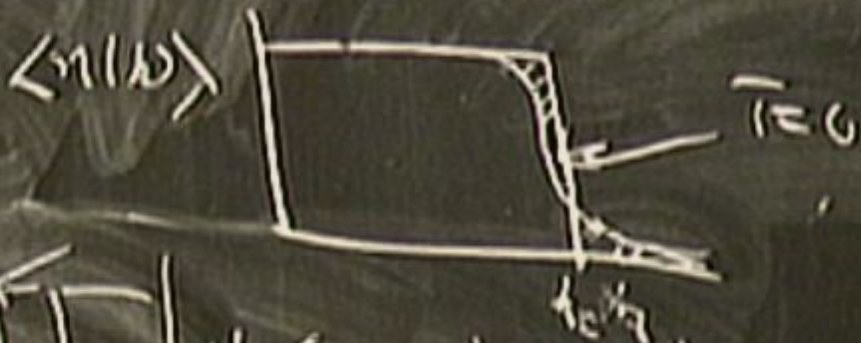
Fermisphere

$T=0$

$n(k) = 1$

$\hbar k < \hbar k_F$

$2 \frac{V \hbar k_F^3}{(2\pi)^3} \frac{\sqrt{\pi}}{3} = N_0$



N_0 : Cooper shows tendency for relations about a passive F of k_F

BCS theory

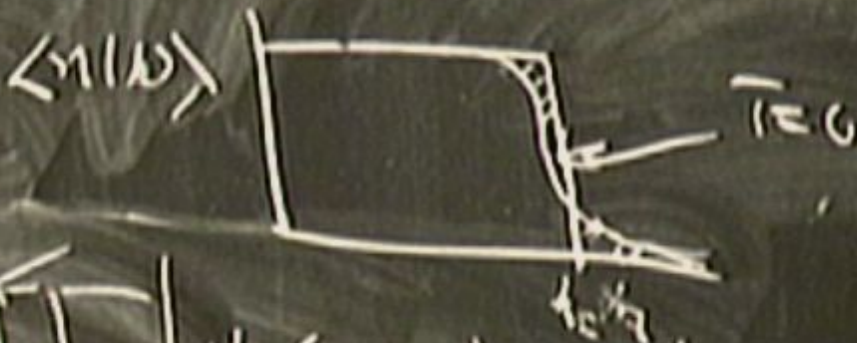


Fermisphere

$$T=0$$

$$n(k) = 1 \quad \hbar k < \hbar k_F$$

$$2 \frac{V \hbar k_F^3}{(2\pi)^3} \frac{\sqrt{\pi}}{3} = N_e$$



No: Cooper shows binding
for 2 electrons about a positive F of holes