

Title: 13/14 PSI - Condensed Matter - Lecture 9

Date: Nov 21, 2013 10:45 AM

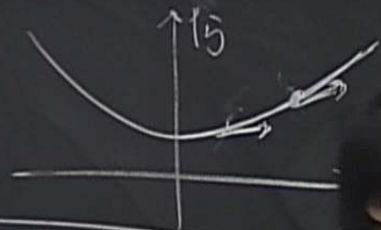
URL: <http://pirsa.org/13110037>

Abstract:

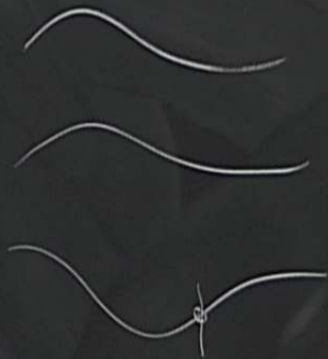
spin-orbital coupling

$$\langle \vec{S}(t) | \vec{S}(t+st) \rangle = e^{i s \phi}$$

$\uparrow B$



crystal



$$\langle \vec{S}(t) | \vec{S}(t+\delta t) \rangle =$$

$$\vec{k}^i = -\frac{\partial \phi}{\partial x^i}$$

$$\dot{x}^i = \frac{\partial \mathcal{L}}{\partial k^i} + D^j k_j$$

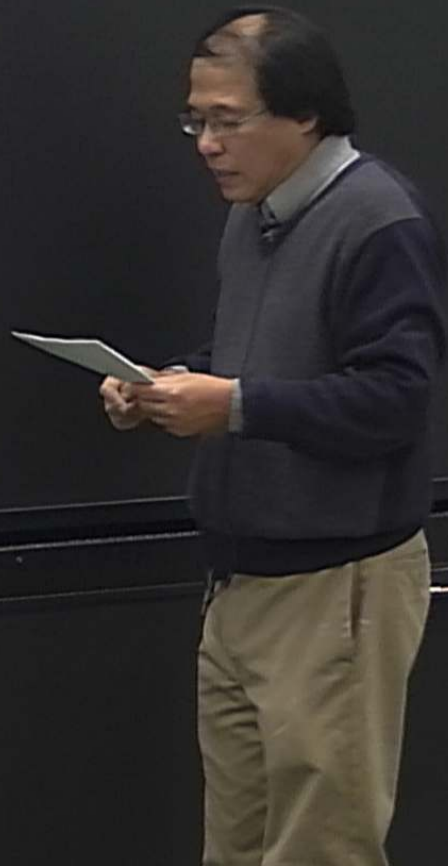
$$D^j = \frac{\partial C^i}{\partial k^i} - \frac{\partial C^j}{\partial k^j}$$

$$C^i(\vec{k}) = i \psi_d^\dagger(\vec{k}) \frac{\partial}{\partial k^i} \psi_d(\vec{k})$$

$$\bar{k}_i = e E_i - \gamma^{-1} \dot{x}^i, \quad \dot{x}^i = (M^{-1})^{ij} k_j + D^i$$

$$\bar{k}_i = e E_i - \gamma^{-1} \dot{x}^i, \quad \dot{x}^i = \frac{\partial \mathcal{E}}{\partial k_j} + D^i_j \dot{k}_j$$

$$\vec{k} = e \vec{E} - \gamma m^{-1} \vec{k}$$



$$\vec{k} = e \vec{E} - \gamma \underbrace{M^{-1}}_{\frac{\partial \epsilon}{\partial \vec{k}}} \vec{k}$$

$$\vec{x} = M^{-1} \vec{k}$$

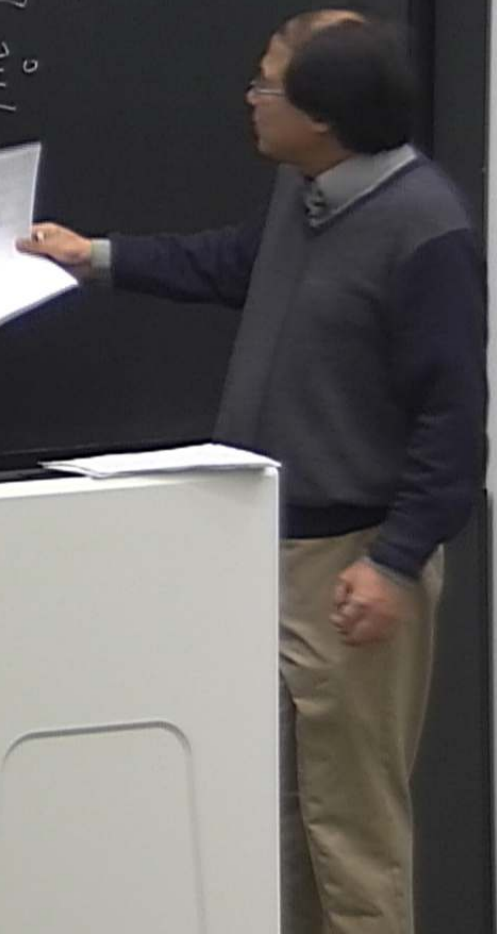


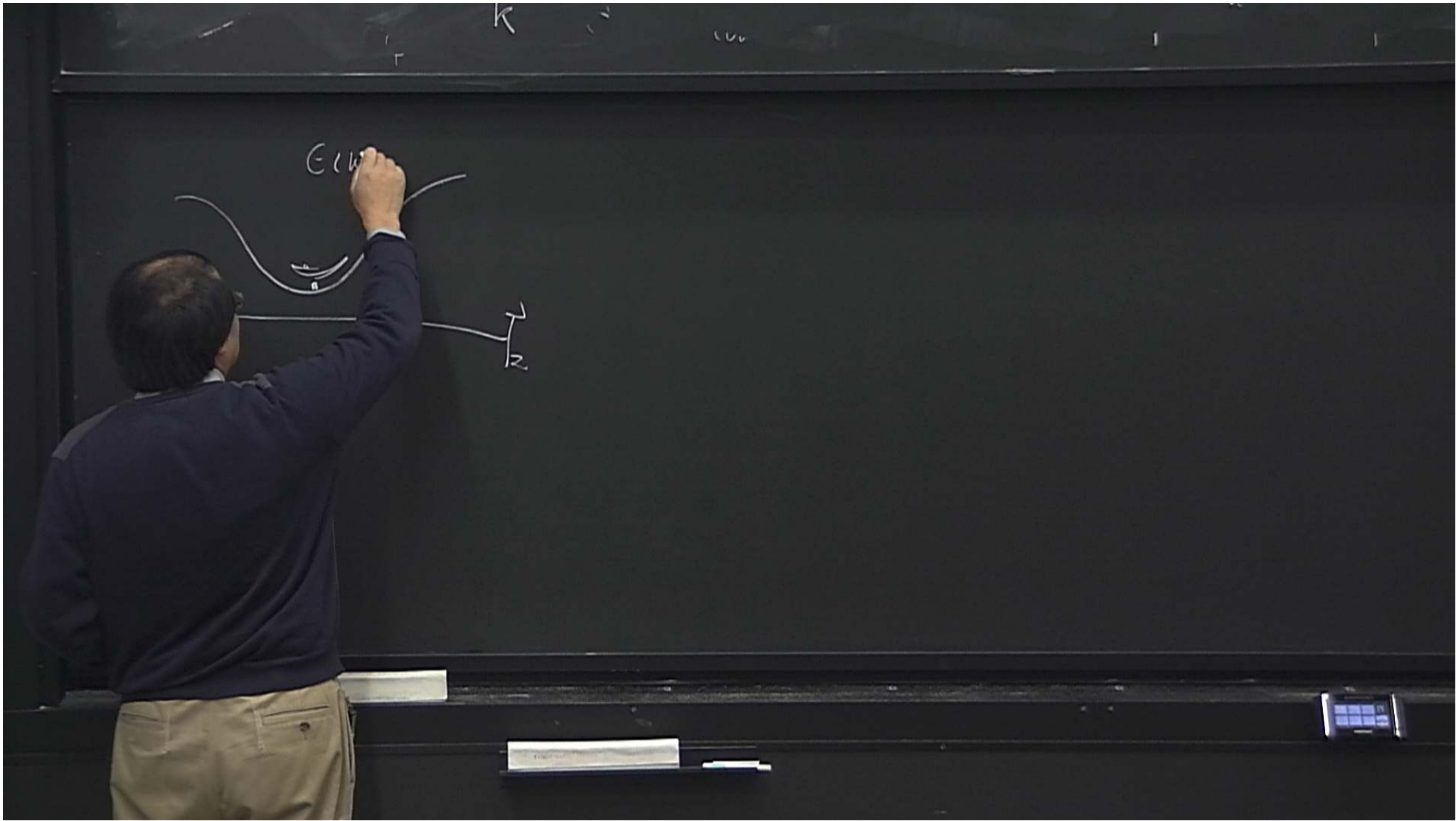
$$\frac{\dot{\vec{x}}}{-i\omega\vec{x}} = M^{-1}\vec{k} + D(e\vec{E} - \gamma^{-1}M^{-1}\vec{k})$$

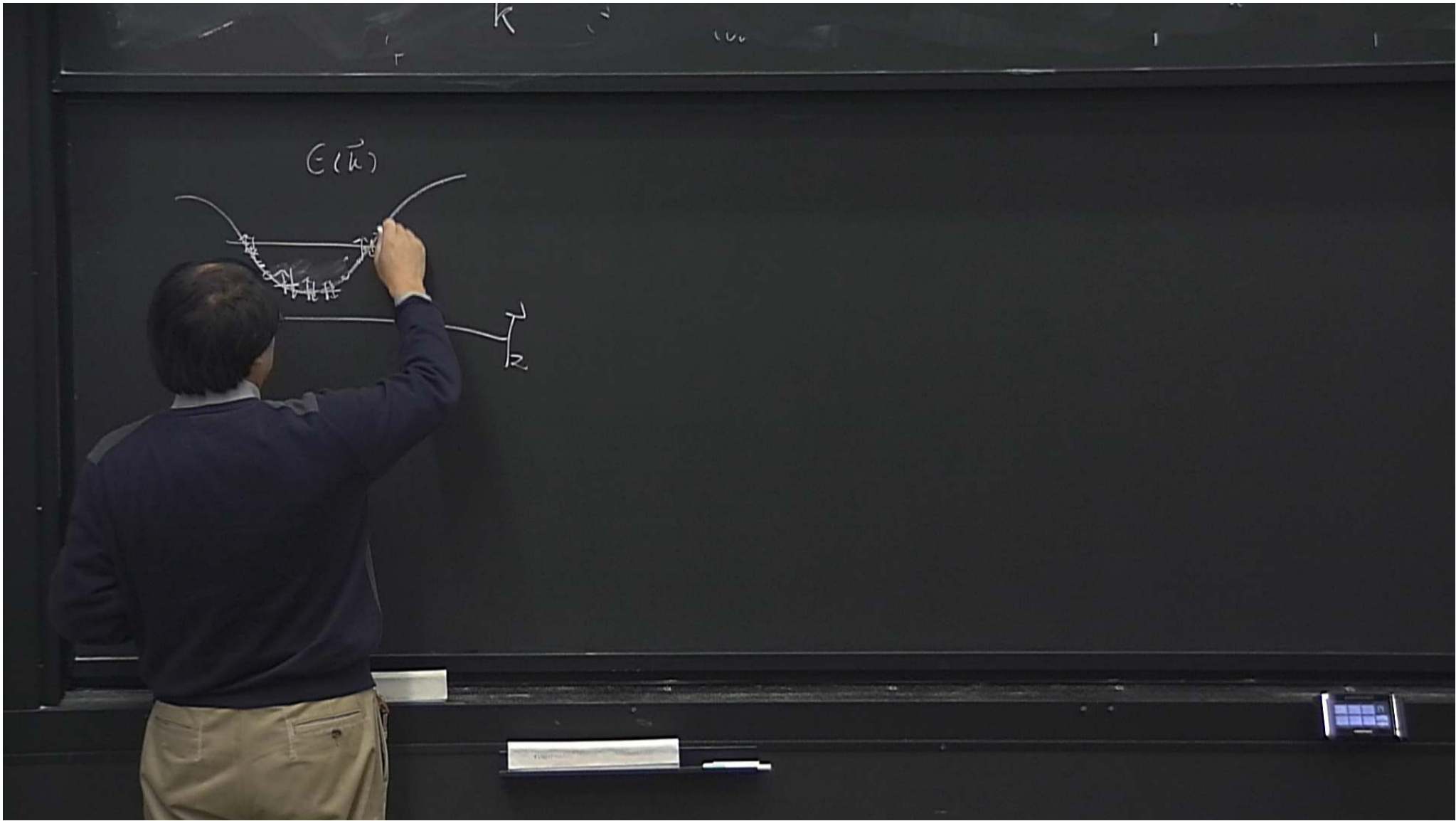
$$\boxed{\dot{\vec{x}} = e\gamma\vec{E}^0} \quad \left| \omega=0 \right.$$

$$\dot{\vec{x}} = e D \vec{E}^0$$

$$\boxed{\vec{x} = e\gamma(1-i\omega DM)(1-i\gamma\omega M)^{-1}\vec{E}^0}$$







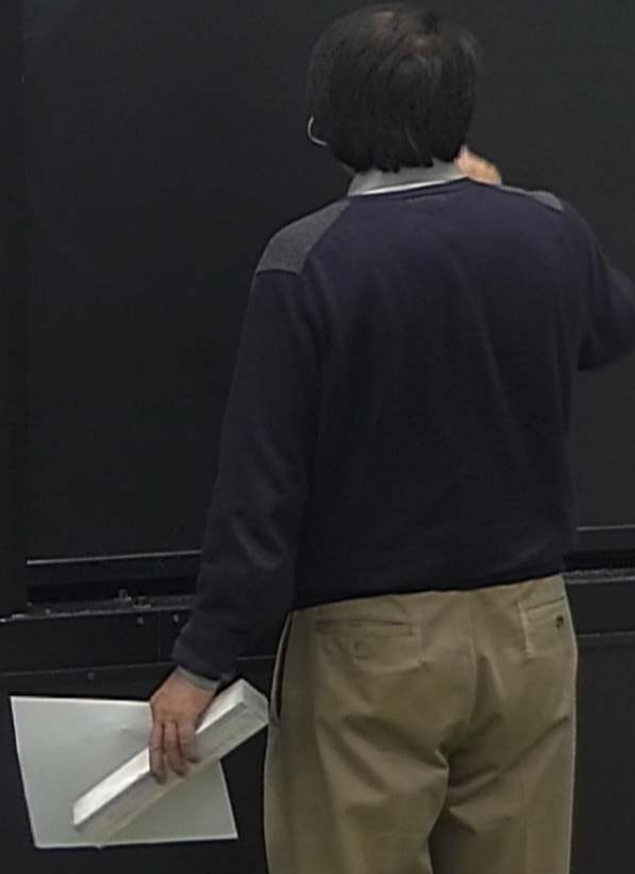
$$g(\vec{r}, \vec{k})$$

$$dN = \frac{d^3\vec{r} d^3\vec{k}}{(2\pi)^3}$$


$$g(\vec{r}, \vec{k})$$

$$\int d^3\vec{r} = \int \frac{d^3\vec{k}}{(2\pi)^3} g(\vec{r}, \vec{k})$$

$$dN(t) = dN(t-st)$$



$$dN(t) = dN(t-st)$$

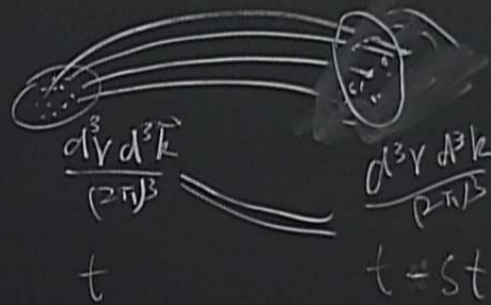


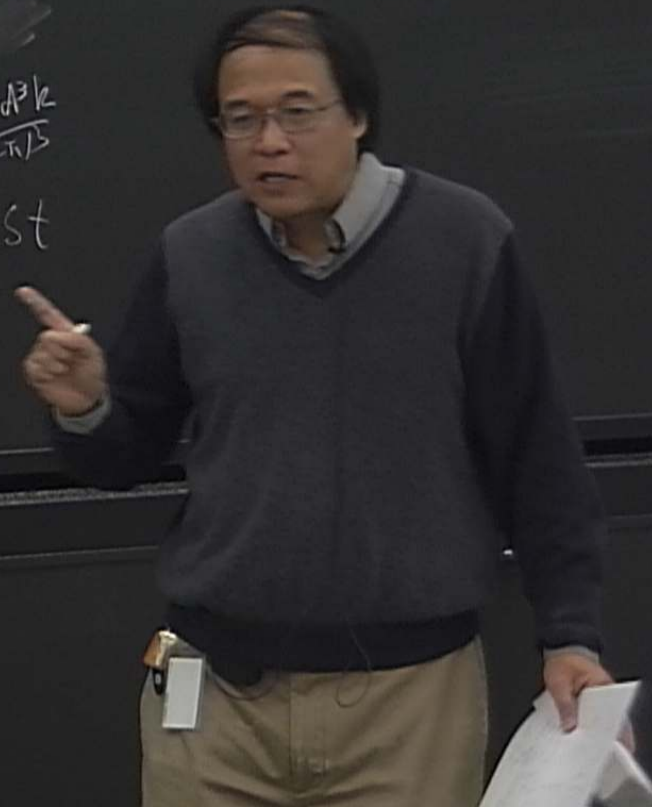
A diagram showing a particle's trajectory. A small circle with a central dot represents the particle at time t . Three curved lines extend from it to the right, representing its path. A larger circle is drawn at the end of these lines, representing the particle's position at a later time $t+st$.

$$\frac{d^3v d^3k}{(2\pi)^3}$$
$$t$$

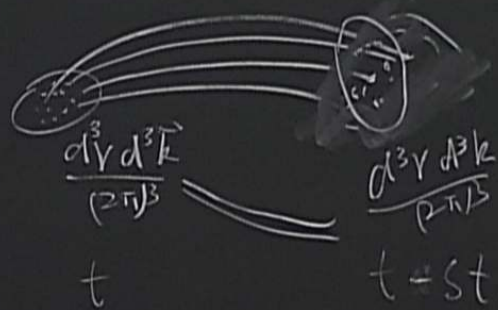
$$\underline{dN(t)} = \underline{dN(t-st)}$$

$$\frac{d}{dt} j = 0$$


$$\frac{d^3y d^3k}{(2\pi)^3} \quad t$$
$$\frac{d^3y d^3k}{(2\pi)^3} \quad t-st$$



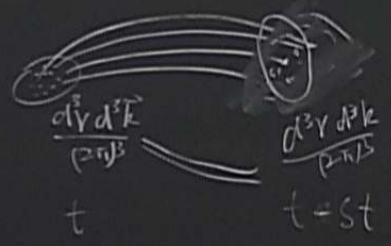
$$\underline{dN(t)} = \underline{dN(t-st)}$$



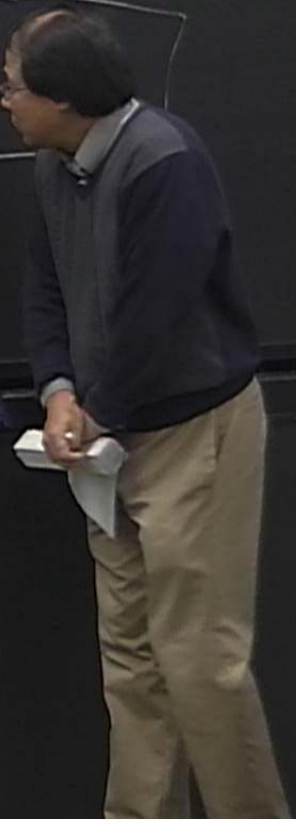
$$\frac{d}{dt} J(\vec{y}(t), \vec{k}(t), t) = 0$$

$$\underline{dN(t)} = \underline{dN(t-st)}$$

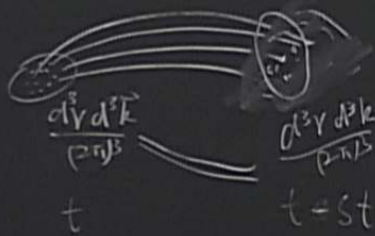
$$\frac{d}{dt} J(\vec{r}(t), \vec{k}(t), t) = 0$$



$$\frac{d}{dt} J = \frac{\partial J}{\partial t} + \vec{v} \cdot \frac{\partial J}{\partial \vec{r}} + \vec{k} \cdot \frac{\partial J}{\partial \vec{k}}$$



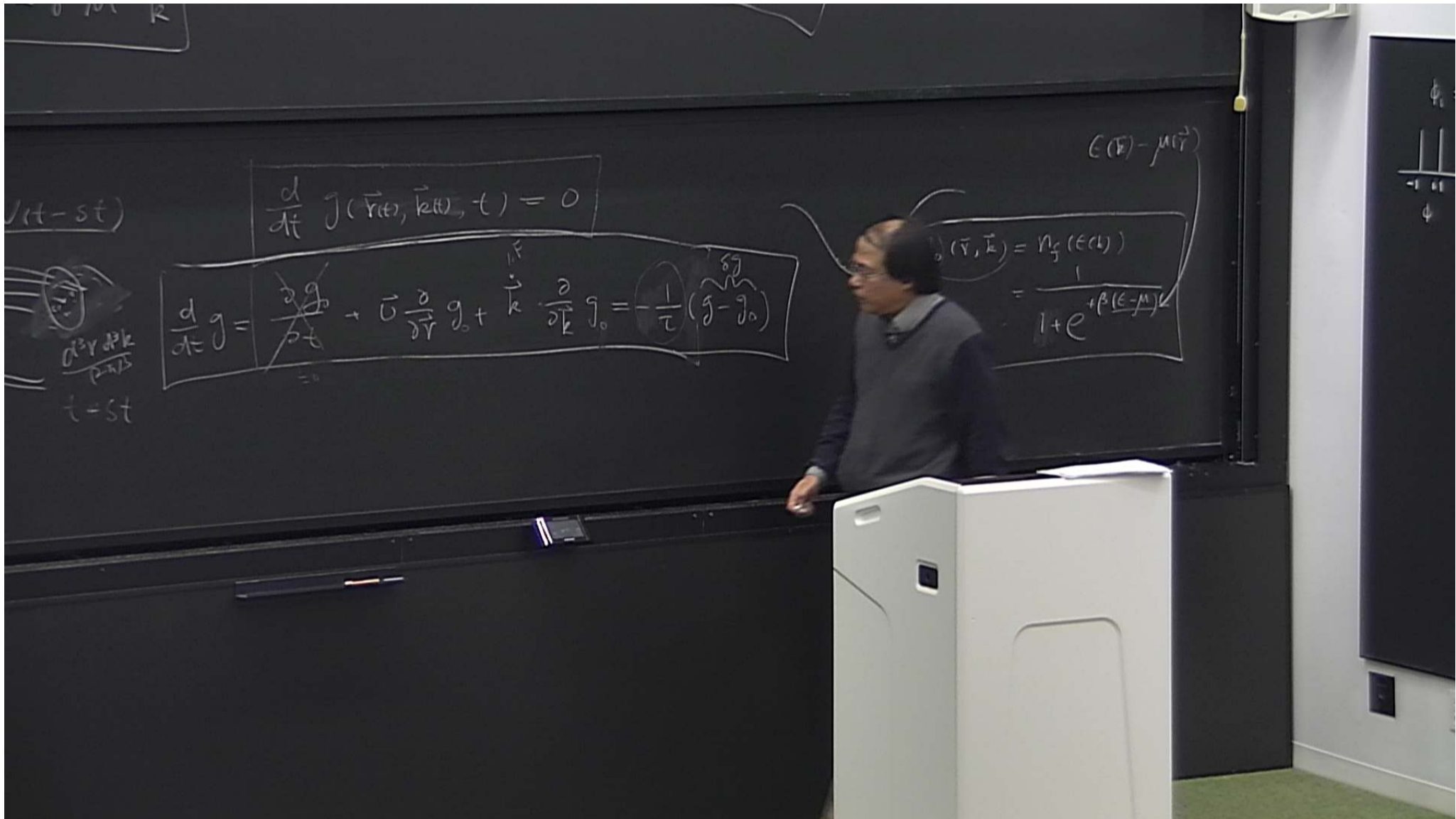
$$\underline{dN(t)} = \underline{dN(t-st)}$$



$$\frac{d}{dt} J(\vec{r}(t), \vec{k}(t), t) = 0$$

$$\frac{d}{dt} g = \frac{\partial g}{\partial t} + \vec{v} \cdot \frac{\partial}{\partial \vec{r}} g + \vec{k} \cdot \frac{\partial}{\partial \vec{k}} g = 0$$

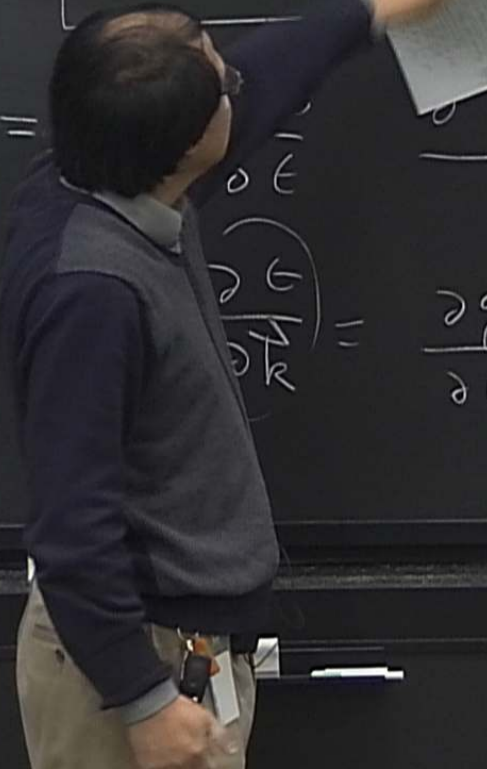




$$(g - g_0) = \delta g = - \frac{\partial g_0}{\partial \epsilon} \tau \vec{U} \cdot (-\nabla \mu + \vec{F})$$

$$\frac{\partial g_0}{\partial \vec{Y}} = \frac{\partial g_0}{\partial \epsilon} \frac{\partial \epsilon}{\partial \vec{Y}}$$

$$\frac{\partial g_0}{\partial \vec{k}} = \frac{\partial g_0}{\partial \epsilon} \left(\vec{U} - D \vec{k} \right)$$



$$(g - g_0) = \delta g = - \frac{\partial g_0}{\partial \epsilon} \tau \vec{U} \cdot (-\nabla \mu + \vec{F})$$

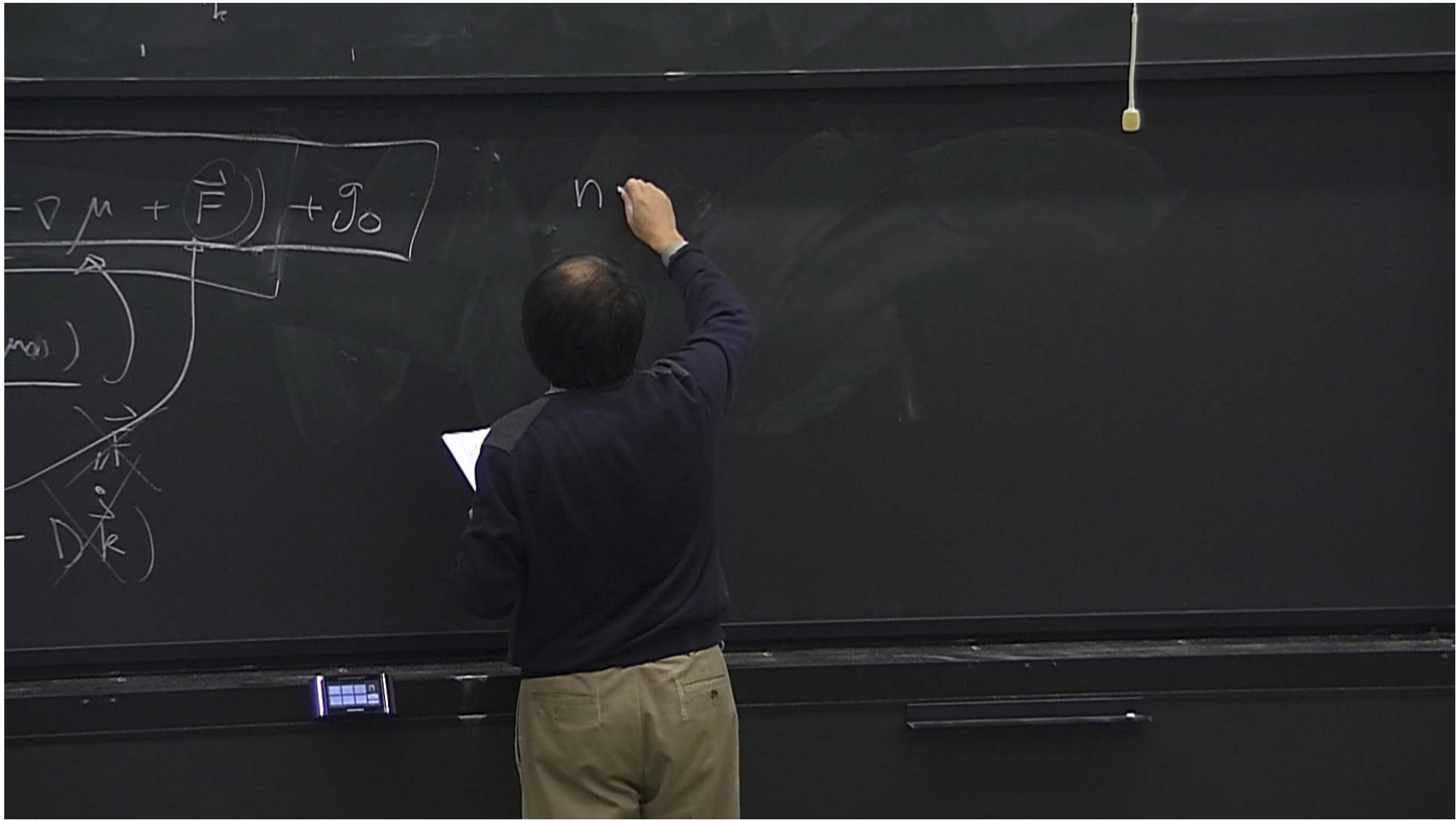
$$\frac{\partial g_0}{\partial \vec{Y}} = \frac{1}{\beta} \frac{\partial g_0}{\partial \epsilon} \frac{\partial (\rho(\epsilon - \mu))}{\partial \vec{Y}}$$

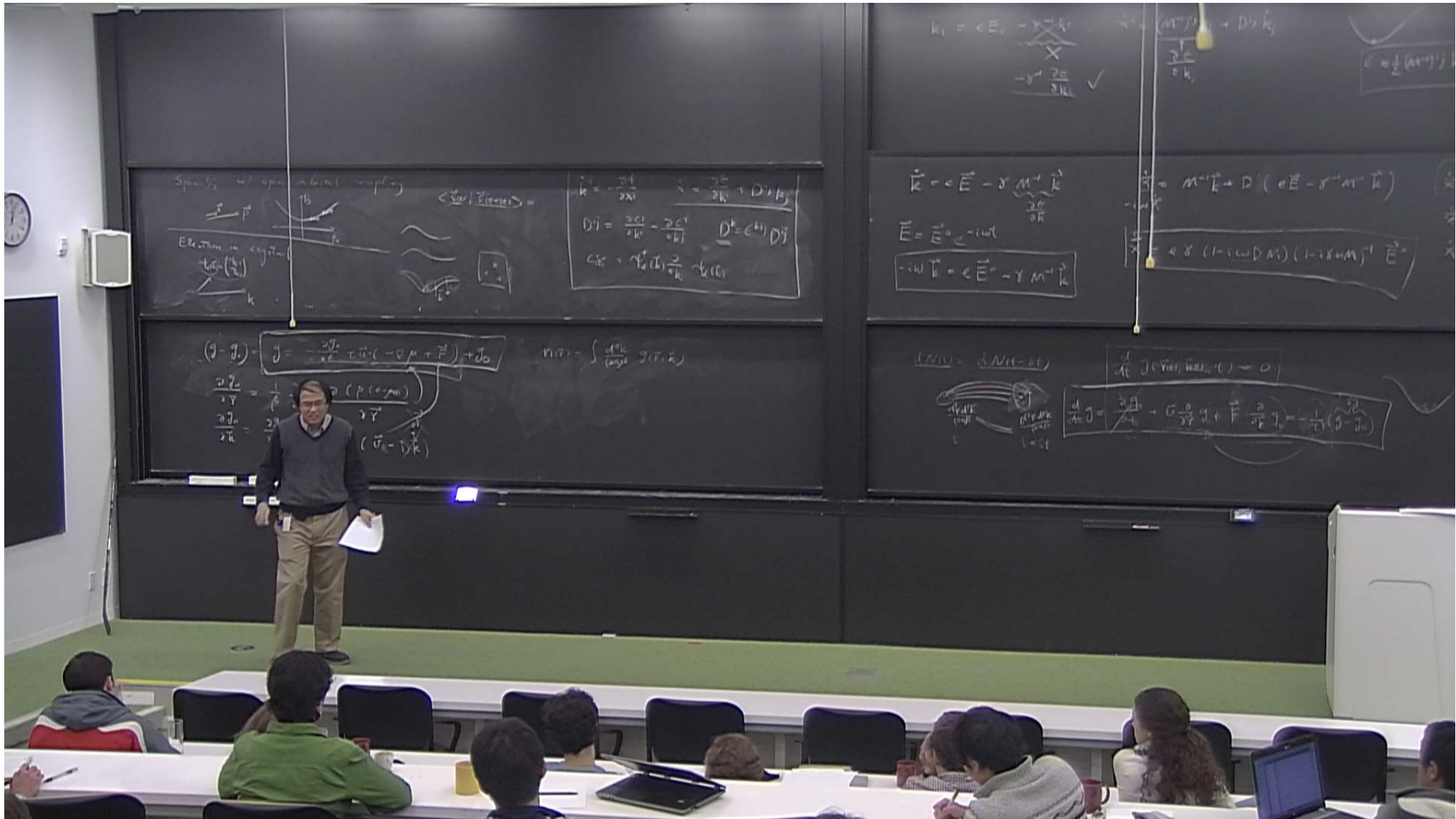
$$\frac{\partial g_0}{\partial \vec{k}} = \frac{\partial g_0}{\partial \epsilon} \left(\frac{\partial \epsilon}{\partial \vec{k}} \right) = \frac{\partial g_0}{\partial \epsilon} (\dots)$$

$$(g - g_0) = \delta g = - \frac{\partial g_0}{\partial \epsilon} \tau \vec{U} \cdot (-\nabla \mu + \vec{F})$$

$$\frac{\partial g_0}{\partial \vec{Y}} = \frac{g_0}{\epsilon} \frac{\partial (\rho(\epsilon - \mu))}{\partial \vec{Y}}$$

$$\frac{\partial g_0}{\partial \vec{k}} = \frac{\partial g_0}{\partial \epsilon} \left(\vec{U} - D \vec{k} \right)$$

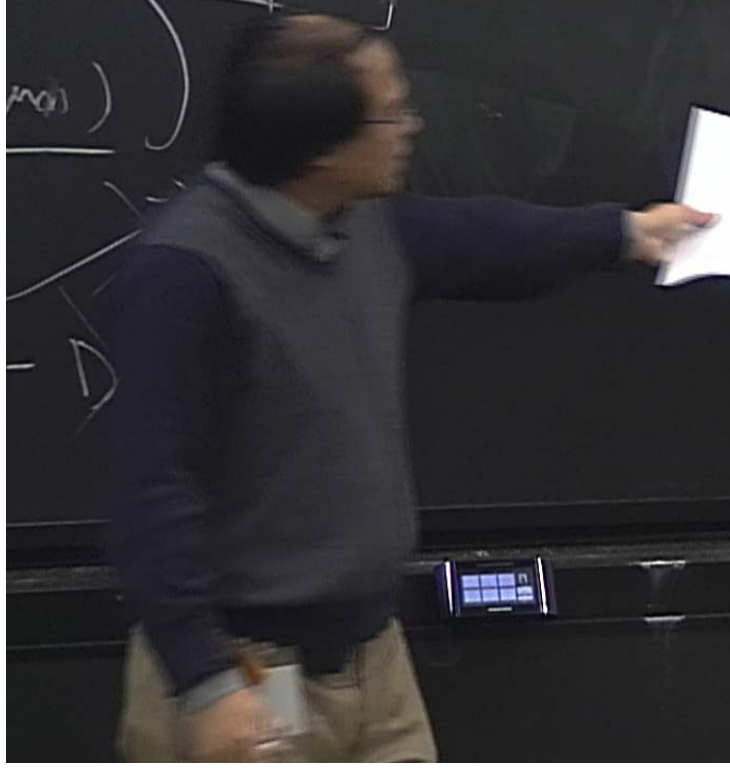




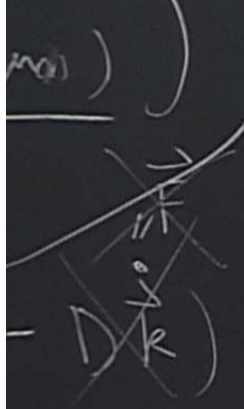
$$-\nabla \mu + \left(\frac{\vec{v}}{F} \right) + \vec{g}_0$$

$$n(\vec{r}) = \int \frac{d^3k}{(2\pi)^3} g(\vec{r}, \vec{k})$$

$$\vec{j}_i = \int \frac{d^3k}{(2\pi)^3} e v_i(\vec{k}) j(\vec{r}, \vec{k})$$



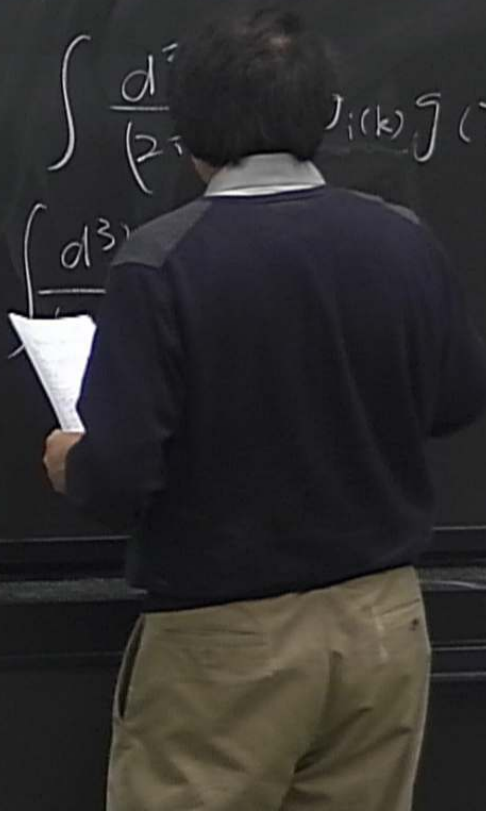
$$-\nabla \mu + \left(\vec{F} \right) + \rho_0$$

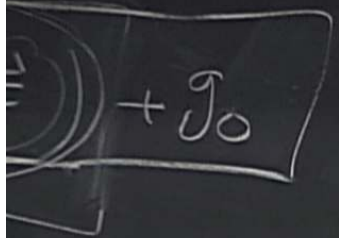


$$n(\vec{r}) = \int \frac{d^3k}{(2\pi)^3} g(\vec{r}, \vec{k})$$

$$j_i = \int \frac{d^3k}{(2\pi)^3} j_i(\vec{k}) g(\vec{r}, \vec{k})$$

$$= \int d^3k$$

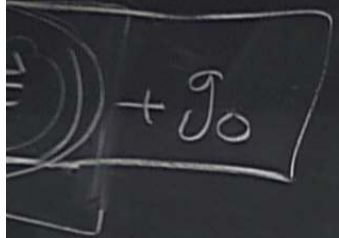




$$\underline{n(\vec{r})} = \int \frac{d^3k}{(2\pi)^3} g(\vec{r}, \vec{k}) \left(\frac{dk}{(2\pi)^3} e^{i\vec{k}\cdot\vec{r}} \right)$$

$$\vec{j}_i = \int \frac{d^3k}{(2\pi)^3} e^{i\vec{k}\cdot\vec{r}} \vec{v}_i(\vec{k}) g(\vec{r}, \vec{k})$$

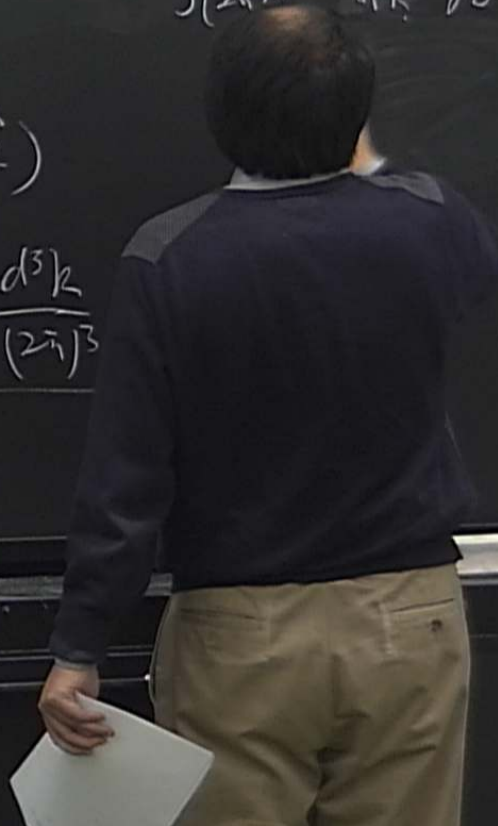
$$= \int \frac{d^3k}{(2\pi)^3} e^{i\vec{k}\cdot\vec{r}} v_i \text{sg} + \int \frac{d^3k}{(2\pi)^3}$$

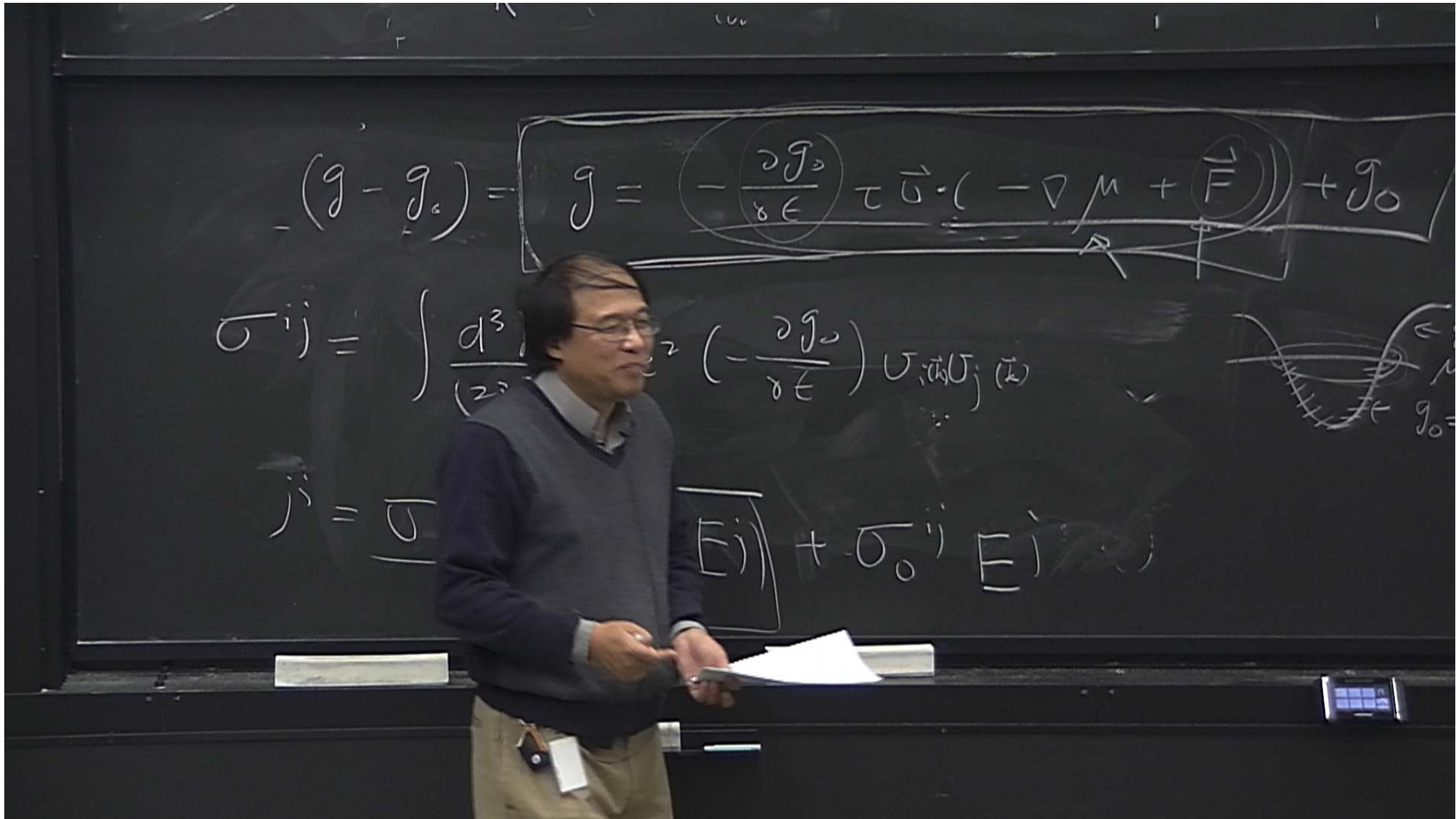


$$n(\vec{r}) = \int \frac{d^3k}{(2\pi)^3} g(\vec{r}, \vec{k}) \quad \left(\frac{dk}{(2\pi)^3} e^{\frac{d\epsilon}{dk}} g_0(\epsilon) \right)$$

$$j_i = \int \frac{d^3k}{(2\pi)^3} e^{i\vec{k}\cdot\vec{r}} j(\vec{r}, \vec{k})$$

$$= \int \frac{d^3k}{(2\pi)^3} e^{i\vec{k}\cdot\vec{r}} s g + \int \frac{d^3k}{(2\pi)^3}$$





$$(g - g_0) = \boxed{g = - \left(\frac{\partial g_0}{\partial \epsilon} \right) \tau \vec{U} \cdot \left(-\nabla \mu + \vec{F} \right) + g_0}$$

$$\sigma^{ij} = \int \frac{d^3}{(2\pi)^3} \left(- \frac{\partial g_0}{\partial \epsilon} \right) U_i \partial_k U_j (\vec{k})$$

$$j^i = \overline{\sigma} \left[E^i \right] + \sigma_0^{ij} \left[E^j \right]$$



$$\overline{\sigma}_{ij} = \frac{e^2}{\hbar} \int \frac{d^3k}{(2\pi)^3} D^{ij} q$$

$$\overline{\sigma}_{ij} = \frac{e^2}{\hbar} \int \frac{d^3k}{(2\pi)^3} D^{ij} g_0(\epsilon)$$

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