FRAGMENT M M

Schrödinger
Wellenmechanik

In der Tat beruht unsere gewöhnliche
Beschreibung der Naturersch. letzten
Endes auf der Voraussetzung, daß in
Rede stehenden Phänomene beobachtet
werden können, ohne sie wesentlich
zu beeinflussen.

Einstein: Jede Beobachtung oder
Messung schließlich auf dem Zussam-
men fallen zweier unabhängigen Ereignisse
im selben Raum-zeitpunkt.

Quantenpostulat: Jede Beob. atomarer
Phänomene eine nicht zu vernachlässigende
Wechselwirkung mit dem Messungsmittel
fordert, und daß also weder Phän. noch dem
Beob. mittel eine selbständige phys. Real.
im gewöhnlichen Sinne zugeschrieben
werden kann.

Eben dieses Zusammenfallen wird
nicht berührt durch den Unterschied, den
die Raum-zeit-Beschreibung verschiedener
Beobachter im übrigen aufweisen mag.

Superpositionsprinzip — Erhaltungssatz.

BOX06

stetige Übergang

S. 58.

$$\psi = \sum_{n=0}^{\infty} \left(\frac{A}{2}\right)^n \frac{\psi_n}{n!}$$

$$= e^{\pi i \nu_0 t} \sum_{n=0}^{\infty} \left(\frac{A}{2} e^{2\pi i \nu_0 t}\right)^n \frac{1}{n!} e^{-\frac{x^2}{2}} H_n(x)$$

Beziehung zur Quantenmech.

S. 68.

$$\int \rho(x) u_k(x) [P, u_l(x)]\, dx$$

$$= \int \rho(x) u_k(x) (f \cdot k^2 \frac{\partial}{\partial} \cdots u_l(x))\, dx$$

$$= -\int \left(\frac{\partial}{\partial x} k^2 f \rho u_k(x)\right)(\quad)\, dx$$

S. 69 (13) $q_l^{ik} = \int q_l \rho(x) u_i(x) u_k(x)\, dx$

$$p_l^{ik} = K \int \rho(x) u_i(x) \frac{\partial u_k(x)}{\partial q_l}\, dx$$

$$q_l^{ij} p_l^{jk} = K \int q_l \rho(x) u_i(x) u_j(x)\, dx \times \int \rho\, u_j(x) \frac{\partial u_k(x)}{\partial q_l}\, dx$$

$$p_l^{ij} q_l^{jk} = K \int q_l \rho(x) u_j(x) u_k(x)\, dx \times \int \rho\, u_i(x) \frac{\partial u_j(x)}{\partial q_l}\, dx$$

$$= - \quad \times \int \rho\, u_j(x) \frac{\partial u_i(x)}{\partial q_l}\, dx$$

$\int q_l \ldots \int$ $\quad \int \rho(x) u_i(x) u_j(x)\, dx$

$\times q_l$

$$q_l^{ik} p_l^{kj} - p_l^{ik} q_l^{kj} = \int q_l \rho(x) u_i(x) u_k(x)\, dx \times K \int \rho(x) u_k(x) \frac{\partial u_j(x)}{\partial q_l}\, dx - K \int \rho(x) u_i(x) \frac{\partial u_k(x)}{\partial q_l}\, dx \int q_k \rho(x) u_k(x) u_j(x)\, dx$$

$$= K \int [q_l \rho(x) u_i(x)] [\rho(x) \frac{\partial u_j(x)}{\partial q_l}]\, dx$$

$$- K \int [q_l \rho(x) u_j(x)] [\rho(x) \frac{\partial u_i(x)}{\partial q_l}]\, dx$$

$$= K \int q_l \rho(x) \left(u_i(x) \frac{\partial u_j}{\partial q} - u_j \frac{\partial u_i}{\partial q}\right) dx$$

$$\frac{1}{2}(p_k^2 q_k + q_k p_k^2) = [illegible] (p q - q p) - [illegible] + \ldots q_k p_k$$

5.16.

$$\delta \int d\tau \{ K^2 T(q, \frac{\partial\psi}{\partial q}) + \psi^2 V \} = 0,$$

$$\int d\tau \{ T(q, \frac{\partial S}{\partial q}) + V(q) \}$$

$S = K \log \psi$ $\quad \frac{\partial S}{\partial q} = \frac{K}{\psi} \frac{\partial \psi}{\partial q}$

$=$

$p = f(q)$

$T = \sum a_{ik} p_i p_k = \sum b_{ik} p_i p_k$

$q = f(q')$

$$\delta \int d\tau \{ K^2 T(q, \frac{\partial\psi}{\partial q}) + \psi^2 V \} \to 0$$

$a_{ik} \frac{\partial\psi}{\partial q} \frac{\partial\psi}{\partial q}$

$b_{ik} \frac{\partial\psi}{\partial q} \frac{\partial\psi}{\partial q}$

$\frac{a_{ik} p_i p_k}{\sqrt{|a_{ik}|}}$

$d\tau =$

grad V·𝔈

$\delta \int \underset{(q, \dot q)}{L}\, dt = 0$

$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot q}\right) - \frac{\partial L}{\partial q} = 0.$

$\int (\mathrm{grad}\, V \cdot \mathfrak{E})\, d\tau$

$\int \mathrm{grad}\, V \cdot \frac{\mathfrak{E}}{d\tau} + \int V \frac{\mathrm{grad}}{d\tau}\, \mathfrak{E}$

$\Delta_p^{\frac{1}{2}} \frac{\partial}{\partial q_k} \left(\Delta_p^{-\frac{1}{2}} \cdot p_k T_{p_k} \right)$

grad V ○

$[H \psi] = \phi\, T(q_k, p_k) - V(q_k)\, \psi$

$\frac{1}{2} \int (\mathrm{grad}\, V)^2 d\tau$

$= \frac{1}{2} \sum_k p_k T_{p_k}(q_k, p_k)\, \psi$

$= \Delta \cdot K (q_k \frac{\partial \psi}{\partial q_k})$

$O = \int \boxed{p(x)} \bigcirc\, dx$

$p(x)$

$$\boxed{q_i^{(k)} = \int u_i(x)\, u_k(x)\, dx}$$

$\int q_l^{ij} q_l^{jk} = \int u_i u_j(x)\, dx.$

$u_i\, u_k\, dx$

$\int u_j(x)\, u_k(x)\, dx$

Raumdichte $= \psi \frac{\partial \bar\psi}{\partial t}$

$$= \sum c_k u_k e^{\frac{2\pi\sqrt{-1}E_k t}{h}}$$

$$\times \sum \bar c_m \bar u_m \frac{2\pi}{h} E_m \sqrt{-1}\, e^{-\frac{2\pi\sqrt{-1}}{h}\cdots t}$$

$$= \sum c_k \bar c_m u_k \bar u_m \frac{2\pi\sqrt{-1}}{h}$$

$$E_m \quad e^{\frac{2\pi\sqrt{-1}}{h}(E_k - E_m)}$$

$$\sin(E_k - E_m)$$

$$\frac{\partial^2\psi}{\partial t^2} = -\frac{4\pi^2 E^2}{h^2}\psi$$

$$\cancel{\Delta\psi - \frac{E^2}{E-V}\psi = 0}$$

$$\Delta\psi - \frac{2(E-V)}{E^2}\frac{\partial^2\psi}{\partial t^2} = 0$$

$$\cancel{\Delta\psi + \frac{\psi\cdot 4\pi^2}{\frac{\partial^2\psi}{\partial t^2}\, h^2}\frac{\partial^2\psi}{\partial t^2}}$$

$$\frac{\partial\psi}{\partial t} = E\frac{2\pi i}{h}\psi$$

$$2(E-V) = 0$$

$$\Delta\psi + \frac{8\pi^2}{h^2}\psi(E-V) = 0$$

$$E = \frac{hi}{2\pi}\left(\frac{\partial\psi}{\partial t}\right)^{\frac{1}{2}} \Big/ \psi^{\frac{1}{2}}$$

$$\left\{\left(\Delta - \frac{8\pi^2}{h^2}V\right)\psi\right\}^2 + \frac{16\pi^2}{2h^2}\frac{\partial\psi}{\partial t^2} = 0.$$

$$\left(\Delta\psi - \frac{8\pi^2}{h^2}V\psi\right)^2 = (\Delta\psi)^2 - 2\frac{8\pi^2}{h^2}V\psi\,\Delta\psi + \left(\frac{8\pi^2}{h^2}V\psi\right)^2$$

$$\Delta^2$$

$$\Delta(\psi\Delta\psi) = \psi\Delta^2\psi + (\Delta\psi)^2$$

$$\Delta\psi + \frac{8\pi^2}{h^2}\left(\frac{\frac{\partial\psi}{\partial t}}{\frac{2\pi i}{h}} - V\psi\right) = 0$$

$$(\Delta - \square)\psi \qquad (\Delta - \square)(\Delta\psi - \square\psi)$$

$$= \Delta\Delta\psi - \square\Delta\psi - \Delta\square\psi + \square\square\psi$$

$$\Delta\psi - \frac{8\pi^2}{h^2}V\psi =$$

$$\psi \sim e^{\pm\frac{2\pi i Et}{h}}$$

$$\frac{\partial\psi}{\partial t} = \psi \cdot \frac{2\pi i}{h}E + \psi\,\frac{2\pi i}{h}\frac{\partial E}{\partial t}\cdot t.$$

$$\frac{\partial^2\psi}{\partial t^2} = \psi\left(-\frac{4\pi^2}{h^2}E^2\right) + \psi\left(\frac{-8\pi^2}{h^2}\,E\frac{\partial E}{\partial t}\cdot t\right)$$

$$+\ \psi\left(\frac{-8\pi^2}{h^2}\frac{\partial E}{\partial t}\right.$$

$$\Delta\left(-\frac{4\pi^2E^2}{h^2}\Delta\psi\right) = \frac{\partial^2}{\partial t^2}(\Delta\psi)$$

$$= \frac{\partial^2}{\partial t^2}\left(\frac{2(E-V)}{E^2}\frac{\partial^2\psi}{\partial t^2}\right)$$

$$\frac{E^2}{2(E-V)}\Delta\psi = -\frac{4\pi^2E^2}{h^2}\psi$$

$$\left(\Delta - \frac{8\pi^2}{h^2}V\right)\psi = \frac{-8\pi^2}{h^2}E\psi.$$

$$\left(\Delta - \frac{8\pi^2}{h^2}V\right)\left(\qquad\right)\psi = \frac{-8\pi^2}{h^2}E\cdot\frac{-8\pi^2}{h^2}E\psi$$

$$= \frac{-16\pi^2}{h^2}\frac{\partial^2\psi}{\partial t^2}.$$

$$\Delta\psi - \frac{8\pi^2}{h^2}(V_0 + A\cos 2\pi\nu t)\psi \mp \frac{4\pi i}{h}\frac{\partial\psi}{\partial t} = 0$$

$$\psi = u(x)\,e^{\pm\frac{2\pi i Et}{h}} + B\ \ .$$

$$-A\cos 2\pi\nu t\{u(x)\cdots\}$$

$$+\ \Delta\psi \quad " \quad " \quad " \quad = 0.$$

$\psi = R \cdot e^{2\pi i\nu t}$

$\Delta\psi = \Delta(R \cdot e^{2\pi i\nu t}) \cancel{+ R \cdot (2\pi i\nu)^2}$

$\frac{1}{u^2}\frac{\partial^2\psi}{\partial t^2} = \frac{1}{u^2} R \cdot (\quad)^2 e^{2\pi i\nu t}$

ψ

$\Delta\psi - \frac{(\quad)^2}{u^2}$ 褁 ψ 褁

$\Delta\psi - \overline{u^2(x,t)}$

$\frac{\partial^2\psi}{\partial x^2} - \frac{1}{u^2(x,t)}\frac{\partial^2\psi}{\partial t^2} = 0.$

$\psi = Re^{2\pi i\nu t},$

$\cancel{\frac{d^2R}{dx^2} + \frac{4(2\pi i\nu)^2}{u^2(x,t)} R = 0}$

$\boxed{\psi = \sum_{n=-\infty}^{+\infty} R_n e^{\frac{2\pi i E_n}{h} t}}$

$(\Delta - \frac{8\pi^2}{h} V)\psi = \sum R_n \frac{2\pi E^2}{h} e^{\frac{2\pi i E_n}{h} t} - V$

$(\Delta - \frac{8\pi^2}{h} V)\psi = R_n \Delta$

$(\Delta - \frac{8\pi^2}{h} V)^2\psi - \frac{64\pi^4}{h^4} E^2\psi$

$(\quad)(\Delta\psi + \frac{8\pi^2}{h}\psi)$

$\Delta\psi - \frac{2(E-V)}{E^2}\frac{\partial^2\psi}{\partial t^2} = 0$

$\frac{\partial^2\psi}{\partial t^2} = -\frac{4\pi^2 E^2}{h^2}\psi.$

$(\Delta + \frac{8\pi^2(E-V)}{h^2})\psi = 0$

$(\Delta - \frac{8\pi^2}{h^2} V)\psi = -\frac{8\pi^2}{h^2} E \psi$

$\boxed{\frac{\partial\psi}{\partial t} = \frac{2\pi i}{h} E\psi.}$

$= \frac{4\pi i}{h}\frac{\partial\psi}{\partial t}$

$(\Delta - \frac{8\pi^2}{h^2} V - \frac{4\pi i}{h}\frac{\partial}{\partial t})\psi = 0$

$$\Psi = \sum R_n e^{\frac{2\pi i n E t}{h}}$$

$$\left(\Delta - \frac{8\pi^2}{h^2} V\right)^2 \psi + \frac{16\pi^2}{h^2} \frac{\partial^2 \psi}{\partial t^2}$$

$$= \left(\qquad\right) \frac{8\pi^2}{h^2} E \sum R_n + \frac{16\pi^2}{h^2} \cancel{\frac{\partial^2\psi}{\partial t^2}} \frac{4\pi E^2}{h} \Psi$$

$$\Delta R + \frac{8\pi^2}{h^2}(E - V) R = 0$$

$$=$$

$$= e^{\circ} \left(\qquad\right)$$

$$H = T(p, q) + V(q, t)$$

$$\begin{cases} \dot{p} = -\frac{\partial H}{\partial q} = -\frac{\partial T}{\partial q} + \frac{\partial V}{\partial q} \quad -\frac{dq}{dt} \quad \frac{dp}{dt} \\ \dot{q} = \frac{\partial H}{\partial p} = \frac{\partial T}{\partial p} \end{cases}$$

$$\frac{dH}{dt} - \frac{\partial H}{\partial t} = \frac{dT}{dt} + \frac{dV}{dt} - \frac{\partial V}{\partial t} = 0$$

$$\frac{dH}{dt} - \frac{\partial V}{\partial t} = 0$$

$$-\frac{\partial T}{\partial t}$$

$$\frac{\partial \psi}{\partial t} = \pm \frac{2\pi i}{h} E \psi$$

$$\frac{\partial^2 \psi}{\partial t^2} = -\frac{4\pi^2}{h^2} E^2 \psi$$

$$\Delta \psi + 2(E - V) \frac{4\pi^2}{h^2} \psi = 0$$

$$\Delta \psi - \frac{8\pi^2}{h^2} V \psi \pm \frac{4\pi i}{h} \frac{\partial \psi}{\partial t} = 0$$

$$\Delta (X + iY) - \frac{8\pi^2}{h^2} V (X + iY) + \frac{4\pi i}{h} \frac{\partial X}{\partial t}$$

$$- \frac{4\pi}{h} \frac{\partial Y}{\partial t} = 0$$

$$\Delta X - \frac{8\pi^2}{h^2} V X \cancel{+ \frac{4\pi i}{h}} - \frac{4\pi}{h} \frac{\partial Y}{\partial t} = 0$$

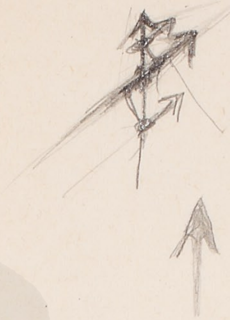
$$\Delta Y - \quad '' X \quad + \frac{4\pi}{h} \frac{\partial X}{\partial t} = 0$$

$$(\quad '' \quad + '' \quad)\left(\Delta - \frac{8\pi^2}{h^2} V - \frac{4\pi i}{h} \frac{\partial}{\partial t}\right) \psi$$

$$= \left(\left(\Delta - \frac{8\pi^2}{h^2} V\right) \psi + \ldots\right)\left(\left(\Delta - \frac{8\pi^2}{h^2} V\right) \psi - \frac{4\pi i}{h} \frac{\partial \psi}{\partial t}\right)$$

$$= (\quad)^2 \psi + \bigcirc$$

$$\boxed{- \frac{\partial (V \cdots)}{\partial x} = - \frac{\partial A}{\partial x} \cos 2\pi \nu t}$$



E

$$\frac{\partial A}{\partial x} = \sum E_{x_i} e_i$$

$$- A = \sum \int E_{x_i} e_i \, dx$$

$$= \int (\sum E_x e_i) \, dS$$

$$= \int \sum E \cdot e_i \, dS$$

$$= \quad F_i \sum e_i \, dz_i$$

$$\boxed{w = w_+(x) \, e^{\frac{2\pi i t}{h}(E_k + h\nu)} + w_-(x) \, e^{\frac{2\pi i t}{h}(E_k - h\nu)}}$$

$$\Delta w = e^{\cdots} \Delta w_+ + e^{\cdots} \Delta w_-$$

$$- \frac{8\pi^2}{h^2} V_0 w =$$

$$- \frac{2\pi i}{h} \frac{\partial w}{\partial t} = \frac{2\pi i}{h} (E_k + h\nu) \, w_+ e^{\cdots} + w_- e^{\cdots}$$

S. 145,

$$w = w_+(x)\, e^{\frac{2\pi i t}{h}(E_k + h\nu)} + w_-(x)\, e^{\frac{2\pi i t}{h}(E_k - h\nu)}$$

$$(11) \to e^{\frac{2\pi i t}{h}(E_k+h\nu)} \Delta w_+ - \frac{8\pi^2}{h^2} V_0 w_+ e^{''} - \frac{4\pi i}{h} \frac{2\pi i}{h}(E_k+h\nu)\, w_+ e^{''}$$

$$+ e^{''(E_k-h\nu)} \Delta w_- -$$

$$= \frac{4\pi^2}{h^2} A u_k \left(e^{\frac{2\pi i t}{h}(E_k+h\nu)} + e^{\frac{2\pi i t}{h}(E_k-h\nu)} \right)$$

$$\Delta w_+ + \frac{8\pi^2}{h^2} (E_k + h\nu - V_0)\, w_+$$

$$+$$

$$= \frac{4\pi^2}{h^2} A u_k.$$

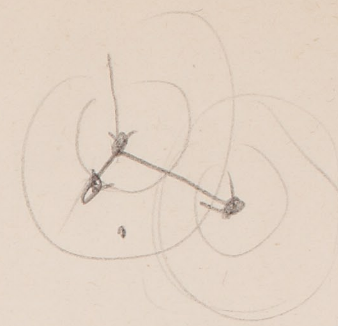
~~S. 148.~~ $\psi \overline{\psi} =$

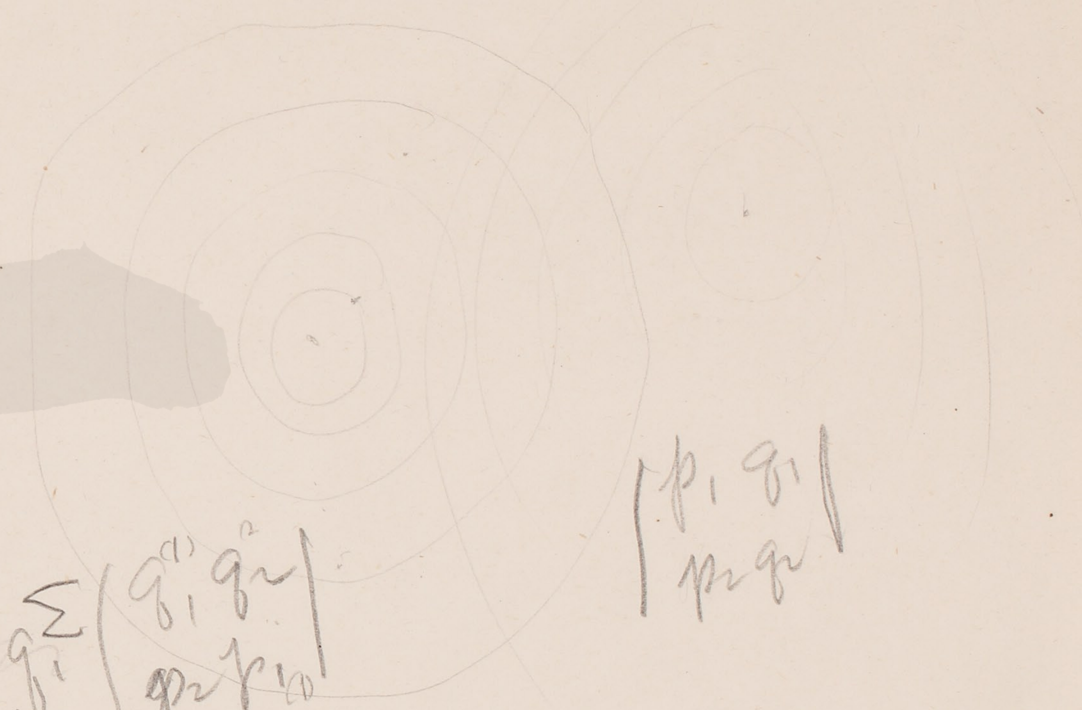
S. 145.

$$\cancel{w = w_+(x,t)\, e^{\frac{2\pi i t}{h}(E_k+h\nu)} + w_-(x,t)\, e^{\frac{2\pi i t}{h}(E_k-h\nu)}}$$

$$w = w_+(x)\, e^{\frac{2\pi i}{h}(E_k+h\nu)} + w_-(x)\, e^{\frac{2\pi i}{h} n (E_k+h\nu)}$$

$$\Delta w_\pm + \frac{8\pi^2}{h^2}\{ (E_k \pm h\nu) - V_0 \} w_\pm = 0$$





$$p_1 \quad q_1 \quad \Sigma \begin{vmatrix} q_1^{(1)} & q^{2} \\ q_2 & p_1^{(1)} \end{vmatrix}$$

$$\begin{vmatrix} p_1 & q_1 \\ p_2 & q_2 \end{vmatrix}$$

Continuum

q, p

$A\cdot B =$

$$p_1 q_1 - p_2 q_2 \leq h$$

$$E_1 t_1 - E_2 t_2 \leq h$$

$q_1 - q$ $\quad p_1 q_1 = p_2 q_2$

$$p_1 q_1 - p_2 q_2 > h$$

$$p_1 q_1 \neq p_2 q_2$$

$$\dot{c}_l = \frac{2\pi i}{h} \sum \varepsilon_{kl} c_k \qquad (l = 1, 2, \cdots \alpha)$$

$$\frac{d}{dt}\left(\sum c_l c_l^*\right) = \frac{2\pi i}{h} \sum \varepsilon_{kl} \left(c_k c_l^* + c_k^* c_l\right)$$

$$= \frac{2\pi i}{h} \sum \varepsilon_{kl} \left(c_l c_k^* + \dot{c}_k c_l^*\right)$$

$86 = 3x^2$