DEPARTMENT OF PHYSICS
OSAKA IMPERIAL UNIVERSITY.

DATE Jan. 6, 1935.

NO.

Note on the Theory of Positrons

By Hideki Yukawa

Infinite charge density due to ~~the~~ electrons in the negative energy state

~~The difficulty of the Dirac's theory of positrons can be~~

& Recently, attempts were made to eliminate the ~~problem~~ difficulty of infinite charge density ~~due to electrons in the negative energy states~~ in ~~the the~~ Dirac's theory of positrons. The present author wants to ~~treat~~ discuss this problem on the assumption of complete symmetry of positive and negative charges.

~~First~~ At first the electron and the ~~proton~~ positron are considered as if they ~~were~~ to be independent particles. If we denote the quantized wave functions for them by ψ_k, $\psi_k^\dagger$ and φ_k, $\varphi_k^\dagger$ respectively, where k takes the values 1, 2, 3 and 4, the charge densit~~y~~ies for them ~~can be ex~~ are

$$-e\sum_k \psi_k^\dagger \psi_k \quad \text{and} \quad +e\sum_k \varphi_k^\dagger \varphi_k$$

respectively. Similarly their current densities ~~are~~ can be expressed ~~as~~ by

$$-ec\sum_{k,l} \psi_k^\dagger \alpha_{kl} \psi_l \quad \text{and} \quad +ec\sum_{k,l} \varphi_k^\dagger \alpha_{lk} \varphi_l,$$

where $c\alpha$ is the ~~vector~~ velocity vector introduced by

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Dirac. ~~and~~ $\tilde{\alpha}$ The wave equations for electrons and positrons are

$$-\left(\frac{i\hbar}{c}\frac{\partial}{\partial t}+\frac{e}{c}V\right)\psi_k+\alpha_{kl}\left(-i\hbar\,\mathrm{grad}+\frac{e}{c}\mathbf{A}\right)\psi_l+\beta_{kl}mc\,\psi_l=0$$

and
$$-\left(\frac{i\hbar}{c}\frac{\partial}{\partial t}-\frac{e}{c}V\right)\varphi_k+\alpha_{lk}\left(-i\hbar\,\mathrm{grad}-\frac{e}{c}\mathbf{A}\right)\varphi_l+\beta_{lk}mc\,\varphi_l=0$$

respectively.

~~Now~~

V-quantum

$$\pi\psi - \pi^*\psi^*$$

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rot

$$-\frac{\partial}{\partial z}\left(\psi\frac{\partial\psi}{\partial y} - \frac{\partial\psi}{\partial y}\psi\right)$$

$$= 2\left(\frac{\partial\psi}{\partial y}\frac{\partial\psi}{\partial z} - \frac{\partial\psi}{\partial z}\frac{\partial\psi}{\partial y}\right)$$

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§ Symmetrisierungsverfahren

$$L = \frac{1}{2}\left\{\frac{1}{c^2}\frac{\partial\tilde{\psi}^*}{\partial t}\frac{\partial\psi}{\partial t} - \operatorname{grad}\tilde{\psi}^* \operatorname{grad}\psi\right.$$

$$\left. + \frac{1}{c^2}\frac{\partial\psi}{\partial t}\frac{\partial\tilde{\psi}^*}{\partial t} - \operatorname{grad}\psi \operatorname{grad}\tilde{\psi}^*\right\}$$

$$+ \cdots$$

$$\frac{\partial L}{\partial\frac{\partial\tilde{\psi}^*}{\partial t}} = \frac{1}{c^2}\frac{\partial\tilde{\psi}^\dagger}{\partial t} = \psi^{*\dagger}$$

$$L = \frac{1}{2}\left\{\psi^\dagger\frac{\partial\psi}{\partial t} + \frac{\partial\psi}{\partial t}\psi^\dagger - \operatorname{grad}\tilde{\psi}\operatorname{grad}\psi\right.$$

$$\left. - \operatorname{grad}\psi\operatorname{grad}\tilde{\psi}\right\}$$

$$\psi + \tilde{\psi} = V$$

$$\psi - \tilde{\psi} =$$

$$L = \frac{1}{2}\left(\widetilde{L_F\psi}\right)\cdot(L_F\psi) + (L_F\psi)\left(\widetilde{L_F\psi}\right)$$

$$= \frac{1}{2}\left\{\psi^\dagger(L_F\psi) + (\tilde{L}_F\psi)\psi^\dagger\right\}$$

$$L_F\psi =$$

$$\psi^\dagger(x)\psi(x') \quad \psi(x)\psi^\dagger(x') = \delta(x, x')$$

$$L_F\psi^\dagger(x)\psi(x') + \psi(x')\psi^\dagger(x') = L_F\,\delta(x, x')$$

$$L_F\cdot(\psi - \tilde{\psi})$$

$$L_F''(\psi + \tilde{\psi})$$

$$\frac{1}{2}\left\{(L_F\psi) + (L_F\psi)\right\} = E$$

$$\frac{1}{2}\left\{(L_F\psi) - (L_F\psi)\right\} = iH.$$

$$(E - iH)(E + iH)$$

$$+ (E + iH)(E - iH).$$

(covariant) (neutral)

(covariant) (neutral)

$$\psi(\psi^\dagger\psi) - (\psi^\dagger\psi)\psi$$

$$\dot{\psi} = \cdots \qquad \dot{\psi}^\dagger =$$

$$\psi^\dagger\psi - \varphi^\dagger\varphi$$

$$\psi^\dagger L_F\psi \pm \varphi^\dagger\tilde{L}_F\varphi = \psi^\dagger L_F\psi - (L_F\psi)\psi^\dagger$$

$$\psi^\dagger = \tilde{L}_F\varphi \qquad \varphi^\dagger = L_F\psi$$

$H\psi = 0$

$\tilde{H}\psi^{\dagger} = 0$

$\left(-i\hbar\frac{\partial}{\partial t} + \frac{e}{c}V\right)$

$\rho \sigma \psi$

$\frac{\partial \psi^{\dagger}}{\partial x}$ $\psi \longrightarrow \Psi^{-}$

論

$$\left(\frac{W}{c} + \frac{e}{c}V\right) + \alpha\left(p + \frac{e}{c}A\right) + \beta mc^2 = 0.$$

$$\alpha_x \alpha_y \left\{\left(p_x + \frac{e}{c}A_x + \frac{g}{c}B_x\right)\left(p_y + \frac{e}{c}A_y + \frac{g}{c}B_y\right) - \left(p_y + \frac{e}{c}A_y + \frac{g}{c}B_y\right)\left(p_x + \frac{e}{c}A_x + \frac{g}{c}B_x\right)\right\}$$

$$+\frac{e\hbar\alpha_z}{c} \quad \frac{g\hbar\alpha_z}{c}\cdot \mathrm{curl}_z B$$

262, ~~Kawai~~ Yokoya-Kawai
Uosakicho ~~near~~ Kobe
Mukogun ~~Japan~~
Hyogoken, Japan

$\psi_k^{\dagger}\psi_e$. 曇晴 聲 涼

$\psi \rightarrow \psi^{\dagger}$

$\psi^{\dagger} \rightarrow \psi$

ψ state → anti

$\rho\alpha_y \psi$ (neutrino)

antineutrino

(antineutrino)

Ψ