1

Interaction of the Neutron and the Proton.

$$H_0 = 4\pi\kappa^2c^2\tilde{U}^\dagger U^\dagger + 4\pi c^2 \operatorname{div}\tilde{U}^\dagger \operatorname{div}U^\dagger + \frac{1}{4\pi\kappa^2}\operatorname{curl}\tilde{U}\operatorname{curl}U + \frac{1}{4\pi}\tilde{U}U$$

$$H' = -\left(\frac{g}{\kappa}\right)\{-U_0 + \rho_1(\vec{\sigma}\vec{U}) + \rho_2(\vec{\sigma}\vec{F}) + \rho_3(\vec{\sigma}\vec{G})\}\tilde{\Psi}Q\Psi$$
+ comp. conj.

$$U_0 = 4\pi\kappa c \operatorname{div}\tilde{U}^\dagger + \frac{4\pi g}{\kappa}\tilde{\Psi}\tilde{Q}\Psi$$

$$\left.\begin{aligned}\operatorname{div}F + \kappa U_0 &= 4\pi g\tilde{\Psi}\tilde{Q}\Psi\\ \operatorname{curl}U - \kappa G &= 4\pi g\tilde{\Psi}\rho_3\vec{\sigma}\tilde{Q}\Psi.\end{aligned}\right\}$$

$$\tilde{U}^\dagger = -\frac{F}{4\pi\kappa c}$$

$$H' = \left(\frac{g}{\kappa}\right)\{4\pi c \operatorname{div}\tilde{U}^\dagger\cdot\tilde{\Psi}Q\Psi - \vec{U}\cdot\tilde{\Psi}\rho_1\vec{\sigma}Q\Psi$$
$$\cancel{+4\pi c\operatorname{div}\tilde{U}^\dagger\cdot\tilde{\Psi}Q\Psi} + 4\pi\kappa c\,\tilde{U}^\dagger\,\tilde{\Psi}\rho_1\vec{\sigma}Q\Psi$$
$$-\frac{1}{\kappa}\operatorname{curl}U\cdot\tilde{\Psi}\rho_3\vec{\sigma}\Psi\} - \frac{4\pi g^2}{\kappa^2}\{\tilde{\Psi}\rho_3\vec{\sigma}Q\Psi\cdot\tilde{\Psi}\rho_3\vec{\sigma}\tilde{Q}\Psi$$
$$+\tilde{\Psi}\tilde{Q}\Psi\cdot\tilde{\Psi}Q\Psi\}$$

$$\dot{U} = 4\pi\kappa^2c^2\tilde{U}^\dagger - 4\pi c^2 \operatorname{grad}\operatorname{div}\tilde{U}^\dagger$$

$$\frac{1}{c}\frac{\partial U}{\partial t} = -\kappa F - \operatorname{grad}U_0 + \cancel{\frac{4\pi g}{\kappa}}\operatorname{grad}(\tilde{\Psi}\tilde{Q}\Psi) - \frac{g}{\kappa}4\pi c\operatorname{grad} + 4\pi\kappa g c\,\tilde{\Psi}\rho_1\vec{\sigma}\tilde{Q}\Psi$$

$$\frac{1}{c}\frac{\partial U}{\partial t} + \operatorname{grad}U_0 + \kappa F = \left\{\begin{aligned}&\cancel{-\frac{4\pi g}{\kappa}\operatorname{grad}(\tilde{\Psi}\tilde{Q}\Psi)}\\ &4\pi g\,\tilde{\Psi}\rho_1\vec{\sigma}\tilde{Q}\Psi.\end{aligned}\right.$$

$$-\dot{\tilde{U}}^\dagger = \frac{1}{4\pi\kappa^2}\operatorname{curl}\operatorname{curl}U + \frac{1}{4\pi}U - \frac{g}{\kappa}\tilde{\Psi}\rho_1\vec{\sigma}\tilde{Q}\Psi$$
$$-\frac{g}{\kappa^2}\operatorname{curl}(\tilde{\Psi}\rho_3\vec{\sigma}\tilde{Q}\Psi)$$

$4\pi\kappa$

$$\frac{1}{c}\frac{\partial F}{\partial t} = \operatorname{curl}G - \frac{4\pi g}{\kappa}\operatorname{curl}\tilde{\Psi}\rho_3\vec{\sigma}\tilde{Q}\Psi$$
$$+\kappa U - 4\pi g\,\tilde{\Psi}\rho_1\vec{\sigma}\tilde{Q}\Psi - \frac{4\pi g}{\kappa}\operatorname{curl}\tilde{\Psi}\rho_3\vec{\sigma}\tilde{Q}\Psi$$

2

$\frac{1}{c}\frac{\partial}{\partial t}$ $\quad \frac{1}{c}\frac{\partial U}{\partial t} + \mathrm{grad}\, U_0 + \kappa F = 4\pi g\, \tilde{\Psi} \rho_2 \vec{\sigma} \tilde{Q} \Psi$

$$\frac{1}{c}\frac{\partial F}{\partial t} - \mathrm{curl}\, G - \kappa U = 4\pi g\, \tilde{\Psi} \rho_1 \vec{\sigma} \tilde{Q} \Psi$$

$$- \frac{\cancel{8}\pi g}{\kappa}\, \mathrm{curl}\, \tilde{\Psi} \rho_3 \vec{\sigma} \tilde{Q} \Psi, \ ?$$

$$\mathrm{div}\, F + \kappa U_0 = 4\pi g\, \tilde{\Psi} \tilde{Q} \Psi$$

$+\,\mathrm{curl}$ $\quad \mathrm{curl}\, U - \kappa G = -4\pi g\, \tilde{\Psi} \rho_3 \vec{\sigma} \tilde{Q} \Psi.$

$$\frac{1}{c}\frac{\partial^2 U}{\partial t^2} + \frac{1}{c}\frac{\partial}{\partial t}\, \mathrm{grad}\, U_0 + \kappa \frac{1}{c}\frac{\partial F}{\partial t} + \mathrm{grad}\,\mathrm{div}\, U - \Delta U$$

$$- \kappa\, \mathrm{curl}\, G = 4\pi g \left\{ \frac{1}{c}\frac{\partial}{\partial t} \tilde{\Psi} \rho_2 \vec{\sigma} \tilde{Q} \Psi - \mathrm{curl}\, \tilde{\Psi} \rho_3 \vec{\sigma} \tilde{Q} \Psi \right\}$$

or $\quad \frac{1}{c}\frac{\partial^2 U}{\partial t^2} - \Delta U + \kappa^2 U$

$$= 4\pi g \left\{ + \kappa\, \tilde{\Psi} \rho_1 \vec{\sigma} \tilde{Q} \Psi \ \cancel{+}\ \mathrm{curl} (\tilde{\Psi} \rho_3 \vec{\sigma} \tilde{Q} \Psi) \right.$$

$$\left. + \frac{1}{c}\frac{\partial}{\partial t} \tilde{\Psi} \rho_2 \vec{\sigma} \tilde{Q} \Psi - \frac{1}{c}\frac{\partial}{\partial t} \tilde{\Psi} \tilde{Q} \Psi - \mathrm{div}\, \tilde{\Psi} \rho \vec{\sigma} \tilde{Q} \Psi \right\}$$

$$\mathrm{grad}\left(\frac{1}{c}\frac{\partial U_0}{\partial t} + \mathrm{div}\, U\right) = \mathrm{grad}\ 4\pi g \left\{ \frac{1}{c}\frac{\partial}{\partial t} \tilde{\Psi} \tilde{Q} \Psi \right.$$

$$\left. + \ \mathrm{div}\ \tilde{\Psi} \rho_1 \vec{\sigma} \tilde{Q} \Psi \right\}$$

$$\left(\frac{1}{c}\frac{\partial}{\partial t} - \Delta + \kappa^2\right)(\mathrm{curl}\, U) \cong 4\pi g \left\{ \cancel{\kappa \tilde{\Psi}}\ \mathrm{curl}\,\mathrm{curl} (\tilde{\Psi} \rho_3 \vec{\sigma} \tilde{Q} \Psi) \right\}$$

$$\therefore g\, \mathrm{curl}\, U \cong g^2 \iiint \left\{ \frac{e^{-\kappa r}}{r}\, \mathrm{curl}\,\mathrm{curl} (\tilde{\Psi} \rho_3 \vec{\sigma} \tilde{Q} \Psi) \right\} dv$$

$$- \frac{g}{\kappa^2}\, \mathrm{curl}\, U \cdot \tilde{\Psi} \rho_3 \vec{\sigma} \Psi = -\frac{g^2}{\kappa^2} \iiint \frac{e^{-\kappa r}}{r}\, dv\, \mathrm{curl}\,\mathrm{curl} (\tilde{\Psi} \rho_3 \vec{\sigma} \tilde{Q} \Psi)$$

grad div $-\ \Delta$

$$\times\ \tilde{\Psi} \rho_3 \vec{\sigma} \Psi$$

$\cancel{\mathrm{curl}}\ \tilde{\Psi} \rho_3 (\mathrm{grad} \times \vec{\sigma}) \tilde{Q} \Psi \ +$

(3)

$$\mathrm{curl}\ \cancel{\mathrm{curl}\ G - \varkappa\,\mathrm{curl}\ U - \frac{1}{c}\frac{\partial}{\partial t}\mathrm{curl}\ F}$$

$$\cancel{= -4\pi g\ \mathrm{curl}\ \tilde{\Psi}\rho_1\vec{\sigma}\tilde{\Omega}\Psi - \frac{8\pi g}{\varkappa}\mathrm{curl}^2\tilde{\Psi}\rho_3\vec{\sigma}\tilde{\Omega}\Psi}$$

$$\frac{1}{c}\frac{\partial U}{\partial t} + \mathrm{grad}\,U_0 + \varkappa F = 4\pi g\,\tilde{\Psi}\rho_2\vec{\sigma}\tilde{\Omega}\Psi \;\big)= 4\pi g S$$

$$\cancel{t}\,\mathrm{curl}\ U - \varkappa G = -4\pi g\,\tilde{\Psi}\rho_3\vec{\sigma}\tilde{\Omega}\Psi \;\big)= -4\pi g T$$

$$\frac{1}{c}\frac{\partial F}{\partial t} - \mathrm{curl}\ G - \varkappa U = -4\pi g\,\tilde{\Psi}\rho_1\vec{\sigma}\tilde{\Omega}\Psi \;\big)= -4\pi g M \quad)$$

$$\mathrm{div}\ F + \varkappa U_0 = 4\pi g\,\tilde{\Psi}\tilde{\Omega}\Psi \;\big)= 4\pi g M_0$$

$$L = \cancel{8}\frac{1}{4\pi}(\tilde{F}F - \hat{G}G + \tilde{U}_0U_0 - \check{U}U)$$

$$\cancel{+}\ \frac{g}{\varkappa}(\cancel{\tilde{F}S - \tilde{G}T} - \tilde{U}_0M_0 + \tilde{U}M)$$

$$+\ \frac{g}{\varkappa}(\cancel{\tilde{F}S - \tilde{G}T} - U_0\tilde{M}_0 + U\check{M})$$

$$(+\ \frac{4\pi g^2}{\varkappa^2}(\cancel{\tilde{S}S - \tilde{T}T} + \tilde{M}_0M_0 - \check{M}M)\,?)$$

$$\cancel{-\ \frac{4\pi g^2}{\varkappa^2}(M\,\tilde{S}S - \tilde{G}G \qquad\qquad - MM)}$$

$$\cancel{-\tilde{T}T + \tilde{S}S + \tilde{M}_0M_0} - \check{M}M)$$

$$+\ \frac{4\pi g^2}{\varkappa^2}(\tilde{T}T - \tilde{S}S)\ \cancel{\pm}\ \frac{4\pi g^2}{\varkappa^2}(\tilde{M}_0M_0 - \check{M}M)$$

$$L = \frac{1}{4\pi\varkappa^2}\left(\frac{1}{c}\frac{\partial \tilde{U}}{\partial t} + \mathrm{grad}\,\tilde{U}_0 - 4\pi g\tilde{S}\right)\left(\frac{1}{c}\frac{\partial U}{\partial t} + \mathrm{grad}\,U_0 - 4\pi g S\right)$$

$$-\ \frac{1}{4\pi\varkappa^2}(\mathrm{curl}\ \tilde{U} + 4\pi g\tilde{T})(\mathrm{curl}\ U + 4\pi g T)$$

$$+\ \frac{1}{4\pi}(\tilde{U}_0U_0 - \check{U}U) - \frac{g}{\varkappa}(\tilde{U}_0M_0 \cancel{+} \check{U}M)$$

$$-\ \frac{g}{\varkappa}(U_0\tilde{M}_0 - U\check{M})$$

$$U^{\dagger} = \frac{\partial L}{\partial \frac{\partial U}{\partial t}} = \frac{1}{4\pi\varkappa^2 c}\left(\frac{1}{c}\frac{\partial \check{U}}{\partial t} + \mathrm{grad}\,\check{U}_0 - 4\pi g\check{S}\right) = -\frac{\tilde{F}}{4\pi\varkappa c}$$

$$\therefore\ \frac{\partial \check{U}}{\partial t} = 4\pi\varkappa^2 c^2 U^{\dagger} - c\,\mathrm{grad}\,\tilde{U}_0 + 4\pi g c\tilde{S}$$

$$\cancel{\partial U}$$

$$U_0^{\dagger} = 0.$$

4

$$
\begin{aligned}
H = & \; U^{\dagger}(4\pi\varkappa^2 c^2 \tilde{U}^{\dagger} - c\,\mathrm{grad}\,U_0 + 4\pi g c S) \\
& + \tilde{U}^{\dagger}(4\pi\varkappa^2 c^2 U^{\dagger} - c\,\mathrm{grad}\,\tilde{U}_0 + 4\pi g c \tilde{S}) \\
& - 4\pi\varkappa^2 c^2 \tilde{U}^{\dagger} \tilde{U}^{\dagger} + \frac{1}{4\pi\varkappa^2}(\mathrm{curl}\,\tilde{U} + 4\pi g \tilde{T})(\mathrm{curl}\,U + 4\pi g T) \\
& - \frac{1}{4\pi}(\tilde{U}_0 U_0 - \tilde{U} U) + \frac{g}{\varkappa}(\tilde{U}_0 M_0 - \tilde{U} M) + \frac{g}{\varkappa}(U_0 \tilde{M}_0 - U \tilde{M})
\end{aligned}
$$

$$\mathrm{curl}\,U - \varkappa G = -4\pi g T$$

$$-4\pi\varkappa c\, \mathrm{div}\,\tilde{U}^{\dagger} + \varkappa U_0 = 4\pi g M_0.$$

$$U_0 = 4\pi c\, \mathrm{div}\,\tilde{U}^{\dagger} + \frac{4\pi g}{\varkappa} M_0 \quad \mathrm{div}$$

$$
\begin{aligned}
H = & \; \boxed{4\pi\varkappa^2 c^2 \tilde{U}^{\dagger} U^{\dagger}} - c\,U^{\dagger}\,\mathrm{grad}\,(4\pi c\,\mathrm{div}\,\tilde{U}^{\dagger} + \frac{4\pi g}{\varkappa} M_0) \\
& + 4\pi g c\, U^{\dagger} S - c\,\tilde{U}^{\dagger}\,\mathrm{grad}\,(4\pi c\,\mathrm{div}\,U^{\dagger} + \frac{4\pi g}{\varkappa}\tilde{M}_0) \\
& + 4\pi g c\, \tilde{U}^{\dagger} \tilde{S} + \frac{1}{4\pi\varkappa^2}\mathrm{curl}\,\tilde{U}\,\mathrm{curl}\,U + \frac{g}{\varkappa^2}\mathrm{curl}\,U \cdot \tilde{T} \\
& + \frac{g}{\varkappa^2}\mathrm{curl}\,\tilde{U} \cdot T + \frac{4\pi g^2}{\varkappa^2}\tilde{T} T \cancel{- \frac{1}{4\pi}\tilde{U}_0 U_0 - \tilde{U}} \\
& - 4\pi(c\,\mathrm{div}\,\tilde{U}^{\dagger} + \frac{g}{\varkappa} M_0)(c\,\mathrm{div}\,U^{\dagger} + \frac{g}{\varkappa}\tilde{M}_0) + \frac{1}{4\pi}\tilde{U} U \\
& + \frac{4\pi g c}{\varkappa}\,\mathrm{div}\,U^{\dagger} \cdot M_0 + \frac{4\pi g^2}{\varkappa^2}\tilde{M}_0 M_0 - \frac{g}{\varkappa}\tilde{U} M \\
& + \frac{4\pi g c}{\varkappa}\,\mathrm{div}\,\tilde{U}^{\dagger} \cdot \tilde{M}_0 + \frac{4\pi g^2}{\varkappa^2}\tilde{M}_0 M_0 - \frac{g}{\varkappa}\tilde{U}\tilde{M}.
\end{aligned}
$$

$$
\begin{aligned}
H = & \; 4\pi\varkappa^2 c^2 \tilde{U}^{\dagger} U^{\dagger} + \frac{1}{4\pi c^2}\,\mathrm{div}\,U^{\dagger}\,\mathrm{div}\,\tilde{U}^{\dagger} + \frac{1}{4\pi\varkappa^2}\mathrm{curl}\,\tilde{U}\,\mathrm{curl}\,U \\
& + \frac{1}{4\pi}\tilde{U} U \\
& + 4\pi g c(U^{\dagger} S + \tilde{U}^{\dagger}\tilde{S}) + \frac{g}{\varkappa^2}(\mathrm{curl}\,U \cdot \tilde{T} + \mathrm{curl}\,\tilde{U} \cdot T) \\
& + \frac{4\pi g c}{\varkappa}(\mathrm{div}\,U^{\dagger} \cdot M_0 + \mathrm{div}\,\tilde{U}^{\dagger} \cdot \tilde{M}_0) - \frac{g}{\varkappa}(\tilde{U} M + U \tilde{M}) \\
& + \frac{4\pi g^2}{\varkappa^2}(\tilde{T} T + \tilde{M}_0 M_0)
\end{aligned}
$$

(5)

a) $\frac{g}{\kappa^2}\,\mathrm{curl}\, U \cdot \tilde{T}$

$$\cancel{\frac{1}{c}\frac{\partial U}{\partial t}} \quad \dot{U} = 4\pi\kappa^2 c^2 \tilde{U}^\dagger + 4\pi c^2 \,\mathrm{grad\,div}\, \tilde{U}^\dagger + 4\pi g c S$$

$\frac{1}{c^2}\frac{\partial}{\partial t}$

$$- \frac{4\pi g c}{\kappa}\,\mathrm{grad}\, M_0$$

$$-\dot{\tilde{U}}^\dagger = \frac{1}{4\pi\kappa^2}\,\mathrm{curl\,curl}\, U + \frac{1}{4\pi} U$$

$$+ \frac{g}{\kappa^2}\,\mathrm{curl}\, T - \frac{g}{\kappa} M$$

$$\frac{1}{c^2}\ddot{U} = -\mathrm{curl\,curl}\, U - \kappa^2 U - 4\pi g\, \mathrm{curl}\, T + 4\pi g \kappa M$$

$$+ \cancel{\frac{1}{4\pi c}}\,\mathrm{grad\,div}\, U + \frac{4\pi g}{\kappa}\,\mathrm{grad\,div}\, M$$

$$+ \frac{4\pi g}{c}\frac{\partial S}{\partial t} - \frac{4\pi g}{\kappa c}\frac{\partial}{\partial t}\,\mathrm{grad}\, M_0$$

$$\frac{1}{c^2}\frac{\partial^2 U}{\partial t^2} - \Delta U + \kappa^2 U = 4\pi g\Big\{ -\mathrm{curl}\, T + \kappa M$$

$$- \frac{1}{\kappa}\,\mathrm{grad\,div}\, M + \frac{1}{c}\frac{\partial S}{\partial t} - \frac{1}{\kappa c}\frac{\partial}{\partial t}\,\mathrm{grad}\, M_0 \Big\}$$

$$\frac{g}{\kappa^2}\,\mathrm{curl}\, U \cdot \tilde{T} = \frac{g^2}{\kappa^2}\int \frac{e^{-\kappa r}}{r}\big(-\mathrm{curl\,curl}\, T(1)\big)\, dv \cdot \tilde{T}(2)$$

$$(-\mathrm{grad\,div} + \Delta)\, T$$

$T_x = T_y = 0$

z-comp. $-\frac{\partial}{\partial y}\left(\frac{\partial T_z}{\partial y}\right) + \frac{\partial}{\partial x}\left(\frac{-\partial T_z}{\partial x}\right) = -\frac{\partial^2 T_z}{\partial x^2} - \frac{\partial^2 T_z}{\partial y^2}$

x-comp. $\frac{\partial}{\partial y}\left(\cancel{\frac{\partial T_z}{\partial x}}\right) - \frac{\partial}{\partial z}\left(-\frac{\partial T_z}{\partial x}\right) = \frac{\partial T_z}{\partial x \partial z}$

$$\frac{g^2}{\kappa^2}(+)\left(\frac{\partial^2 T_z}{\partial x^2} + \frac{\partial^2 T_z}{\partial y^2}\right)\frac{e^{-\kappa r}}{r}\,\tilde{T}$$

$$\boxed{-\mathrm{curl}_1\,\mathrm{curl}_1\left(\frac{e^{-\kappa r}}{r}\right)} T(2)\, \Big|\, T(1)\ \cancel{T(2)}$$

$$= \frac{\quad}{r^3}$$

⑥

$\cancel{T(1)\cdot \mathrm{grad}_1 \cdot (T(2)\cdot g}$ $\frac{e}{r}$

$$\mathrm{div}\left(\frac{e^{-\varkappa r}}{r}\tilde{T}(2)\right)\cdot \mathrm{div}(\quad)$$

$+(\tilde{T}(1)\mathrm{grad}_1)(\tilde{T}(2)\mathrm{grad}_1)$

$$T(1)\,\Delta_1 \frac{e^{-\varkappa r}}{r}\tilde{T}(2) = T(1)\{+\varkappa^2 \frac{e}{r} - 4\pi\delta\}T(2)$$

$$= \varkappa^2 T(1)\frac{e^{-\varkappa r}}{r}T(2) - 4\pi\delta\, T(1)T(2).$$

$$\Delta \frac{e^{-\varkappa r}}{r} = \varkappa^2 \frac{e^{-\varkappa r}}{r} - 4\pi\delta.$$

$$-\frac{g^2}{\varkappa^2}\iint \mathrm{curl}\,\mathrm{curl}\,T(1)\,dv_1 dv_2 \cdot \frac{e^{-\varkappa r}}{r}\tilde{T}(2)$$

$$= -\frac{g^2}{\varkappa^2}\int\cdots\int\Big\{\mathrm{div}_1 T(1)\cdot dv_1 dv_2 \cdot \mathrm{div}_1 \frac{e^{-\varkappa r}}{r}\tilde{T}(2)$$

$$+ T(1)T(2)\,dv_1 dv_2 \cdot \Delta \frac{e^{-\varkappa r}}{r_1}\Big\}$$

$$\boxed{\begin{aligned} = &-\frac{g^2}{\varkappa^2}\int\cdots\int (T(1)\mathrm{grad})(\tilde{T}(2)\mathrm{grad})\frac{e^{-\varkappa r}}{r}dv_1 dv_2 \\ &+ g^2\int\cdots\int T(1)\tilde{T}(2)\frac{e^{-\varkappa r}}{r}dv_1 dv_2 \\ &- \frac{4\pi g^2}{\varkappa^2}\int\cdots\int T(1)\tilde{T}(2)\,\delta(1,2)\,dv_1 dv_2 \end{aligned}}$$

b) $\frac{4\pi g c}{\varkappa}\,\mathrm{div}\,\tilde{U}^{\dagger}\cdot\tilde{M}_0$

$$-\ddot{\tilde{U}}^{\dagger} = +c^2\,\mathrm{curl}\,\mathrm{curl}\,\tilde{U}^{\dagger} + \frac{g c}{\varkappa^2}\frac{\partial}{\partial t}\mathrm{curl}\,\mathrm{curl}\,S^T + \varkappa^2 c^2 \tilde{U}^{\dagger}$$

$$- c^2\,\mathrm{grad}\,\mathrm{div}\,\tilde{U}^{\dagger} + g c\,S^T - \frac{g c}{\varkappa}\mathrm{grad}\,M_0 + \frac{g}{\varkappa^2}\mathrm{curl}\frac{\partial T^S}{\partial t}$$

$$- \frac{g}{\varkappa}\frac{\partial M}{\partial t}$$

⑦

$$\frac{1}{c^2}\frac{\partial^2 \tilde{U}^\dagger}{\partial t^2} - \Delta \tilde{U}^\dagger + \varkappa^2 \tilde{U}^\dagger \cong \frac{g}{\varkappa c}\,\mathrm{grad}\,M_0$$

$$\left(\frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \Delta + \varkappa^2\right)\mathrm{div}\,\tilde{U}^\dagger \cong \frac{g}{\varkappa c}\,\Delta M_0 \qquad \Delta M_0 = \varkappa^2 M_0 - 4\pi$$

$$\frac{4\pi g c}{\varkappa}\,\mathrm{div}\,\tilde{U}^\dagger \cdot \tilde{M}_0 \cong \frac{g^2}{\varkappa^2}\iiint \Delta M_0(1)\cdot \tilde{M}_0(2)\,\frac{e^{-\varkappa r}}{r}\,dv_1$$

$$= \frac{g^2}{\varkappa^2}\int\!\cdots\!\int \{M_0(1)\tilde{M}_0(2)\}\,\Delta\,\frac{e^{-\varkappa r}}{r}\,dv_1$$

$$= g^2\int\!\cdots\!\int \{M_0(1)\tilde{M}_0(2)\}\frac{e^{-\varkappa r}}{r}\,dv_1 - \frac{4\pi g^2}{\varkappa^2}\int M_0(1)\tilde{M}(2)\,\delta(1,2)\,dv_1$$

$$(\vec{\sigma}^{(1)}\mathrm{grad})(\vec{\sigma}^{(2)}\mathrm{grad})\frac{e^{-\varkappa r}}{r}$$

$$= (\vec{\sigma}^{(1)}\mathrm{grad})\Big\{\underbrace{(\vec{\sigma}^{(2)}\vec{r})\frac{e^{-\varkappa r}}{r^2}}_{-\varkappa} - (\vec{\sigma}^{(2)}\vec{r})\frac{e^{-\varkappa r}}{r^3}\Big\}$$

$$\cancel{= \varkappa^2(\vec{\sigma}^{(1)}\vec{\sigma}^{(2)})\frac{}{r}}$$

$$= \varkappa^2(\vec{\sigma}^{(1)}\vec{r})(\vec{\sigma}^{(2)}\vec{r})\frac{e^{-\varkappa r}}{r^3} - \varkappa(\vec{\sigma}^{(1)}\vec{\sigma}^{(2)})\frac{e^{-\varkappa r}}{r^2}$$

$$+ 2\varkappa(\vec{\sigma}^{(1)}\vec{r})(\vec{\sigma}^{(2)}\vec{r})\frac{e^{-\varkappa r}}{r^4} + \varkappa(\vec{\sigma}^{(1)}\vec{r})(\vec{\sigma}^{(2)}\vec{r})\frac{e^{-\varkappa r}}{r^4}$$

$$- (\vec{\sigma}^{(1)}\vec{\sigma}^{(2)})\frac{e^{-\varkappa r}}{r^3} + 3(\vec{\sigma}^{(1)}\vec{r})(\vec{\sigma}^{(2)}\vec{r})\frac{e^{-\varkappa r}}{r^5}$$

$$= \varkappa^2(\vec{\sigma}^{(1)}\vec{r})(\vec{\sigma}^{(2)}\vec{r})\frac{e^{-\varkappa r}}{r^3} \;\cancel{-\varkappa(\vec{\sigma}^{(1)}\vec{\sigma}^{(2)})\frac{e^{-\varkappa r}}{r^2}}$$

$$\cancel{-3\sigma^{(1)}}\;\cancel{\varkappa}\Big\{(\vec{\sigma}^{(1)}\vec{\sigma}^{(2)}) - \frac{3(\vec{\sigma}^{(1)}\vec{r})(\vec{\sigma}^{(2)}\vec{r})}{r^2}\Big\}\cancel{\frac{e^{-\varkappa r}}{r^2}}$$

$$-\;0 \qquad \Big\{\varkappa - \frac{1}{r}\Big\}\frac{e^{-\varkappa r}}{r^2}$$

s-state,
$$\frac{(\vec{\sigma}^{(1)}\vec{r})(\vec{\sigma}^{(2)}\vec{r})}{r^2} = \iint \frac{x^2}{r^2}\sigma_x^{(1)}\sigma_x^{(2)} + \cdots = \frac{\vec{\sigma}^{(1)}\vec{\sigma}^{(2)}}{3}$$

$$\{(\vec{\sigma}_x^{(1)}\cos\theta\sin\theta\cos\varphi)(\sigma_x^{(2)}\sin\theta\cos\varphi) + (\quad)(\quad) + (\quad)(\quad)\}u$$

$$= 0.$$

$$L = \tilde{F}F - (\tilde{U}U + \tilde{U}_0 U_0 - (M\tilde{U} - M_0\tilde{U}_0)) - (\tilde{G} - \tilde{T})(G - T)$$

$$\kappa F = \kappa S - \left(\frac{1}{c}\frac{\partial U}{\partial t} + \mathrm{grad}\, U_0\right)$$

$$\kappa G = \kappa T + \mathrm{curl}\, U$$

$$- \tilde{G}\tilde{T} - \tilde{G}\tilde{T}$$

$$\delta L = \delta U \{$$

$$\frac{\partial L}{\partial \frac{\partial U}{\partial t}} = \frac{-1}{\kappa c}\tilde{F}$$

$$H = -\frac{1}{\kappa c}\tilde{F}\cdot\frac{\partial U}{\partial t} \pm \quad - L$$

$$= - \tilde{F}(F - S + \cdots)$$

$$+ (\kappa\tilde{T} + \mathrm{curl}\,\tilde{U})(\kappa T + \mathrm{curl}\, U)$$

$$L = (\tilde{F} + \tilde{S})(F + S) - (\tilde{G} + \tilde{T})(G + T) - \tilde{U}U + \tilde{U}_0 U_0$$

$$- (M\tilde{U} - M_0\tilde{U}_0) + \text{comp. conj.}$$

$$= \frac{1}{\kappa^2}\left(\frac{1}{c}\frac{\partial\tilde{U}}{\partial t} + \mathrm{grad}\,\tilde{U}_0\right)\left(\frac{1}{c}\frac{\partial U}{\partial t} + \mathrm{grad}\, U_0\right) - \frac{1}{\kappa^2}\mathrm{curl}\,\tilde{U}\,\mathrm{curl}\, U$$

$$- \tilde{U}U + \tilde{U}_0 U_0 - (M\tilde{U} - M_0\tilde{U}_0) + \text{comp. conj.}$$

$$\delta L = \delta\tilde{U}\cdot\left\{\frac{1}{\kappa c}\frac{\partial(F+S)}{\partial t} - \frac{1}{\kappa}\mathrm{curl}(G + T) - \cancel{\kappa}\, U - M\right\}$$

$$+ \delta U_0 \left\{\frac{1}{\kappa}\mathrm{div}(F + S) + U_0 + M_0\right\} +$$

$$\left.\begin{aligned} &\frac{1}{\kappa c}\frac{\partial F}{\partial t} - \mathrm{curl}\, G - \kappa U = \kappa M - \frac{1}{c}\frac{\partial S}{\partial t} + \mathrm{curl}\, T \\ &\mathrm{div}\, F + \kappa U_0 = -\kappa M_0 - \mathrm{div}\, S. \end{aligned}\right\}$$

$$\left.\begin{aligned} &\frac{1}{c}\frac{\partial\tilde{U}}{\partial t} + \mathrm{grad}\,\tilde{U}_0 + \kappa F = \kappa S \\ &\mathrm{curl}\, U - \kappa G = \kappa T. \end{aligned}\right\}$$

$$U^{+} = -\frac{1}{\kappa c}(\tilde{F} + \tilde{S}) = \frac{1}{\kappa c}\left(\frac{1}{c}\frac{\partial\tilde{U}}{\partial t} + \mathrm{grad}\,\tilde{U}_0\right)$$

$$H = \frac{1}{\kappa c}\left(\tilde{F} + \frac{\partial \tilde{U}}{\partial t} [illegible] \frac{\partial U^{+}}{\partial t} [illegible] \tilde{S}\right)(F+S)$$

$$-(\tilde{G}+\tilde{T})(G+T) + \tilde{U}U - \tilde{U}_0 U_0 + (M\tilde{U} - M_0\tilde{U}_0)$$

+ comp. conj.

$$= U^{+}(\kappa^2c^2\tilde{U}^{+} - c\,\mathrm{grad}\,\tilde{U}_0) + \tilde{U}^{+}(\kappa^2c^2U^{+} - c\,\mathrm{grad}\,U_0)$$

$$- \kappa^2c^2U^{+}\tilde{U}^{+} - \ldots$$

$$= \kappa^2c^2U^{+}\tilde{U}^{+} - c(U^{+}\,\mathrm{grad}\,\tilde{U}_0 + \tilde{U}^{+}\,\mathrm{grad}\,U_0) - \mathrm{curl}\,\tilde{U}\,\mathrm{curl}\,U$$

$$+ \tilde{U}U - \tilde{U}_0U_0 + (M\tilde{U} - M_0\tilde{U}_0)$$ + comp conj.

$$\frac{1}{c}\frac{\partial \vec{F}}{\partial t} - \mathrm{curl}\,\vec{G} - (\varkappa \vec{U} + \mathrm{grad}\,M) = 0 \qquad \mathrm{div}\,\vec{F} + (\varkappa U_0 - \frac{1}{c}\frac{\partial M}{\partial t}) = 0$$

$$\frac{1}{c}\frac{\partial U}{\partial t} +$$

$$\left.\begin{aligned} &\frac{1}{c}\frac{\partial \vec{F}}{\partial t} - \mathrm{curl}\,\vec{G} = \varkappa \vec{U} + \mathrm{grad}\,S \qquad && \mathrm{div}\,\vec{F} = -\varkappa U_0 + \frac{1}{c}\frac{\partial S}{\partial t}. \\ &\frac{1}{c}\frac{\partial \vec{U}}{\partial t} + \mathrm{grad}\,U_0 + \varkappa \vec{F} = 0 && \mathrm{curl}\,\vec{U} - \varkappa \vec{G} = 0. \end{aligned}\right\}$$

$$\frac{1}{c}\frac{\partial}{\partial t}(\varkappa \vec{U} + \mathrm{grad}\,S) + \mathrm{grad}\,(\varkappa U_0 - \frac{1}{c}\frac{\partial S}{\partial t}) + \varkappa \vec{F} = 0.$$