

Title: Quantum Fields and Strings Lecture - 230327

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Collection: Quantum Fields and Strings (2022/2023)

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$$\int \delta(f(x)) dx \quad \frac{\partial f}{\partial x} \rightarrow \nabla_{\bar{z}} : v^z \rightarrow \nabla_{\bar{z}} v^z$$

$$h_{ab} \rightarrow e^{\phi} \delta_{ab}$$

$$\int \delta(h_{zz}) \int \delta(h_{\bar{z}\bar{z}})$$

$$\delta h_{zz} = \nabla_{\bar{z}} v^{\bar{z}}$$

$$\delta h_{\bar{z}\bar{z}} = \nabla_z v^z$$

$$S_{bc} = \int_{\Sigma} b_{z\bar{z}} \nabla_{\bar{z}} c^z d\bar{z}^2 + \int_{\Sigma} b_{\bar{z}\bar{z}} \nabla_z c^{\bar{z}} d\bar{z}^2$$

$$\int \delta(f(x)) dx \quad \frac{\partial f}{\partial x} \rightarrow \nabla_{\bar{z}} : v^z \rightarrow \nabla_{\bar{z}} v^z$$

$$h_{ab} \rightarrow e^{\phi} \delta_{ab}$$

$$\delta(h_{zz}) \delta(h_{\bar{z}\bar{z}})$$

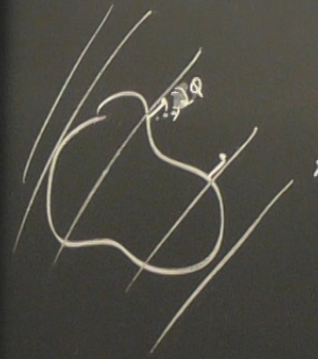
$$\delta h_{zz} = \nabla_{\bar{z}} v^{\bar{z}}$$

$$\delta h_{\bar{z}\bar{z}} = \nabla_z v^z$$

$$S_{bc} = \int_{\Sigma} b_{zz} \nabla_{\bar{z}} c^z \text{vol}^2 + \int_{\Sigma} b_{\bar{z}\bar{z}} \nabla_z c^{\bar{z}} \text{vol}^2$$

$$Q: b_{ab} \rightarrow T_{ab}$$

$$: X \rightarrow c^z \partial_z X + c^{\bar{z}} \partial_{\bar{z}} X$$



x^a
↑
Bosons

dx^a
↑
FERMIONS

$$dx^1 dx^2 = -dx^2 dx^1$$

$$f(x^a, dx^a) = f^{(0)}(x) + dx^a f_{,a}^{(1)}(x) + \frac{1}{2} dx^a dx^b f_{ab}^{(2)}(x) + \dots + \int^{(6L)} dx^1 dx^2 \dots dx^D$$

$$(dx^a) = dx^b \frac{\partial x^a}{\partial x^b}$$

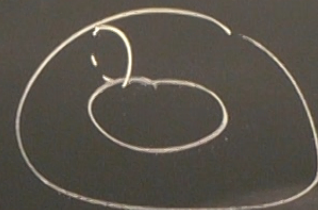
5
 dx^1

$$f^{(0)}(x) + dx^a f_{,a}^{(1)}(x) + \frac{1}{2} dx^a dx^b f_{,ab}^{(2)}(x) + \dots + f^{(D)} dx^1 dx^2 \dots dx^D$$

$$d^2 = 0$$

$$\int_{\gamma_d} f = \int_{\gamma_d} f_{\alpha_1 \dots \alpha_d}^{(d)} \frac{\partial x^{\alpha_1}}{\partial u^1} \dots \frac{\partial x^{\alpha_d}}{\partial u^d} du^1 \dots du^d$$

$$\int_{\gamma_d} df = \int_{\partial \gamma_d} f$$



PLOU

$\pi a \pi \bar{a} |p\rangle$

$$\mathcal{H}_X \otimes \mathcal{H}_{gh} \in |gh\rangle$$

$$\vec{p} = (p_1, \dots, p_D)$$

$$E |p\rangle = \sum_{i=1}^{26} (p_i^2 - \frac{1}{12}) = |\vec{p}|^2 - \frac{26}{12}$$

$$E(|p\rangle \otimes |gh\rangle) = |\vec{p}|^2 - 2$$

$$|PHYS\rangle \in \mathcal{H}_X \otimes \mathcal{H}_{GH}$$

$$\langle PHYS | T | PHYS \rangle = 0$$

$$\langle PHYS | NULL \rangle = 0$$

PHYS / NULL

$$L_m |PHYS\rangle = 0 \quad m > 0$$

$$\bar{L}_n |PHYS\rangle = 0$$

$$(L_0 - 1) |PHYS\rangle = 0$$

$$(\bar{L}_0 - 1) |PHYS\rangle = 0$$

$$|NULL\rangle = L_{-n} | \dots \rangle \quad m > 0$$

$\left(\mathcal{H}_X \otimes \mathcal{H}_{gh} \right) \in |gh\rangle$

$\vec{p} = (p_1, \dots, p_D)$

$E |p\rangle = \sum_{i=1}^{26} (p_i^2 - \frac{1}{12}) = |\vec{p}|^2 - \frac{26}{12}$

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$(\bar{L}_0 - 1) |PHYS\rangle = 0$

$|NULL\rangle = L_{-n} | \dots \rangle \quad m > 0$

$$\frac{\partial x^{\alpha d}}{\partial u^d} du^1 \dots du^d$$

$$E_{\mu\nu}(p) p^\mu = 0$$

$$E_{\mu\nu} p^\nu = 0$$

$$L_1 (a_{-1}^\mu \bar{a}_{-1}^\nu | p \rangle \omega | p \rangle$$

$$p^2 = 0$$

$$E_{\mu\nu}(p) = p_\mu \eta_{\nu}(p) \text{ NULL}$$

$$E_{\mu\nu} = \eta_{\mu\nu}^{(p)} p_\mu \text{ NULL}$$

$$E_{\mu\nu} = E_{\mu\nu}^{ST} + E_{\mu\nu}^A + E_{\mu\nu}^{\tilde{g}}$$

$$\textcircled{g_{\mu\nu}}$$

$$L_n = \sum a_n^+ a_m a_{m-n} + \sum b_n^+ b_m c_{m-n}$$

$$\int \partial_\mu x^\mu \partial_\nu x^\nu$$

$$dx^2 \dots dx^D$$

$$\frac{\partial x^{\alpha d}}{\partial u^d} du^1 \dots du^d$$

$$|\vec{p}\rangle \otimes |gl\rangle$$

WHEN IS IT PHYSICAL?

$$\frac{p^2}{2} - 1 = 0$$

$$p^2 = 2 = -m^2$$

"TACHYON"

SCALAR FIELD

$$E_{\mu\nu}^{(p)} a_{-1}^{\mu-\nu} |p\rangle \otimes |gl\rangle$$

$$L_2 = 0, L_3 = 0 \dots$$

$$E_{\mu\nu}(p) p^\mu = 0$$

$$E_{\mu\nu} p^\nu = 0$$

$$L_1 (a_{-1}^{\mu-\nu} |p\rangle \otimes |gl\rangle) = p^\mu a_{-1}^{-\nu} |p\rangle \otimes |gl\rangle$$

$$E_{\mu\nu}(p) = p_\mu \eta_{\nu\alpha} \text{ NULL}$$

$$p^2 = 0$$

$$E_{\mu\nu} = \eta_{\mu\alpha} p_\alpha \text{ NULL}$$

$$E_{\mu\nu} = E_{\mu\nu}^{ST} + E_{\mu\nu}^A + E_{\mu\nu}^\varphi$$

$$g_{\mu\nu}$$

$$B_{\mu\nu}$$

$$\varphi$$

$$a_{-1}^2 \quad a_{-2}$$

$$p^2 = -2$$

$$E_{\mu\nu} \alpha_{-1}^\mu \tilde{\alpha}_{-1}^\nu |p\rangle$$

$$\int (x^\mu \otimes H_{gl}) \in$$

$$E |p\rangle = \sum_{i=1}^D (p_i^2 - 1)$$

$$E(|p\rangle \otimes |gl\rangle) =$$

|PHYS>