Title: Quantum Fields and Strings Lecture - 230327

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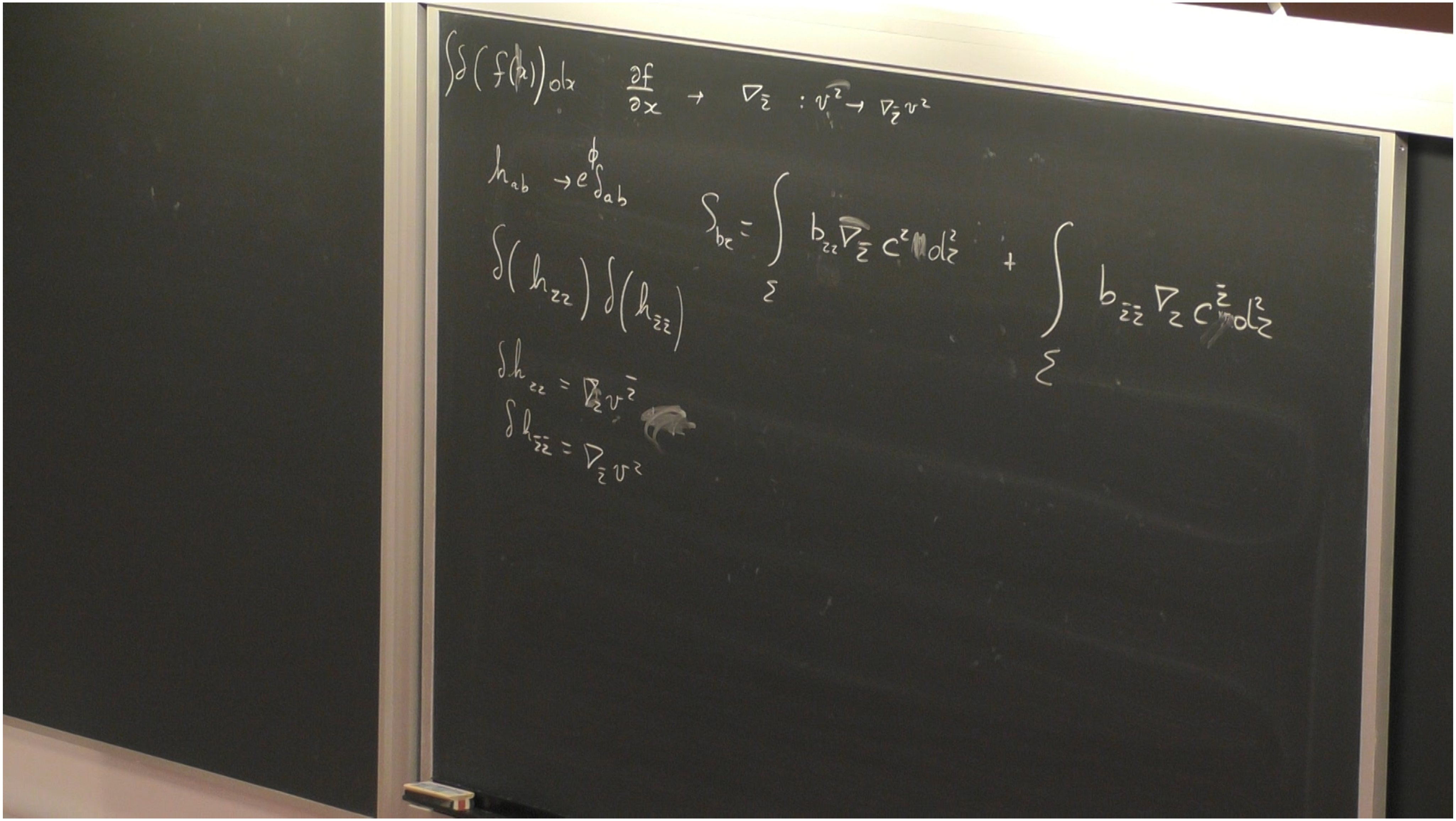
Collection: Quantum Fields and Strings (2022/2023)

Date: March 27, 2023 - 10:15 AM

URL: https://pirsa.org/23030026


$\int \delta(f(x))\,dx$ $\quad \frac{\partial f}{\partial x} \to \nabla_{\bar z} : v^z \to \nabla_{\bar z} v^z$
$h_{ab} \to e^{\phi}\delta_{ab}$
$S_{bc} = \int_\Sigma b_{zz} \nabla_{\bar z} c^z d^2z + \int_\Sigma b_{\bar z \bar z} \nabla_z c^{\bar z} d^2 z$
$\delta(h_{zz})\,\delta(h_{\bar z \bar z})$
$\delta h_{zz} = \nabla_z v^{\bar z}$
$\delta h_{\bar z \bar z} = \nabla_{\bar z} v^z$

$$\int \delta(f(x))\,dx \qquad \frac{\partial f}{\partial x} \to \nabla_{\bar z} : v^z \to \nabla_{\bar z} v^z$$

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

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

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

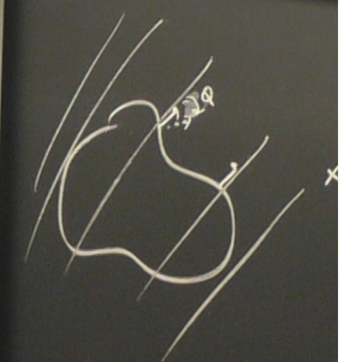
$$\delta h_{zz} = \nabla_z v^{\bar z}$$

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

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

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

$$\ldots$$



x^a , dx^a

BOSONS   FERMIONS

ODD

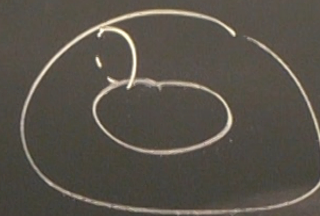
$$dx^1 dx^2 = -dx^2 dx^1$$

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

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

dx^1

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



$d^2 = 0$

$$\int_{\gamma_d \in M_D} f = \int_{\gamma_d} f^{(d)}_{a_1 \dots a_d} \frac{\partial x^{a_1}}{\partial u^1} \cdots \frac{\partial x^{a_d}}{\partial u^d} du^1 \cdots du^d$$

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

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

$$\mathcal{H}_{X^\mu} \otimes \mathcal{H}_{gh} \in |gh\rangle \qquad \vec{p} = (p_1 \cdots p_D)$$

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

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

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

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

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

$$PHYS / NULL$$

$$L_n |PHYS\rangle = 0 \qquad n > 0$$

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

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

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

$$|NULL\rangle = L_{-n}|\cdots\rangle \qquad n > 0$$

?

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

$\mathcal{H}_{X^\mu} \otimes \mathcal{H}_{gh} \in |gh\rangle$

$\vec{p} = (p_1 \cdots p_D)$

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

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

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

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

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$PHYS/NULL$

$L_n|PHYS\rangle = 0 \quad n>0$

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

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

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

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

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

$$\cdots \frac{\partial x^{a_d}}{\partial u^{d}}\, du^{1} \dots du^{d}$$

$$\epsilon_{\mu\nu}\, p^{\nu} = 0$$

$$L_1 \left(a^{\mu}_{-1}\, \bar{a}^{\nu}_{-1}\, |p\rangle \otimes |0\rangle \right.$$

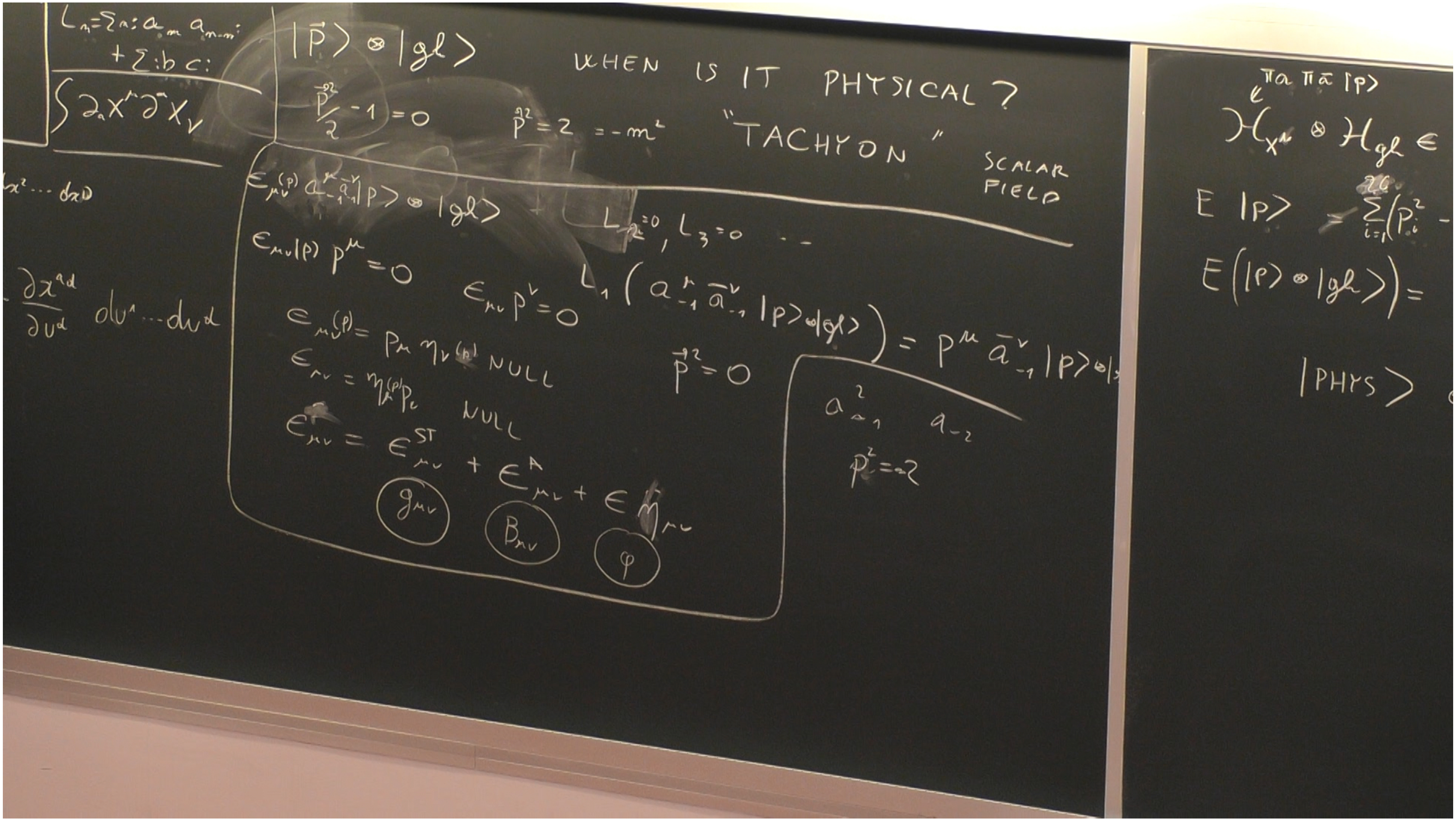
$$\epsilon_{\mu\nu}(p) = p_{\mu}\, \eta_{\nu}(p) \quad \text{NULL}$$

$$\vec{p}^{\,2} = 0$$

$$\epsilon_{\mu\nu} = \eta_{\mu}(p)\, p_{\nu} \quad \text{NULL}$$

$$\epsilon_{\mu\nu} = \epsilon^{ST}_{\mu\nu} + \epsilon^{A}_{\mu\nu} + \epsilon\, \eta_{\mu\nu}$$

$$g_{\mu\nu}$$


|P> ⊗ |gh>
WHEN IS IT PHYSICAL ?
"TACHYON"
SCALAR FIELD
NULL
NULL
|PHYS>