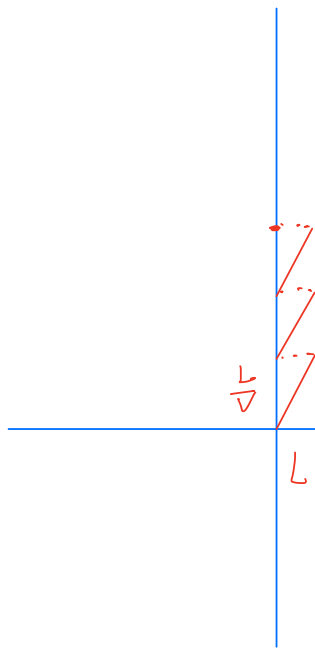1.

y axis contracted by $\sqrt{1-v^2}$

$y = \bar{y} \cdot \sqrt{1-v^2}$

So the angle of the wall relative to x axis

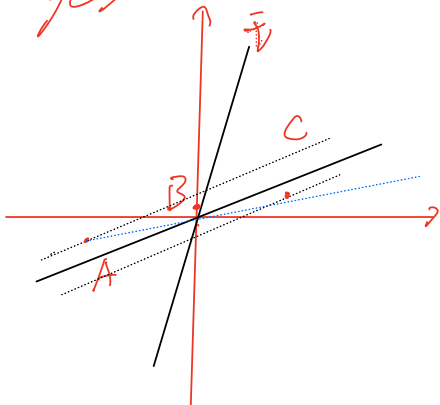is contlat by $\tan^{-1}(\sqrt{1-v^2})$

use w as ball's v,

2)

$$A't = \frac{L}{V} = \Delta t$$

$$B't = \sqrt{\Delta t^2 - \Delta x^2}$$

$$= \sqrt{\frac{L^2}{V^2} - L^2}$$
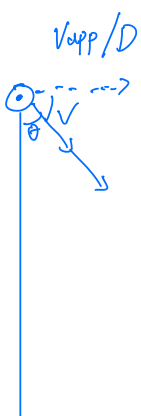
$$= \sqrt{1-V^2}\left(\frac{L}{V}\right)$$

$\frac{L}{V}$

L

3. yes

in $\bar{O}$, C happen fist, then B then A.
dot line are line of simultaneity

blue line represent X axis of
a coordinate that ACB

4)

V_{app}/D

gas emit at $t=0$, arrive our eyes at $t_0 = \frac{D}{C}$
gas at t_{00} arrows at point that projection is
$V \cdot \frac{D}{C} \sin\theta$, for this arrive our eye the take $\frac{L}{C}$
which $t_{01} = \frac{D}{C} + \frac{L}{C}$
for $\frac{L}{C}$, gas then $V \cdot \frac{D}{C} \sin\theta$ in our eyes

$$V_{app} = V\frac{D}{C}\sin\theta \Big/ \frac{L}{C} = V\frac{D}{L}\sin\theta$$

$$L = \left(D - V\cdot\frac{D}{C}\cos\theta, \ V\cdot\frac{D}{C}\sin\theta\right)$$

$$= \sqrt{\left(D - V\cdot\frac{D}{C}\cos\theta\right)^2 + \left(V\cdot\frac{D}{C}\sin\theta\right)^2}$$

$$= \sqrt{D^2\left[\left(1 - \frac{V}{C}\cos\theta\right)^2 + \frac{V^2}{C^2}\sin^2\theta\right]}$$

$$= D\sqrt{1 - 2\frac{V}{C}\cos\theta + \frac{V^2}{C^2}\cos^2\theta + \frac{V^2}{C^2}\sin^2\theta}$$

$$= D\sqrt{\frac{V^2}{C^2} + 1 - 2\frac{V}{C}\cos\theta}$$

$$V_{app} = \frac{V\sin\theta}{\sqrt{1 + V^2 - 2V\cos\theta}}$$

$$\sqrt{}\ \sin^2\theta > 1 + V^2 - 2V\cos\theta$$

$$\sin^2\theta > 2 - 2\cos\theta \qquad \checkmark$$

⑤

$$0.106 \ \text{GeV} \qquad 2.19 \times 10^{-6}\ S$$

⬓ 1km

$$0.106 \cdot \gamma = 1000$$

$$\gamma = 9434 = \frac{1}{\sqrt{1-V^2}} \qquad\qquad 1 - V^2 = \frac{1}{9434^2}$$

$$t = c \cdot 9434 = 0.021 \, S$$

$$0.021 \cdot c / \pi \, km = 0.021 \cdot 3 \cdot 10^5 / \pi$$

$$= 6300 / \pi$$

$$= 2006.4$$

$$radian = 12600$$

(6)

(a)

$$\frac{\partial X_i}{\partial \lambda} = (1, 2(\lambda - 1), -1)$$

$$at \, p = (1, -2, -1)$$

$$\frac{\partial X_i}{\partial u} = (-\sin u, \cos u, 1)$$

$$at \, p = (-\sin 1, 1, 1)$$

$$\frac{\partial X_i}{\partial \theta} = (2\theta, 3\theta^2 + 2\theta, 1)$$

$$at \, p = (2, 0, 1)$$

(b)

$$\frac{df}{d\lambda} = \frac{d}{d\lambda}\left[\lambda^2 + (\lambda-1)^4 + \lambda(\lambda^{-1}-1)^2\right]$$

(7) (a)

$$X^\mu{}_\nu = \eta_{\alpha\nu} \cdot X^{\mu\nu}$$

$$= \eta_{00} \cdot X^{\mu 0} + \eta_{11} \cdot X^{\mu 1} + \eta_{22} \cdot X^{\mu 2} + \eta_{33} \cdot X^{\mu 3}$$

$$= \begin{pmatrix} -2 & 0 & 1 & -1 \\ 1 & 0 & 3 & 2 \\ 1 & 1 & 0 & 0 \\ 2 & 1 & 1 & -2 \end{pmatrix}$$

(b) $X_\mu{}^\nu = \begin{pmatrix} -2 & 0 & -1 & 1 \\ -1 & 0 & 3 & 2 \\ -1 & 1 & 0 & 0 \\ -2 & 1 & 1 & -2 \end{pmatrix}$

ⓒ
$$X^{(\mu\nu)} = \frac{1}{2}\left(X^{\mu\nu} + X^{\nu\mu}\right)$$

ⓓ
$$X_{\mu\nu} = \begin{pmatrix} 2 & 0 & -1 & 1 \\ 1 & 0 & 3 & 2 \\ 1 & 1 & 0 & 0 \\ 2 & 1 & 1 & -2 \end{pmatrix}$$

$$X_{[\mu\nu]} = \frac{1}{2}\left(X_{\mu\nu} - X_{\nu\mu}\right)$$

ⓔ
$$X^{\mu}{}_{\nu} = \begin{pmatrix} -2 & 0 & 1 & -1 \\ 1 & 0 & 3 & 2 \\ 1 & 1 & 0 & 0 \\ 2 & 1 & 1 & \sim 2 \end{pmatrix}$$

$$X^{\lambda}{}_{\lambda} = -4$$

ⓕ
$$V_{\mu} = \begin{pmatrix} 1 \\ 2 \\ 0 \\ -2 \end{pmatrix}$$

$$V^{\mu}V_{\mu} = -1 + 4 + 0 + 4$$

$$= 7$$

⑦

$$V_\mu X^{\mu\nu} = \begin{pmatrix} 2 & 0 & 1 & -1 \\ -2 & 0 & 6 & 4 \\ 0 & 0 & 0 & 0 \\ 4 & -2 & -2 & 4 \end{pmatrix}$$

$$= (4, -2, 5, 7)$$

⑧

space derivative of momentum

basrelly mean changing of momentum with space displement.

⑨

$$T^{\alpha\beta} = \eta^{\alpha\mu} \eta^{\beta\nu} T_{\mu\nu}$$

$$T^{\mu\nu} = \sum_a \frac{p^{\mu(a)} p^{\nu(a)}}{p^{0(a)}} \delta^{(3)}(x - x^{(a)})$$

10

(a)

$$F_{\mu\nu} = \begin{pmatrix} 0 & -E_1 & -E_2 & -E_3 \\ E_1 & 0 & B_3 & -B_2 \\ E_2 & -B_3 & 0 & B_1 \\ E_3 & B_2 & -B_1 & 0 \end{pmatrix} -$$

$$F^{\mu'\nu'} = \Lambda^{\mu'}_{\mu} \Lambda^{\nu'}_{\nu} F^{\mu\nu}$$

$$A^{\alpha}_{\beta} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & 0 & \sin\theta \\ 0 & 0 & 1 & 0 \\ 0 & -\sin\theta & 0 & \cos\theta \end{pmatrix} \rightarrow$$

$$F_{\mu\nu'} = A^{\nu}_{\nu'} F_{\mu\nu} = \sum_{\nu=0}^{3} A^{\nu}_{\nu'} F_{\mu\nu}$$

$$= \begin{bmatrix} 0 & -\cos\theta E_1 - \sin\theta E_3 & -E_2 & \sin\theta E_1 - \cos\theta E_3 \\ E_1 & -\sin\theta B_2 & B_3 & -\cos\theta B_2 \\ E_2 & -\cos\theta B_3 + \sin B_1 & 0 & \sin\theta B_3 + \cos\theta B_1 \\ E_3 & -\cos\theta B_2 & -B_1 & -\sin\theta B_2 \end{bmatrix}$$

$$F_{\mu'\nu'} = \Lambda_{\mu'}{}^{\mu}\, F_{\mu\nu'}$$

$$\begin{pmatrix} 0 & -\cos\theta\,E_1 + \cos\theta\,E_3 & -E_2 & -\sin\theta\,E_1 - \cos\theta\,E_3 \\[2mm] E_1\cos\theta + E_3\sin\theta & 0 & B_3\cos\theta - B_1\sin\theta & -B_2 \\[2mm] E_3 & -B_3\cos\theta + B_1\sin\theta & 0 & B_3\sin\theta + B_1\cos\theta \\[2mm] E_3\cos\theta - E_1\sin\theta - B_2 & B_3\sin\theta + B_1\cos\theta & 0 & \end{pmatrix}$$

11,

$$\partial_{[\mu} F_{\nu\lambda]} = 0$$

$$\frac{1}{6}\left[\partial_\mu F_{\nu\lambda} - \partial_\lambda F_{\nu\mu} + \partial_\nu F_{\lambda\mu} - \partial_\mu F_{\lambda\nu}\right.$$

$$\left. + \partial_\lambda F_{\mu\nu} - \partial_\nu F_{\mu\lambda}\right] = 0$$

$$\frac{1}{6}\left[\partial_\mu F_{\nu\lambda} - \partial_\lambda F_{\nu\mu} + \partial_\nu F_{\lambda\mu} - \partial_\mu F_{\lambda\nu} + \partial_\lambda F_{\mu\nu} - \partial_\nu F_{\mu\lambda}\right] = 0$$

$$\frac{1}{6}\left[\partial_\mu F_{\nu\lambda} + \partial_\mu F_{\nu\lambda} + \partial_\lambda F_{\mu\nu} + \partial_\lambda F_{\mu\nu} + \partial_\nu F_{\lambda\mu} + \partial_\nu F_{\lambda\mu}\right] = 0$$

$$\partial_\mu F_{\nu\lambda} + \partial_\lambda F_{\mu\nu} + \partial_\nu F_{\lambda\mu} = 0$$

Ⓑ

$$F_{0k} = E_k$$

$$B_i = \varepsilon^{aji} F_{aj} = \frac{1}{2}\varepsilon^{kji} F_{kj}$$

$$F_{ij} = \varepsilon^{ijk} B_k$$

$$\varepsilon^{ijk}\partial_j F_{0k} + \frac{1}{2}\partial_0 \varepsilon^{ijk} F_{ij} = 0$$

$$\frac{1}{2}\partial_k \varepsilon^{zjk} F_{zj} = 0$$

$$\nabla \cdot B = 0 \quad = \partial_i B^i$$

$$= \partial_i \frac{1}{2} \varepsilon^{ijk} F_{jk}$$

$$= \frac{1}{2} \partial_{[i} F_{jk]} = 0$$

$$\partial_j F_{0i} + \partial_i F_{0j} + \partial_0 F_{ij} = 0$$

$$= \partial_j E_i - \partial_i E_j + \varepsilon_{ijk} \dot{B}^k$$

$$= (\delta_{im} \delta_{jn} - \delta_{in} \delta_{jm}) \partial_m E_n + \varepsilon_{ijk} \dot{B}^k$$

$$= \varepsilon_{ijk} \varepsilon_{kmn} \partial_m E_n + \varepsilon_{ijk} \dot{B}^k$$

$$= \varepsilon_{ijk} (\nabla \times E)^k + \varepsilon_{ijk} \dot{B}^k = 0$$

$$= (\nabla \times E)^k + \dot{B}^k = 0$$

$$= \nabla \times E + \partial_t B = 0$$

$$\partial_0 F_{jk} + \partial_j F_{k0} + \partial_k F_{0j} = 0 \quad \bigcirc \!\!\!\! \ddot\smile$$