

Title: Exactly Solvable Topological and Fracton Models as Gauge Theories 2

Speakers: Xie Chen

Collection: Online School on Ultra Quantum Matter

Date: August 12, 2020 - 12:30 PM

URL: <http://pirsa.org/20080008>



Home

Insert

Draw

View



Text Mode



Lasso Select



Insert Space



Shapes



Link to Shape

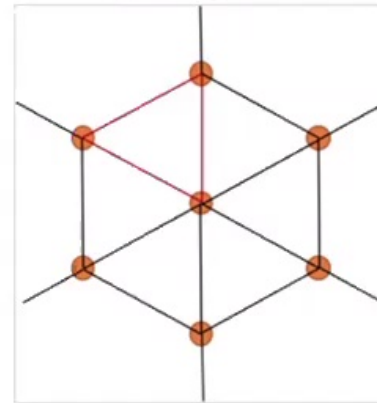
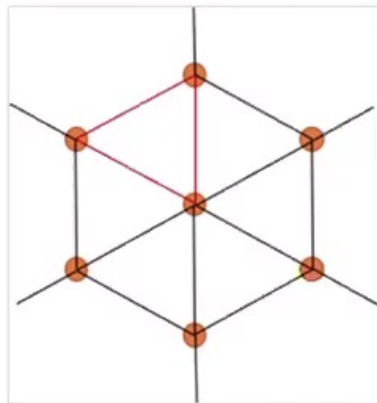


Drawing Mode

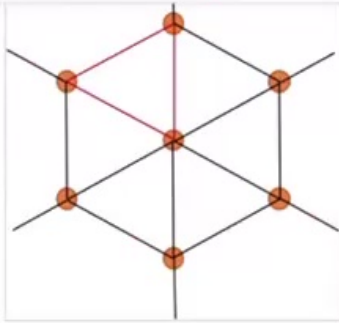
Exactly Solvable Topological and Fracton Models as Gauge Theories

1. Toric Code
2. Toric Code as Gauge Theory
3. Toric Code from Gauging
4. Double Semion from Gauging
5. X-cube from Gauging

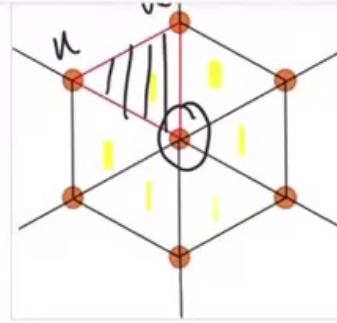
4. Double Semion from Gauging SPT.



$$|h\rangle = -\sum \sigma_x$$



$$H_0 = -\sum \sigma_x$$



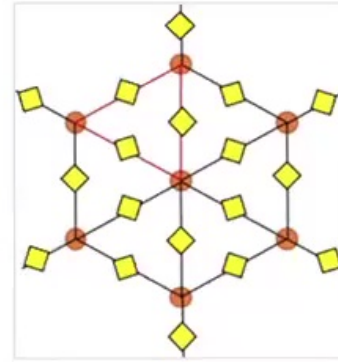
$$H_1 = -\sum \sigma_x \prod_{\Delta} i$$

$$\frac{1 - \sigma_u^z \sigma_{u'}^z}{2}$$

$$U = \prod \sigma_x$$

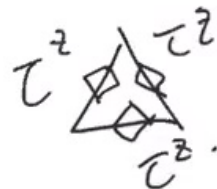
unique gapped ground state.

unique gapped ground state.

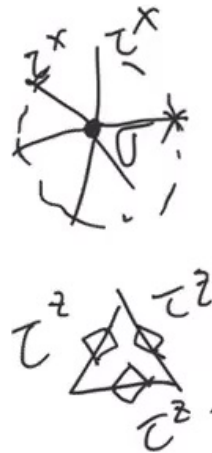
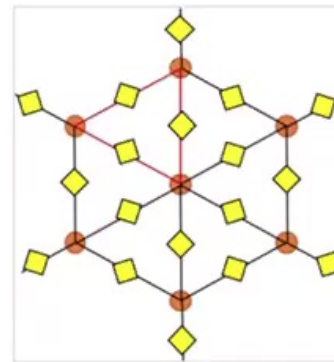
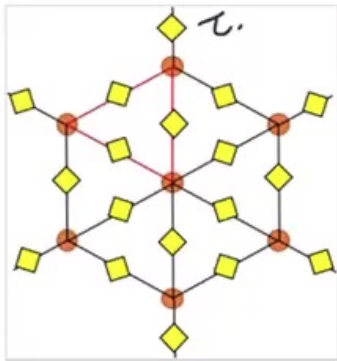


$$\sigma_x \pi \tau^x$$

$$H_1 = -\frac{2}{1 - \sqrt{2}}$$



unique gapped ground state



$$H_i^g = -\sum \sigma_x \tau^x$$

$$+ G.S. + Flux.$$

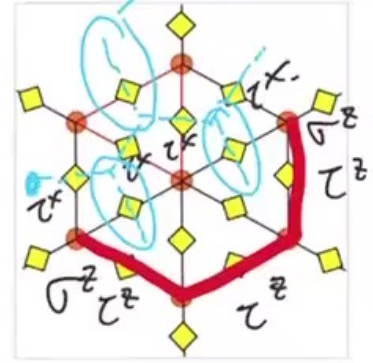
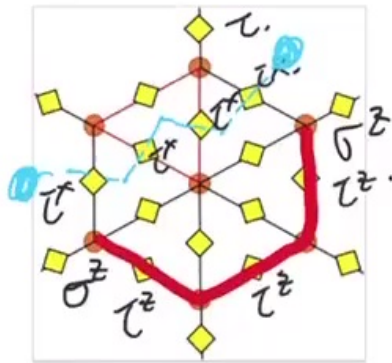
$$H_i^g = -\sum \sigma_x \tau^x \frac{1 - \sigma^z \tau^z}{2}$$

$$+ G.S. + Flux.$$



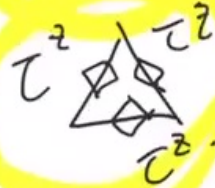
unique gap

phase factors in τ^z basis.



$$H_0^g = -\sum \sigma_x$$

+ G.S. + Flux.



$$\sigma_x \pi \tau^x$$

$$H_1^g = -\sum$$

$$\sigma_x \pi i$$

+ G.S. + Flux.





Home Insert Draw View



A Text Mode

Lasso Select

Insert Space

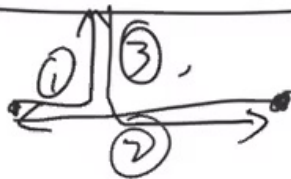


Shapes

Ink to Shape

Drawing Mode

e : bosonic
 $m-e$: -1 statistics.

m :  $i, \pi/2$.

1 : bosonic.

m : semion em : semion $-i$.

Double semion.



Home Insert Draw View



A Text Mode

Lasso Select

Insert Space



Shapes

Ink to Shape

Drawing Mode

< M : boson CC.

M : semion

EM : semion

Double semion.

symmetry Protected Topo Order.





Home Insert Draw View

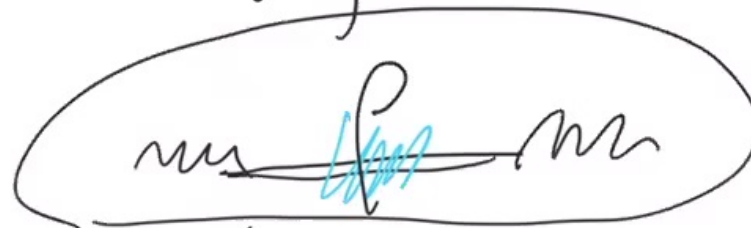


A Text Mode Lasso Select Insert Space

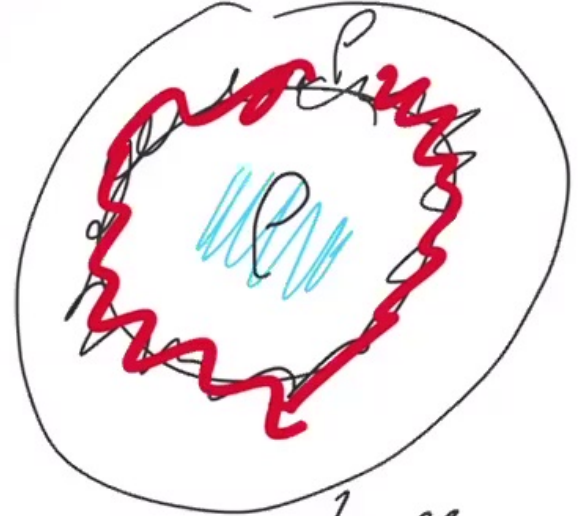


Shapes Ink to Shape Drawing Mode

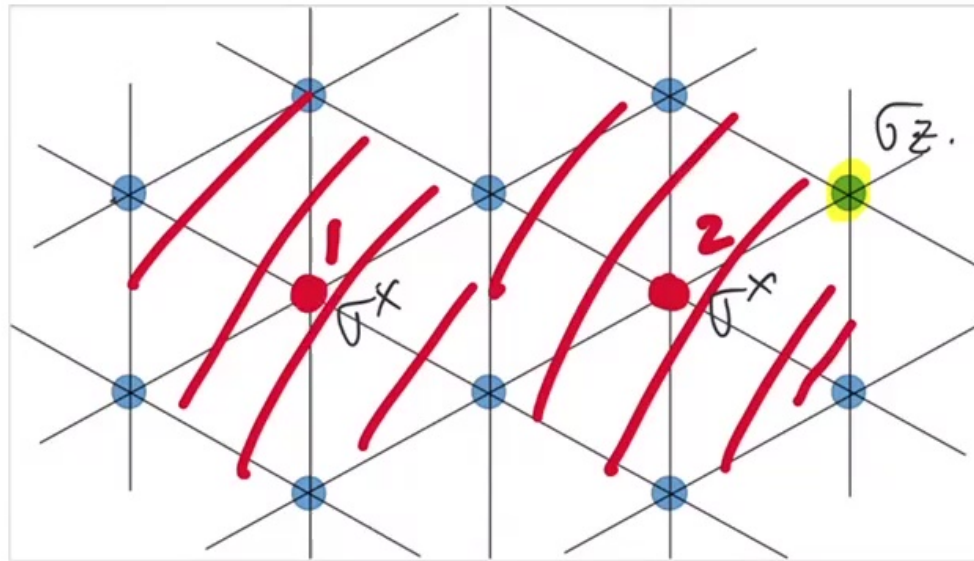
symmetry Protected Topo Order.
degenerate.



Edge State.

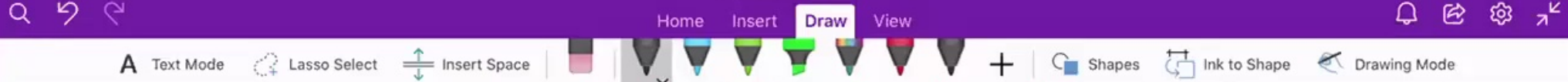


gapless.



$H_0 = -\sum \sigma_x$
 no edge state.

$H_1 = h_1 + h_2$
 ① $-\sum \sigma_z$ explicit S.B.



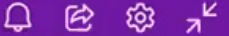
$H_0 = -\sum \sigma_x$
no edge state.

$$H_1 = h_1 + h_2$$

① $-\sum \sigma_z$ explicit S.B.
gap.

② $-\sum \sigma^z \sigma^z$ $\pi \sigma^z \sigma^z = I$

2-fold degenerate.
spo



$H_0 = -\sum \sigma_x$
no edge state.

$$H_1 = h_1 + h_2$$

① $-\sum \sigma_z$ explicit S.B. gap.

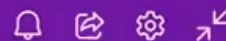
② $-\sum \sigma^z \sigma^z$ $\pi \sigma^z \sigma^z = I$

2-fold degenerate.
spontaneous S.B. gap.

$$\partial_\mu \phi \rightarrow D_\mu \phi = \partial_\mu \phi + A_\mu$$



Home Insert Draw View



A Text Mode Lasso Select Insert Space Shapes Ink to Shape Drawing Mode

no edge state.

① $-\Sigma\sigma_z$ explicit S.B. gap.

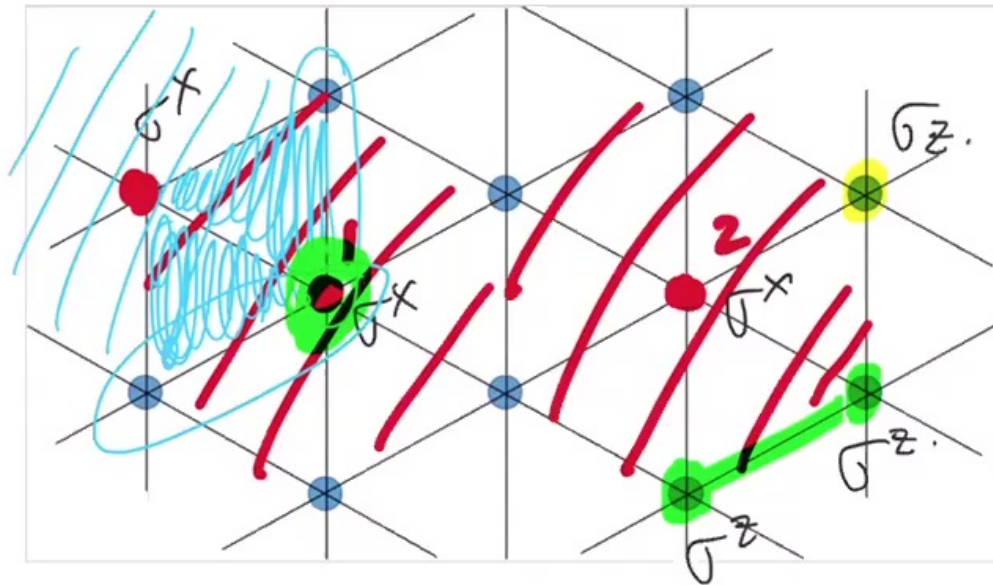
② $-\Sigma\sigma^z\sigma^z$ $\Pi\sigma^z\sigma^z = I$

2-fold degenerate.
spontaneous S.B. gap.

$$\partial_\mu \phi \rightarrow D_\mu \phi = \partial_\mu \phi + A_\mu$$

$$\sigma_z \sigma_z \rightarrow \sigma_z \bar{\tau}_z \sigma_z$$

large gapless



$$H_0 = -\sum \tau_x.$$

no edge state.

$$|h|_1 = h_1 + h_2$$

① - $\Sigma \sigma_z$ explicit S.B. gap.

② $-2\sigma^z\sigma^z \cdot \pi\sigma^z\sigma^z = I$

$\phi = -\sum \sigma_x$
edge state.

$$H_1 = h_1 + h_2$$

① $-\sum \sigma_z$ explicit S.B. gap.

② $-\sum \sigma^z \sigma^z$ $\pi \sigma^z \sigma^z = I$

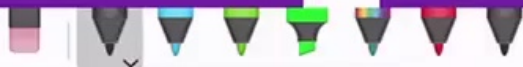
2-fold degenerate.
spontaneous S.B. gap.
sym boundary terms.
gapless.



Home Insert Draw View



A Text Mode Lasso Select Insert Space



Shapes Ink to Shape Drawing Mode

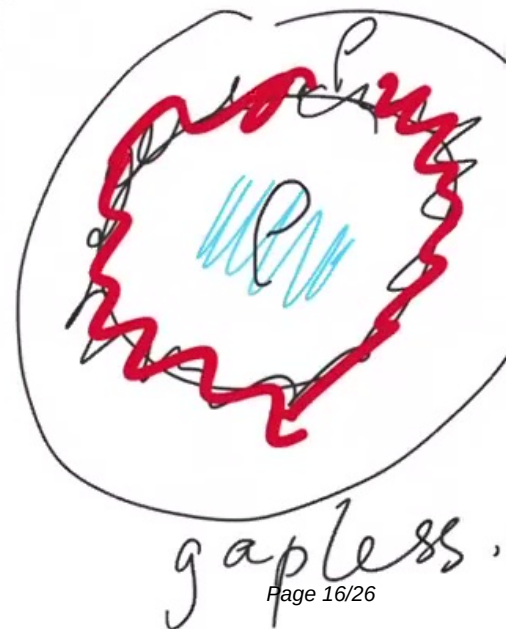
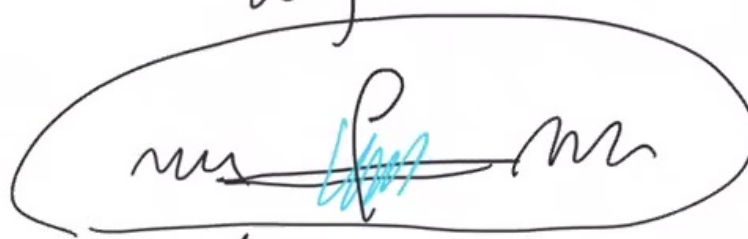
 m : bosonic.

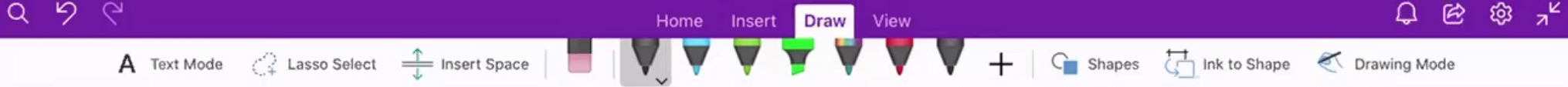
 m : semion $i, \pi/2$
 m : semion em : sem

Double semion.

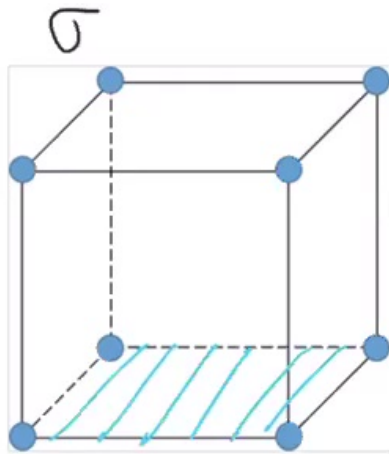
 symmetry Protected Topo Order.
 degenerate.

Edge State.





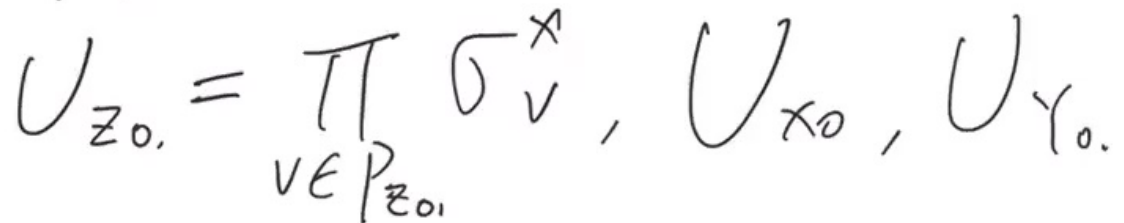
5. X-cube from Gauging (Subsystem Symmetry)
(Fracton).



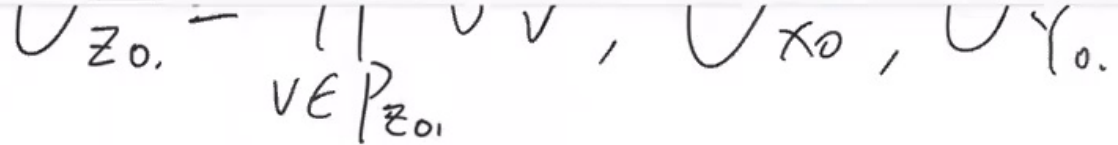
$$H = - \sum \sigma^x.$$

$$U_{z_0} = \prod_{v \in P_{z_0}} \sigma_v^x, U_{x_0}, U_{y_0}.$$

higher-form symmetry.
higher-rank

$$H = - \sum \sigma^x$$


Page 18/26



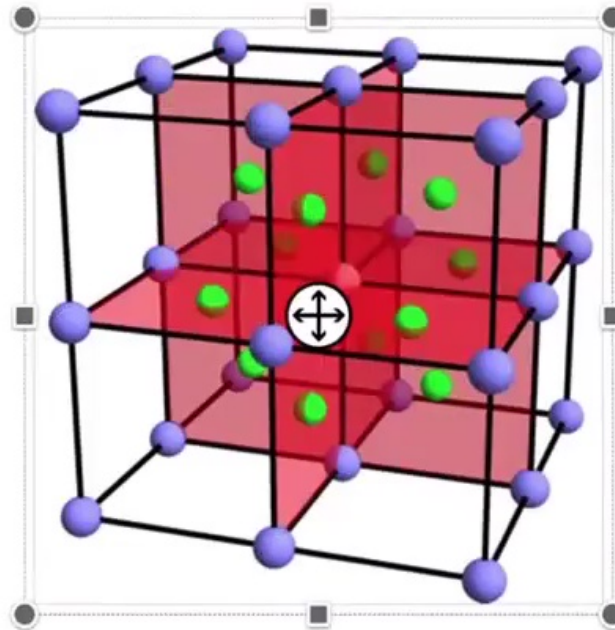
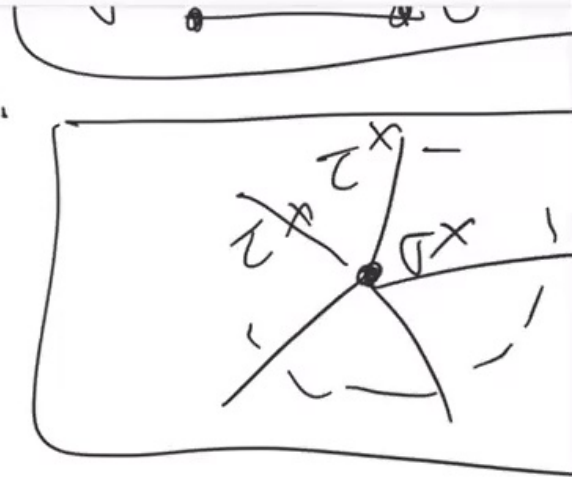
The diagrams illustrate the construction of a square root function using branch cuts and Riemann surfaces. The top diagram shows a horizontal branch cut on the real axis starting from the origin and extending to the right. A vertical line segment is drawn to the left of the cut, and a circular path is drawn around the origin, crossing the cut. The bottom diagram shows a square Riemann surface with four sheets. The sheets are labeled with z and $\sqrt{z}$ to indicate the value of the function on each sheet. The square is divided into four quadrants, each representing a different branch of the multi-valued function. The edges of the square represent the branch cuts, and the interior of the square represents the Riemann surface.



Home Insert Draw View

Table Pictures Camera Audio File PDF Link π Equation Date Meeting Details

Gauge symmetry



cubic2



Home Insert Draw View



A Text Mode

Lasso Select

Insert Space

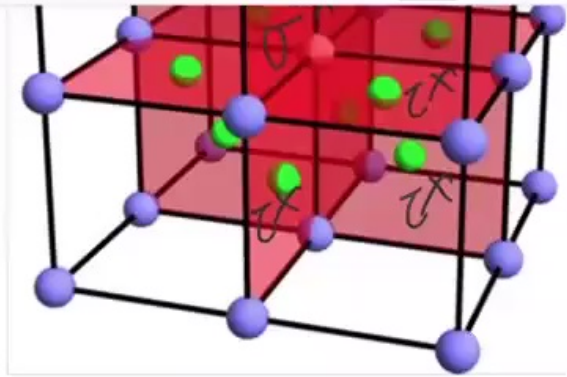
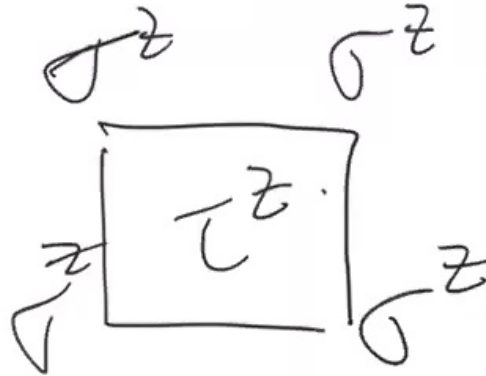


+

Shapes

Ink to Shape

Drawing Mode


 $\sigma^x \parallel \vec{L}$


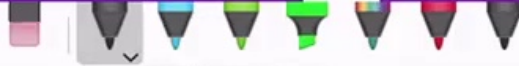
$$H/g = -\sum \sigma^x - \sum \sigma^x \tau \tau^x - J \sum$$



Home Insert Draw View



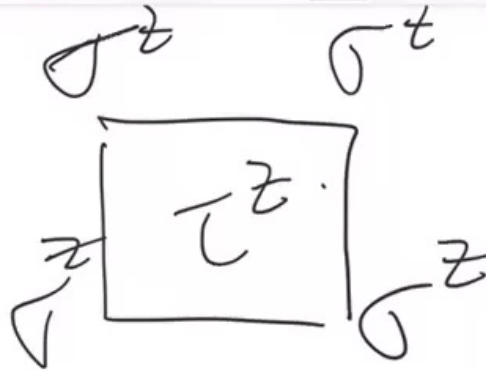
A Text Mode Lasso Select Insert Space



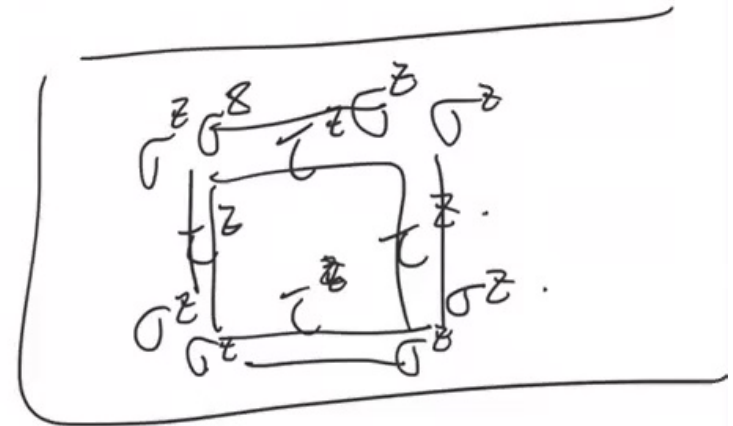
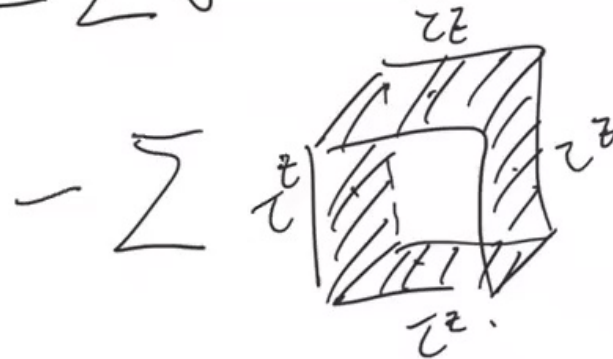
Shapes

Ink to Shape

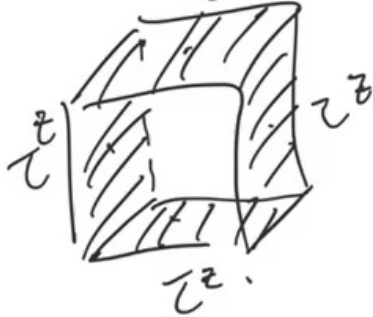
Drawing Mode



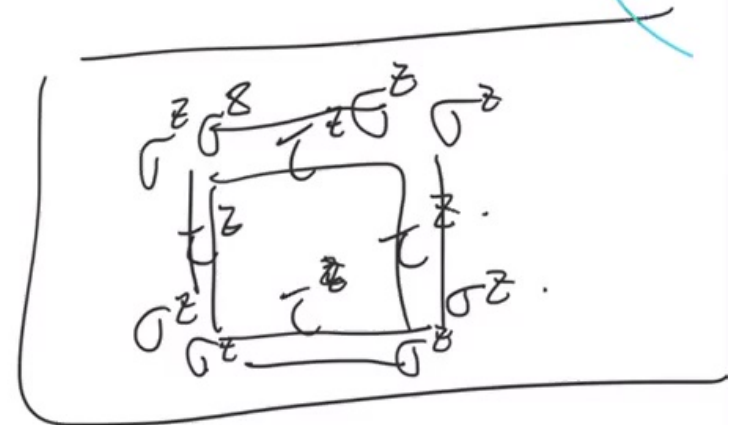
$$H/g = -\sum \sigma^x - \sum \sigma^x \prod \tau^x - J \sum_{\langle ij \rangle} \left[\sigma^z_i \tau^z_{ij} \sigma^z_j \right]$$





$$H|g = -\cancel{\sum \sigma^x} - \cancel{\sum \sigma^x \tau^z} - J \sum_{\langle ij \rangle} \tau^z_i \tau^z_j$$


X-cube.





Home Insert Draw View



A Text Mode

Lasso Select

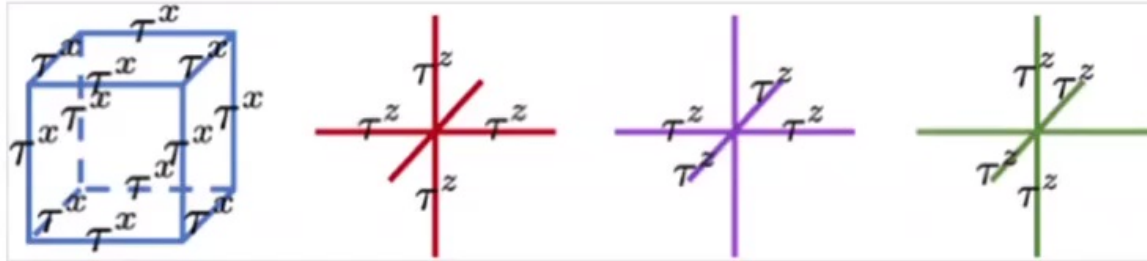
Insert Space



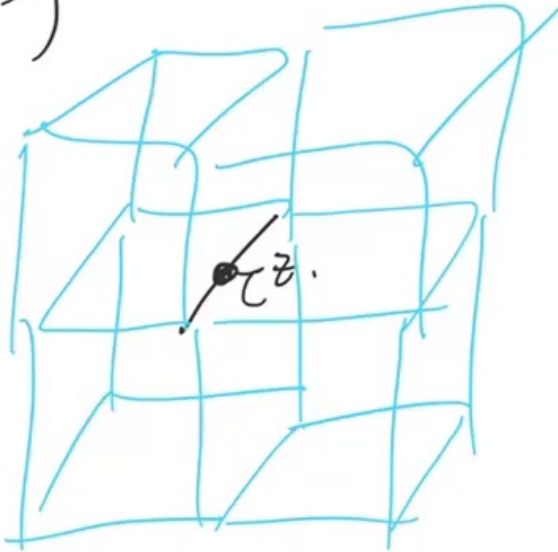
Shapes

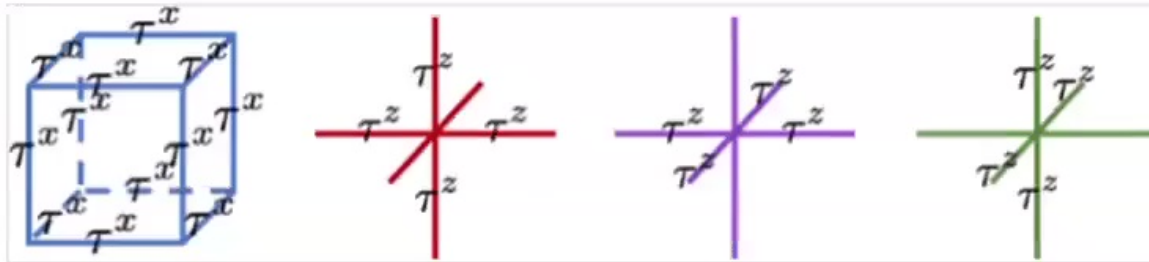
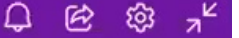
Link to Shape

Drawing Mode

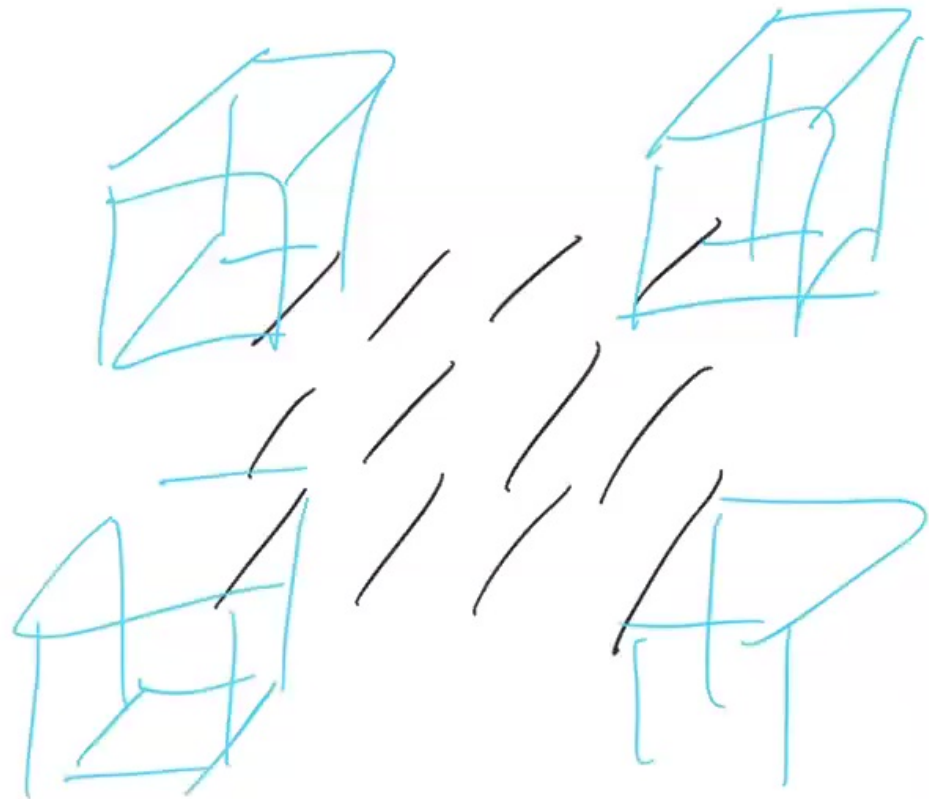
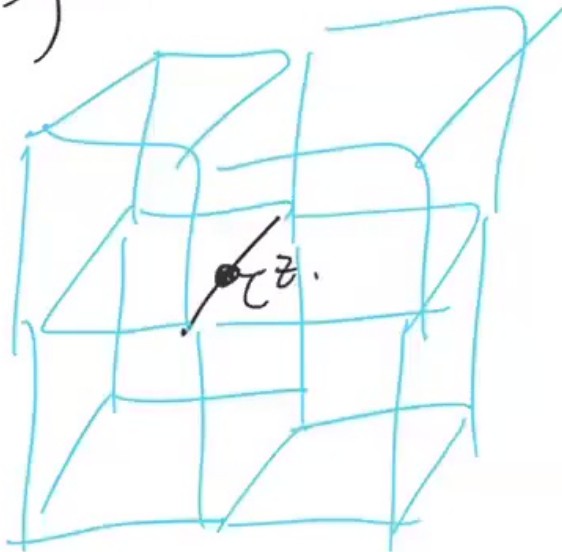


Gauge
Sym.





Gauge
Sym.



e.

