

Title: Introduction to Tensor Network Algorithms - Lecture 3

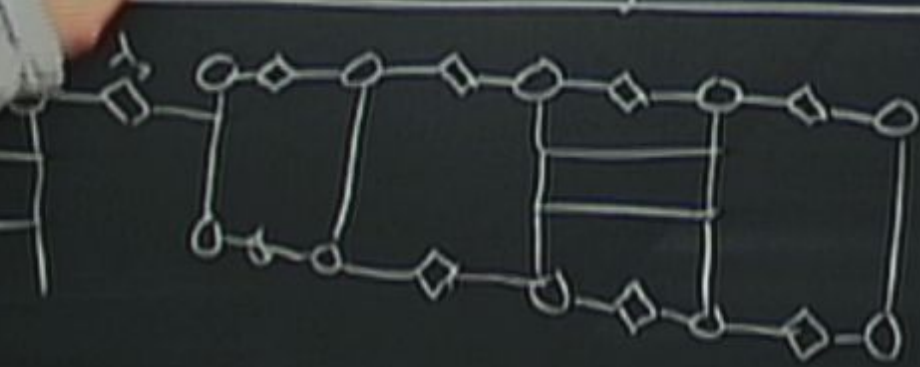
Date: Jun 15, 2011 11:00 AM

URL: <http://pirsa.org/11060006>

Abstract: Tensor network algorithms are a powerful technique for the study of quantum systems in condensed matter physics. In this short series of lectures, I will present an applied perspective on tensor network algorithms. Topics to be covered will include motivation and methodology, graphical notation, Matrix Product States (MPS) and the Time-Evolving Block Decimation (TEBD) algorithm, identifying the capabilities and limitations of tensor network algorithms, the Multi-scale Entanglement Renormalisation Ansatz (MERA) and the study of systems at criticality, and the exploitation of global internal symmetries. The intent of this lecture series is to provide attendees with the necessary theoretical background to be able to understand and implement the more common tensor network algorithms.

Introduction to Tensor Network Algorithms III

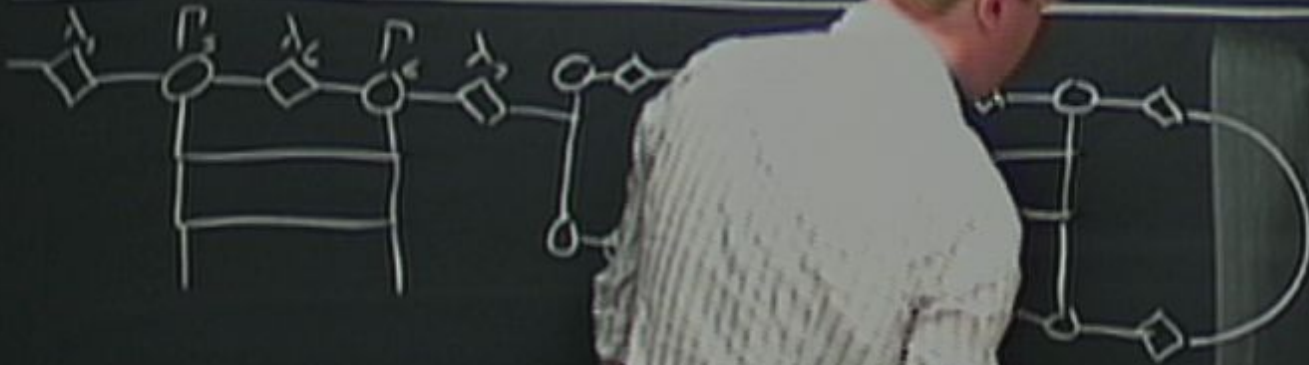
Introduction to Tensor Network Algorithms III



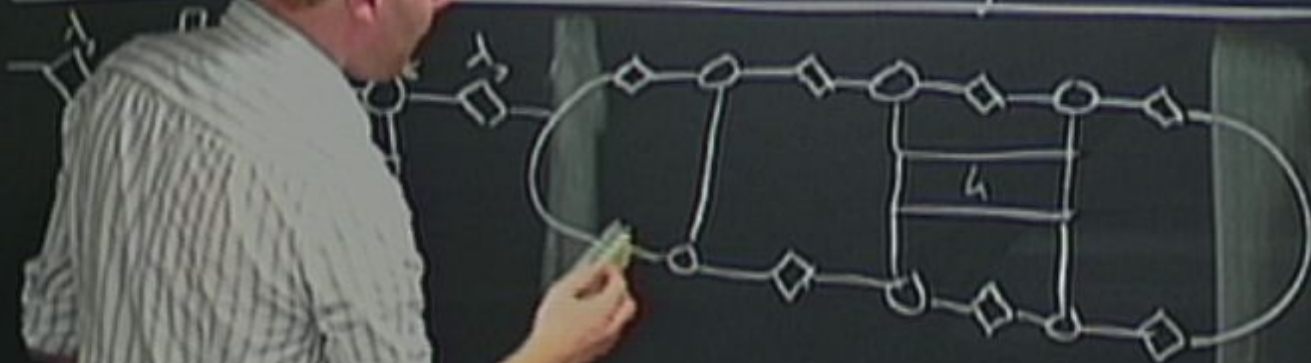
Introduction for Network Algorithms III



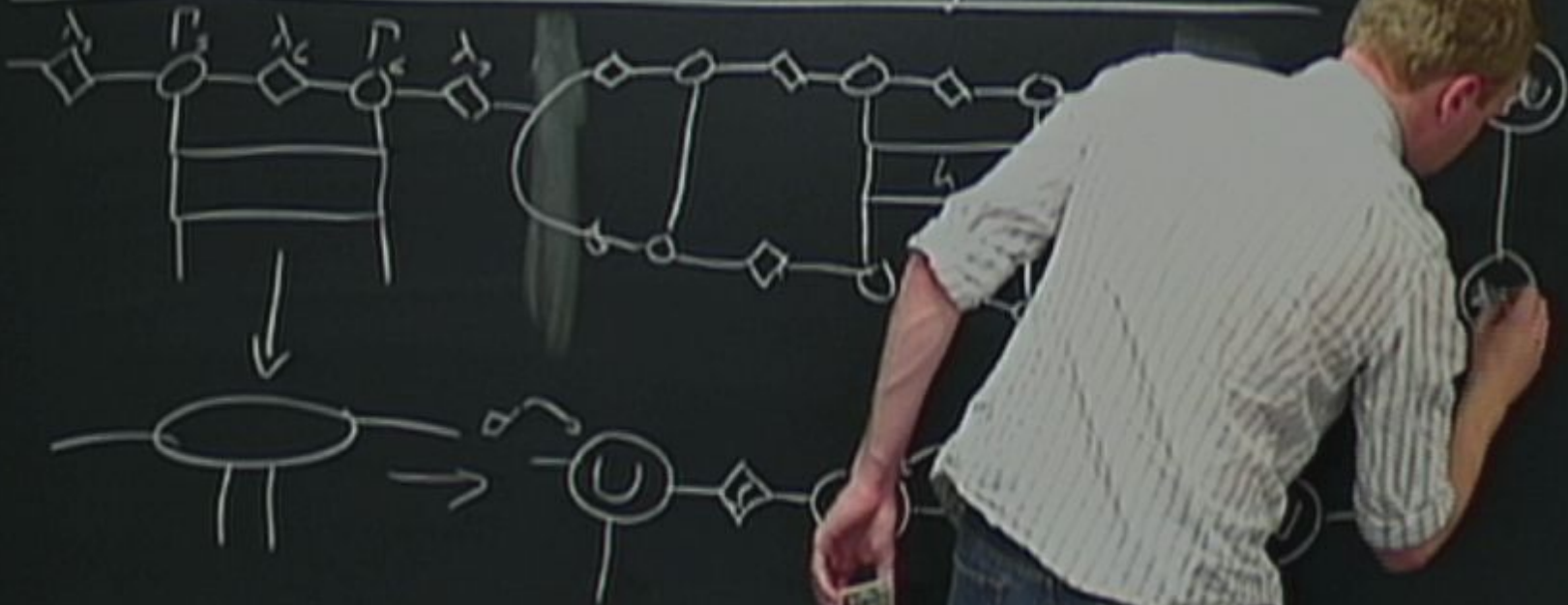
Introduction to Tensor Networks Algorithms III



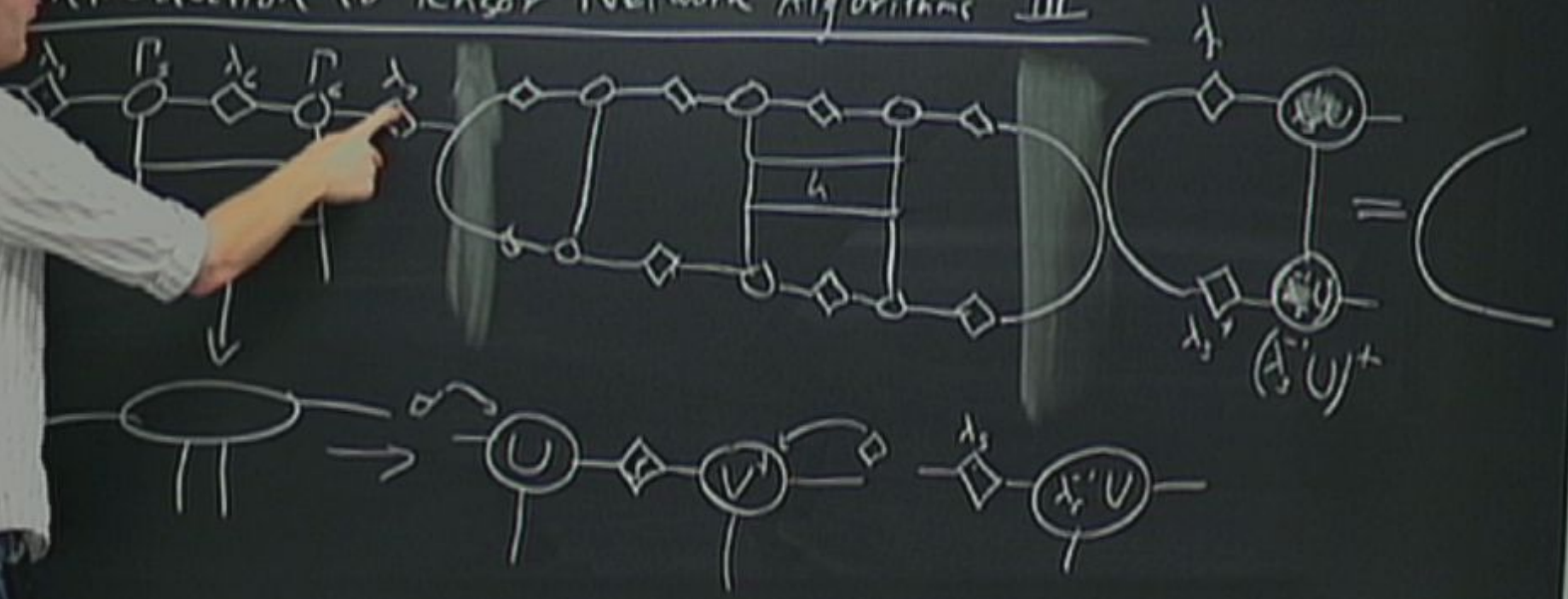
Introduction to Tensor Network Algorithms III



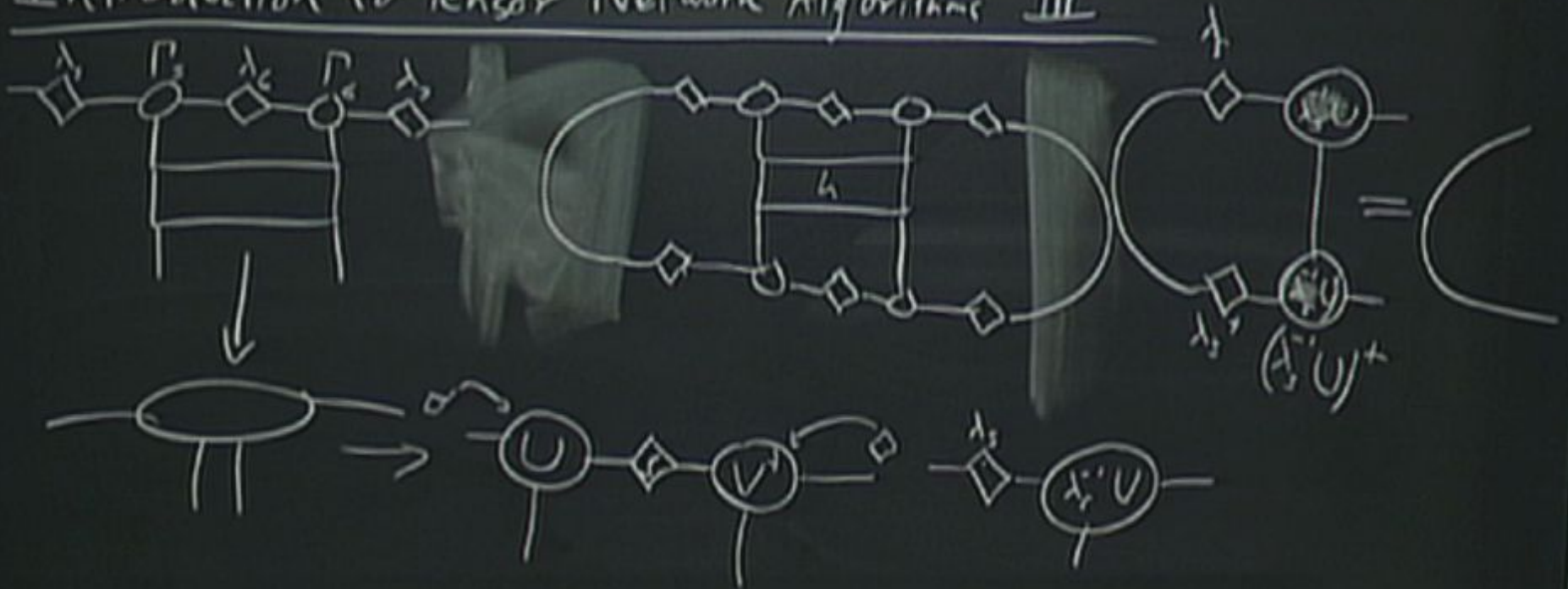
Introduction to Tensor Network Algorithms III



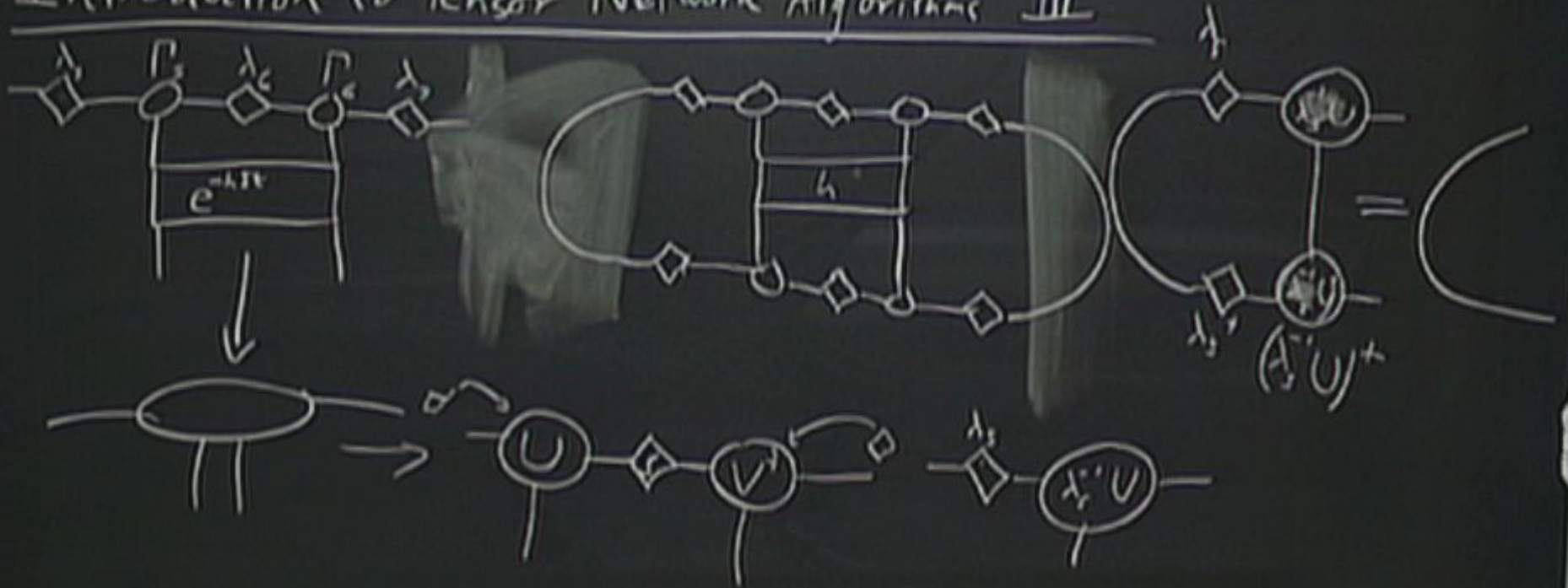
Introduction to Tensor Network Algorithms III



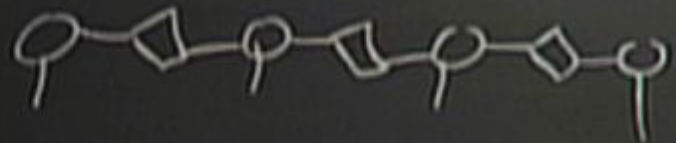
Introduction to Tensor Network Algorithms III



Introduction to Tensor Network Algorithms III

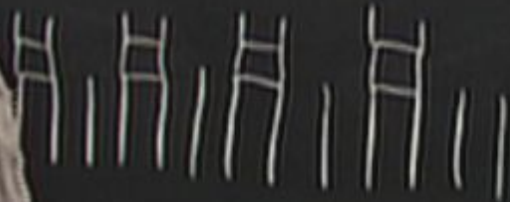
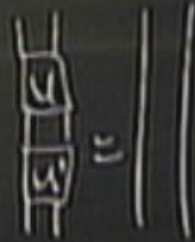


Multiscale Entanglement Renormalization Ansatz

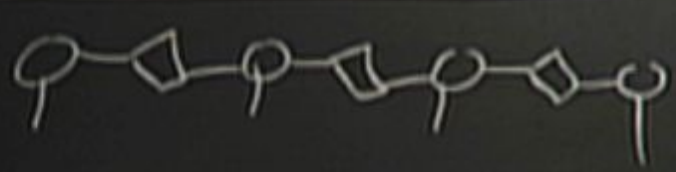


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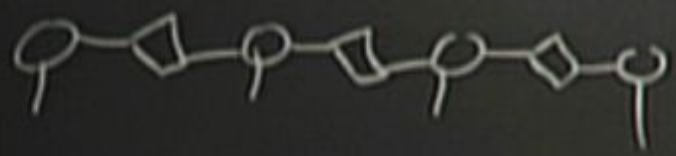
Multiscale Entanglement Renormalisation Ansatz (MERA)



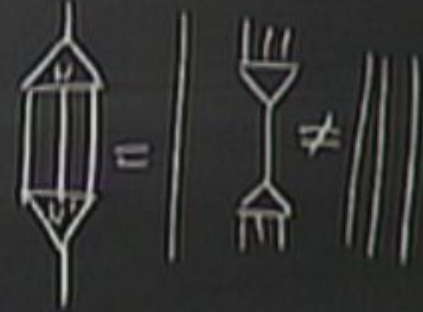
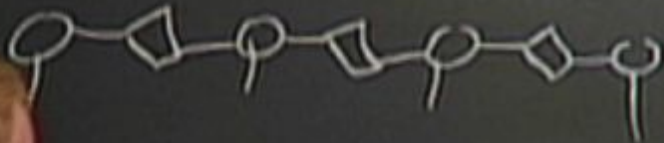
Multiscale Entanglement Renormalisation Ansatz (MERA)



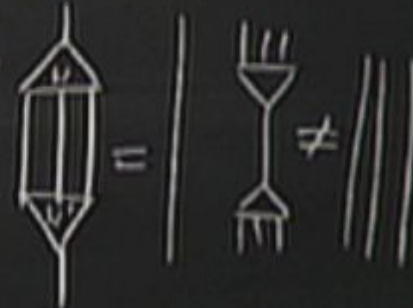
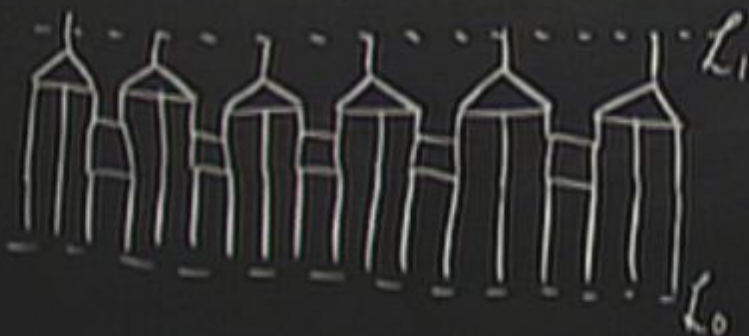
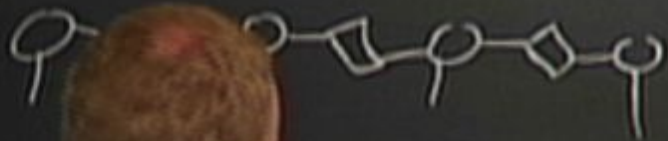
Multiscale Entanglement Renormalisation Ansatz (MERA)



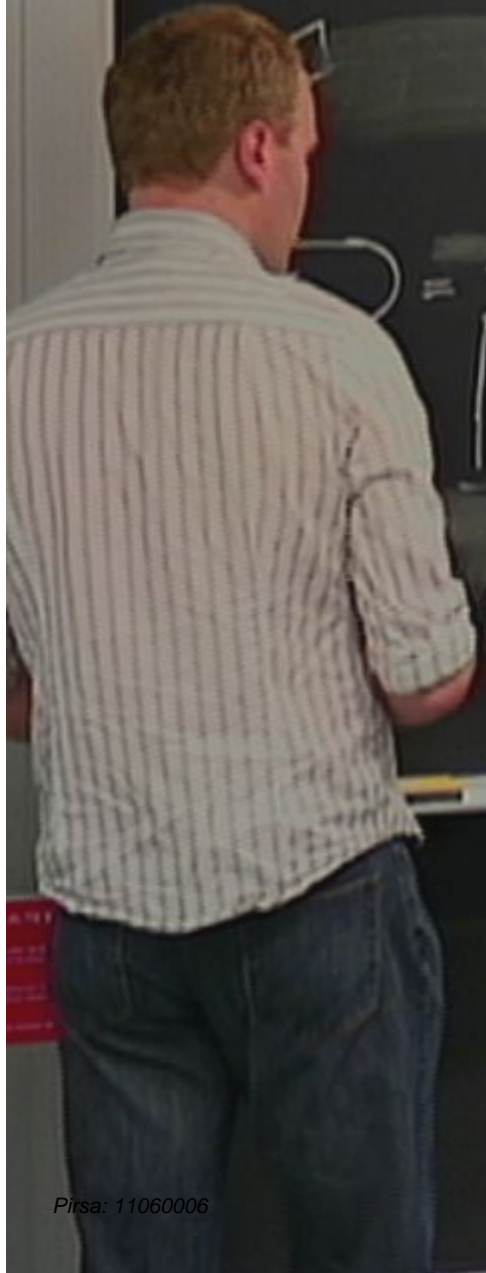
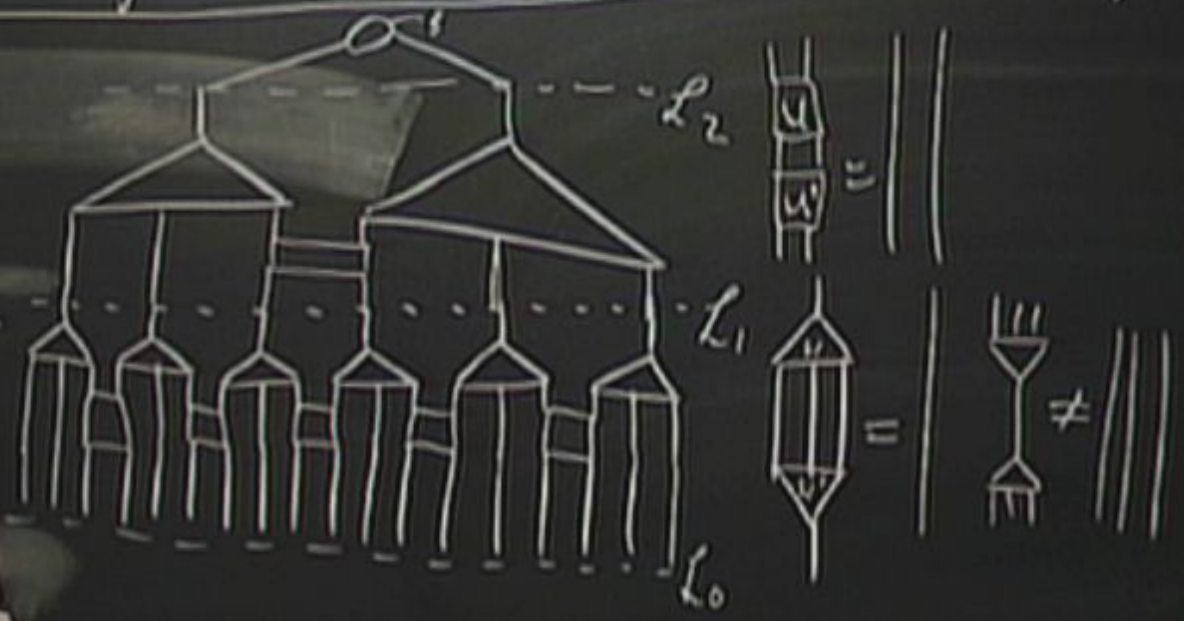
Multiscale Entanglement Renormalization Ansatz (MERA)



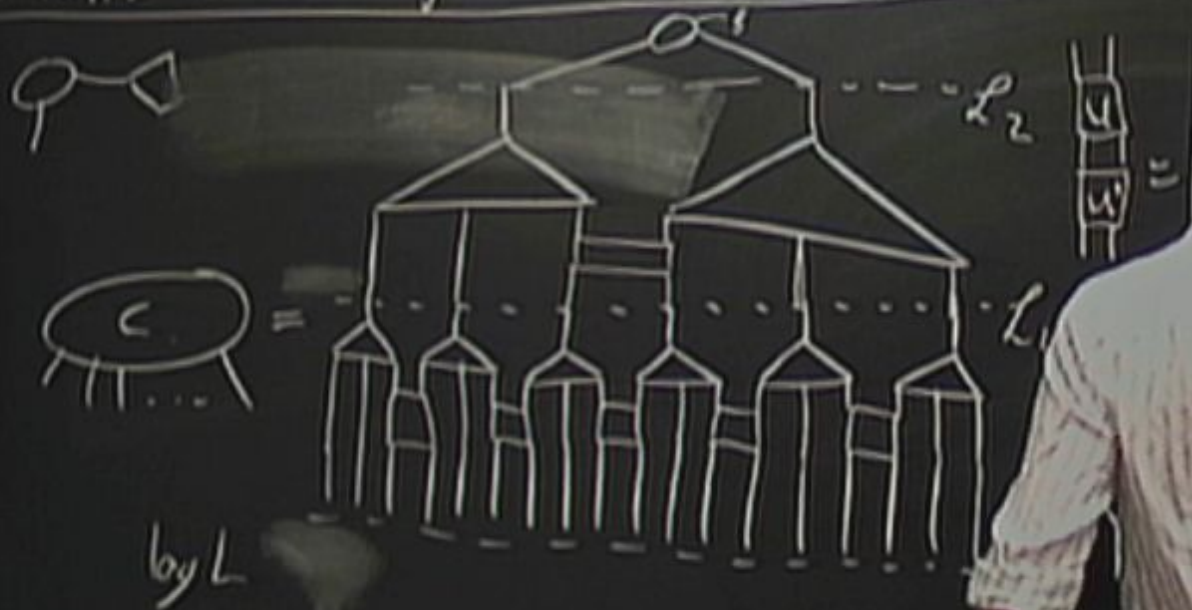
Multiscale Entanglement Renormalization Ansatz (MERA)



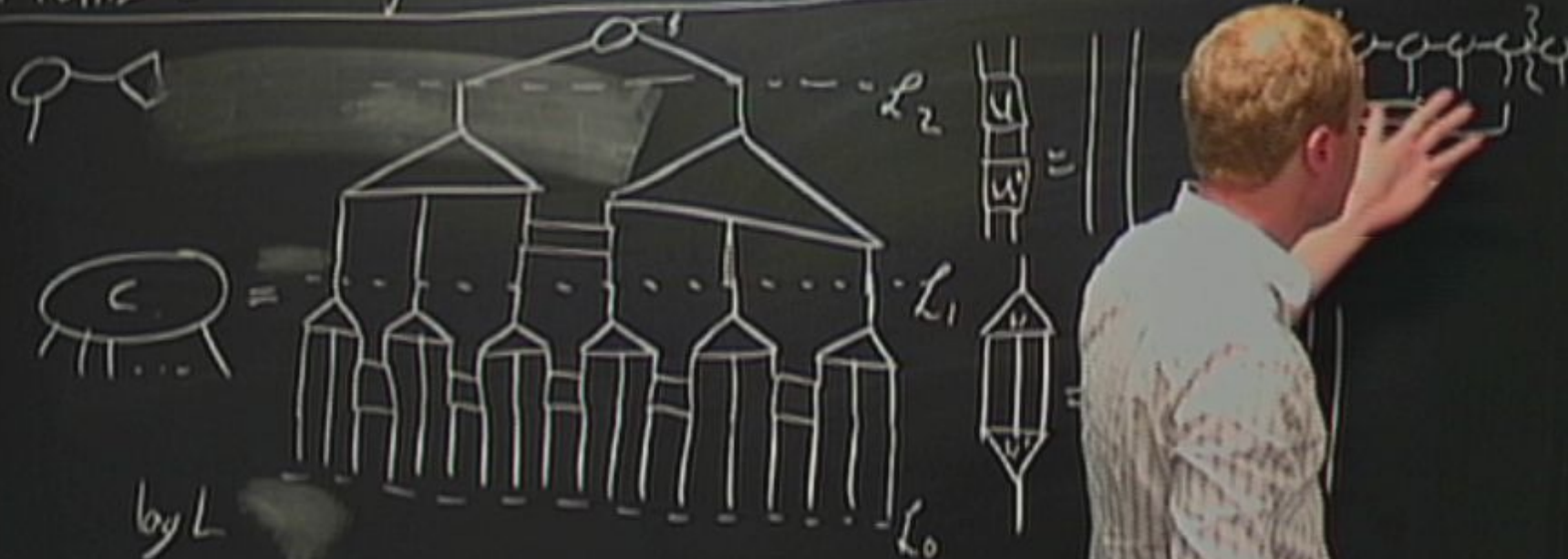
Multiscale Entanglement Renormalisation Ansatz (MERA)



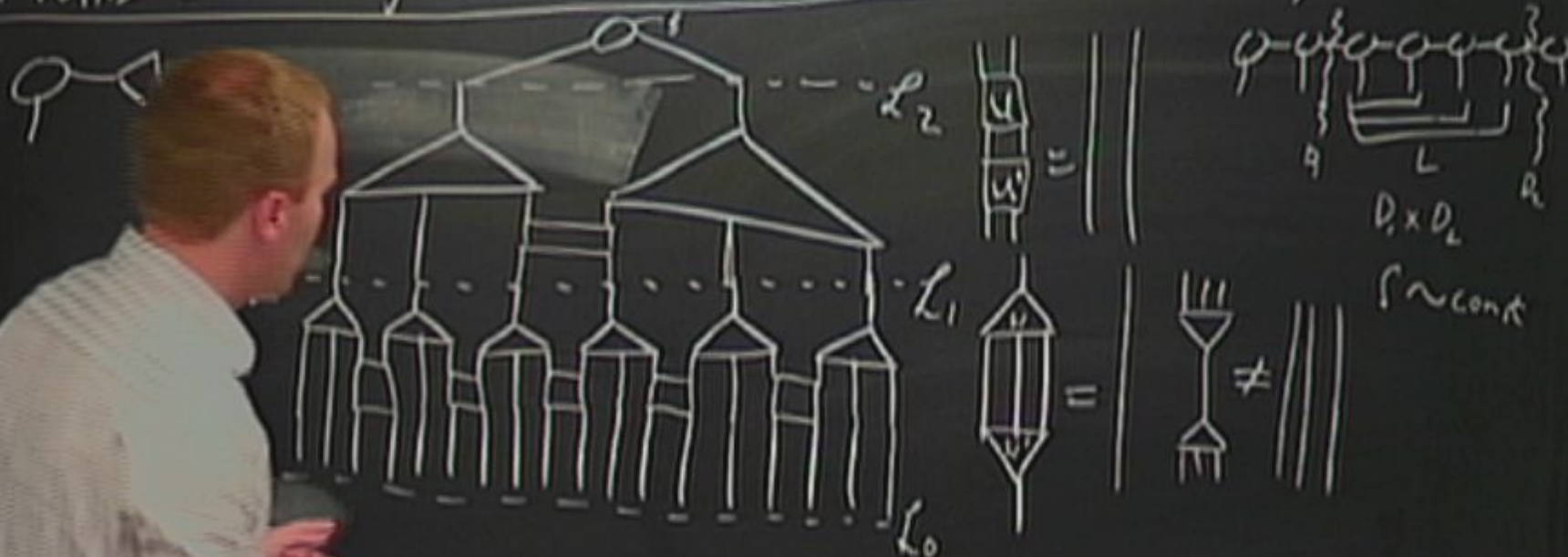
Multiscale Entanglement Renormalisation Ansatz (MERA)



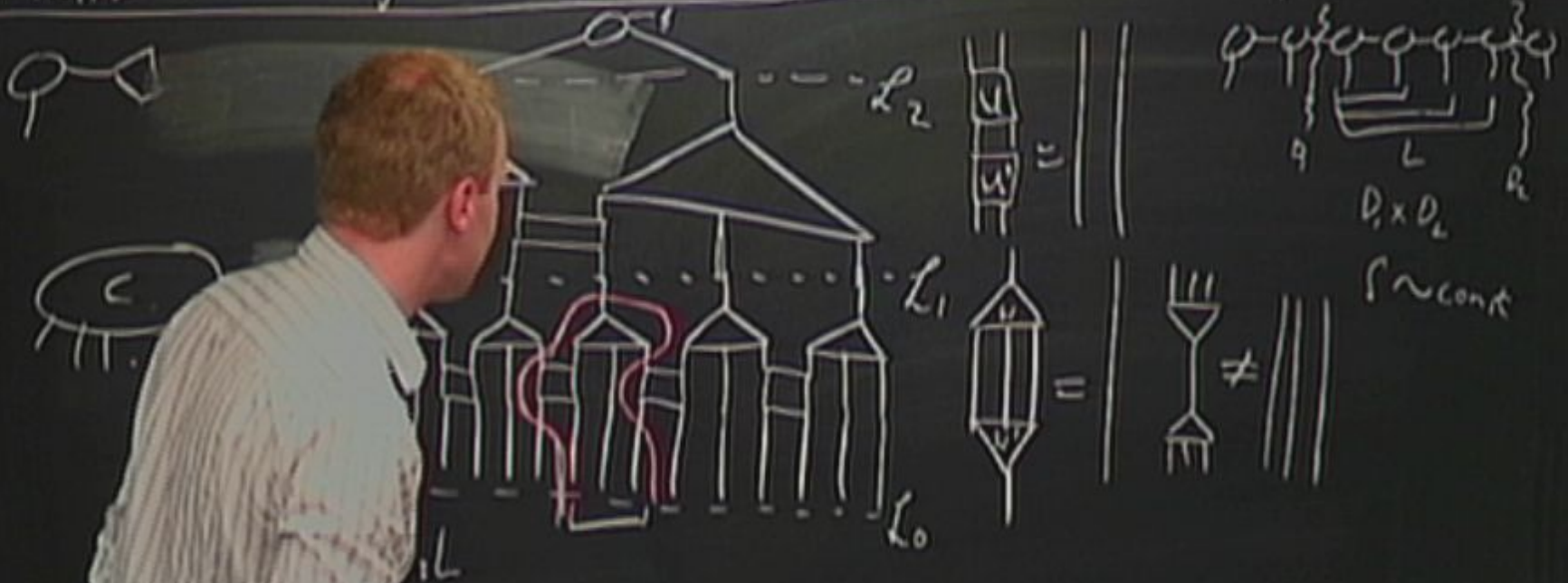
Multiscale Entanglement Renormalisation Ansatz (MERA)



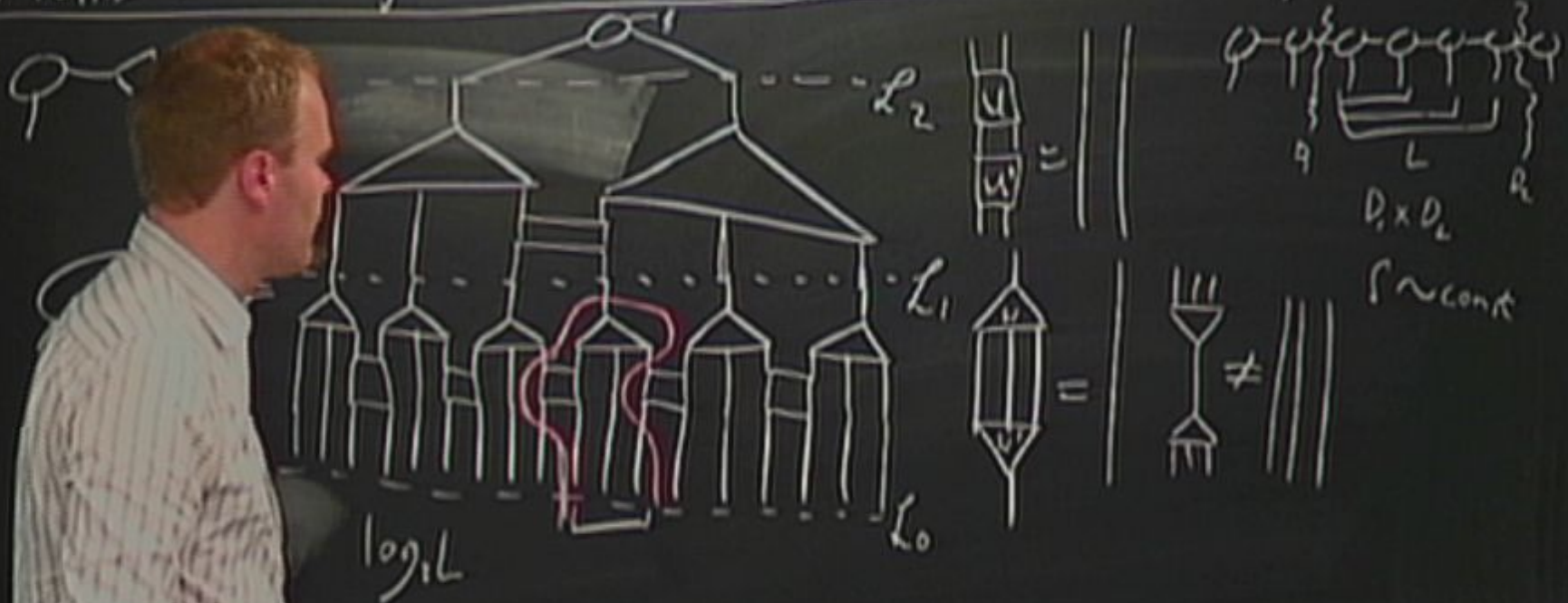
Multiscale Entanglement Renormalisation Ansatz (MERA)



Multiscale Entanglement Renormalization Ansatz (MERA)



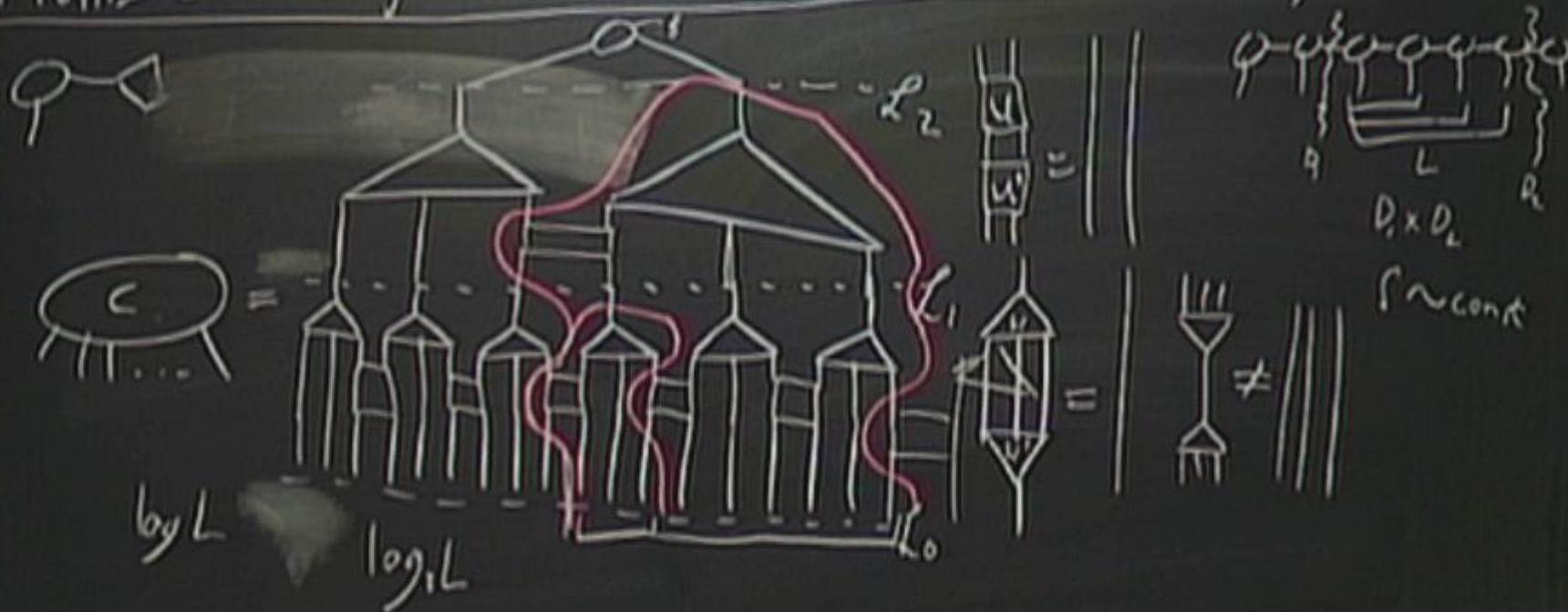
Multiscale Entanglement Renormalisation Ansatz (MERA)

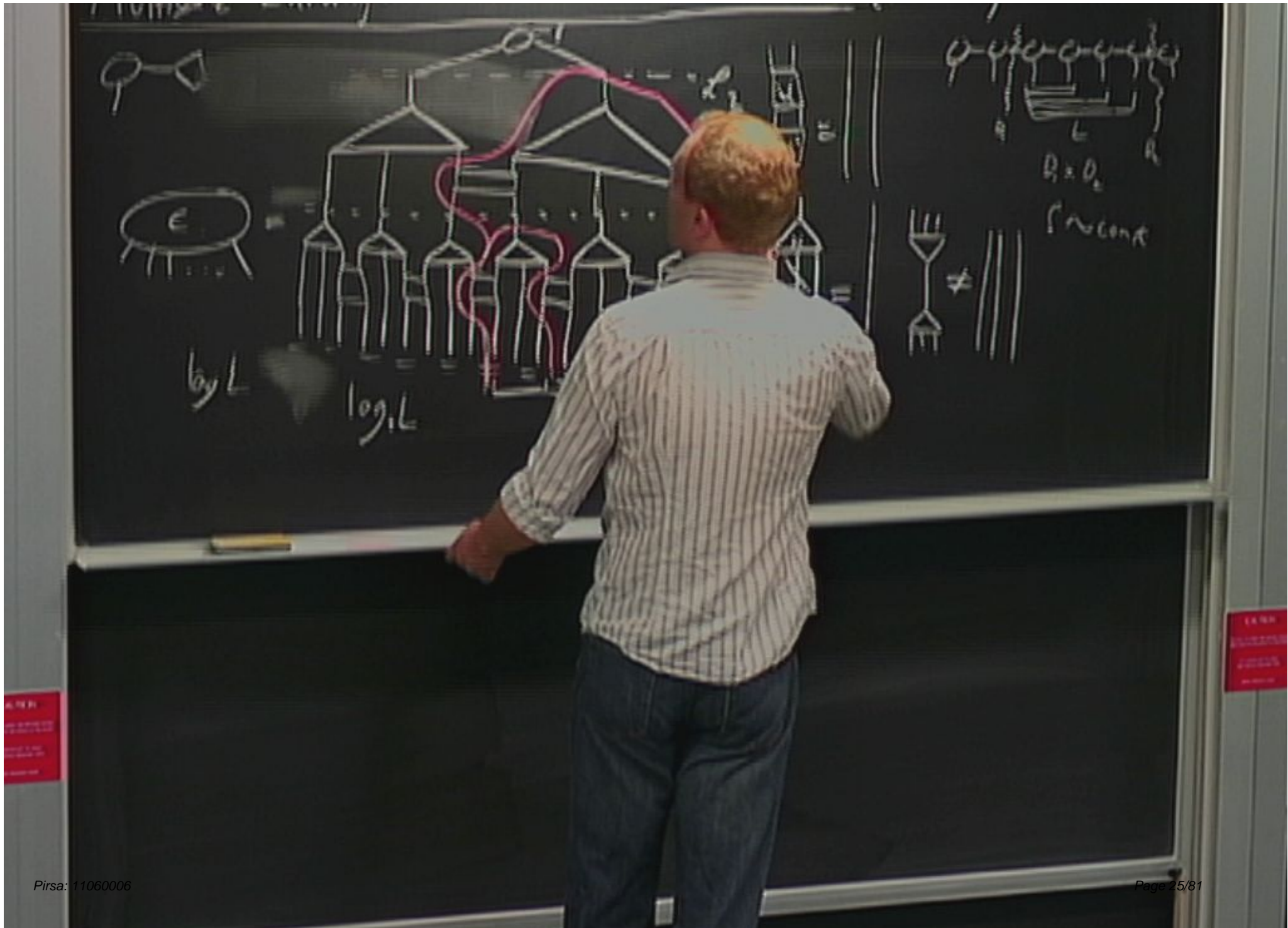


Multiscale Entanglement Renormalisation Ansatz (MERA)



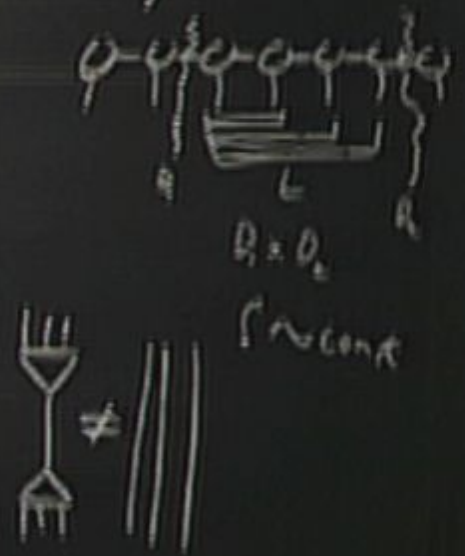
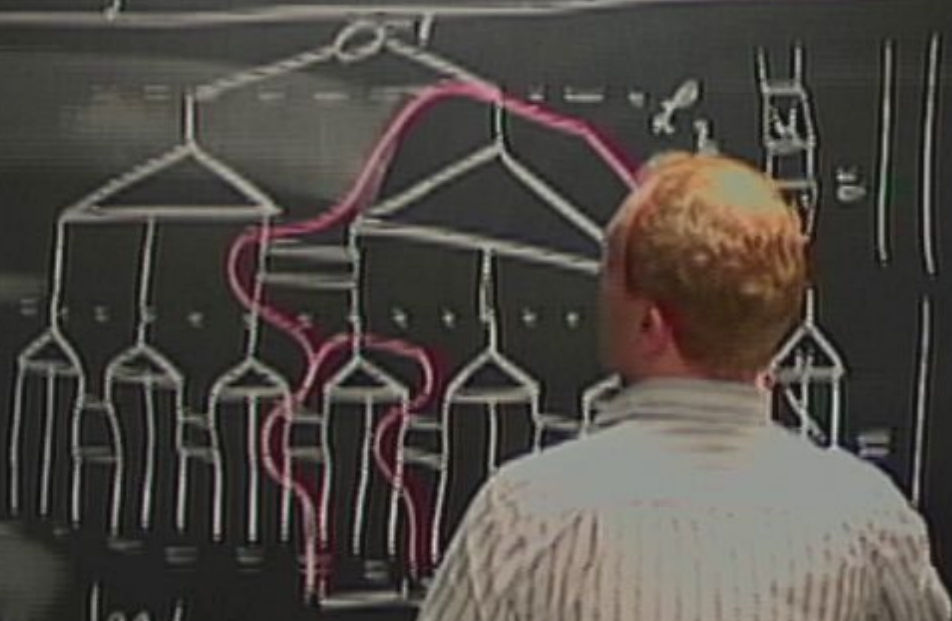
Multiscale Entanglement Renormalisation Ansatz (MERA)





$\log L$

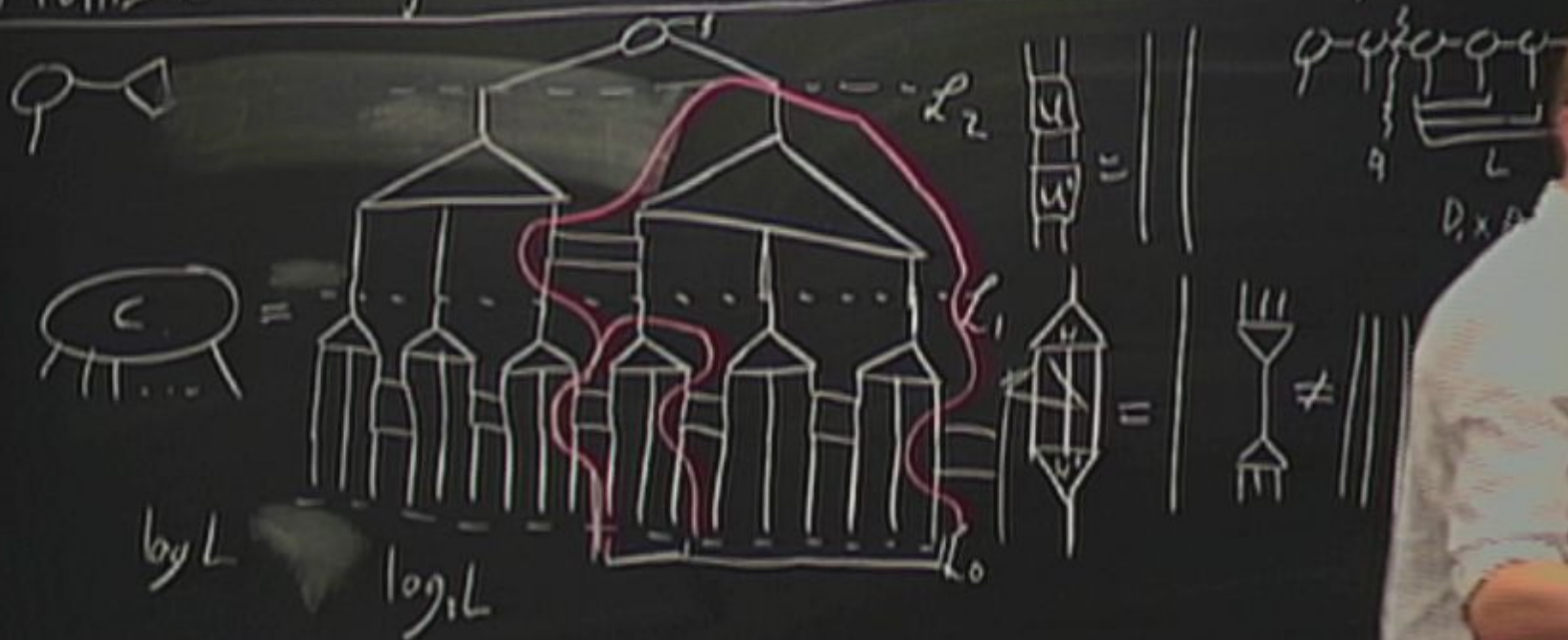
$\log L$



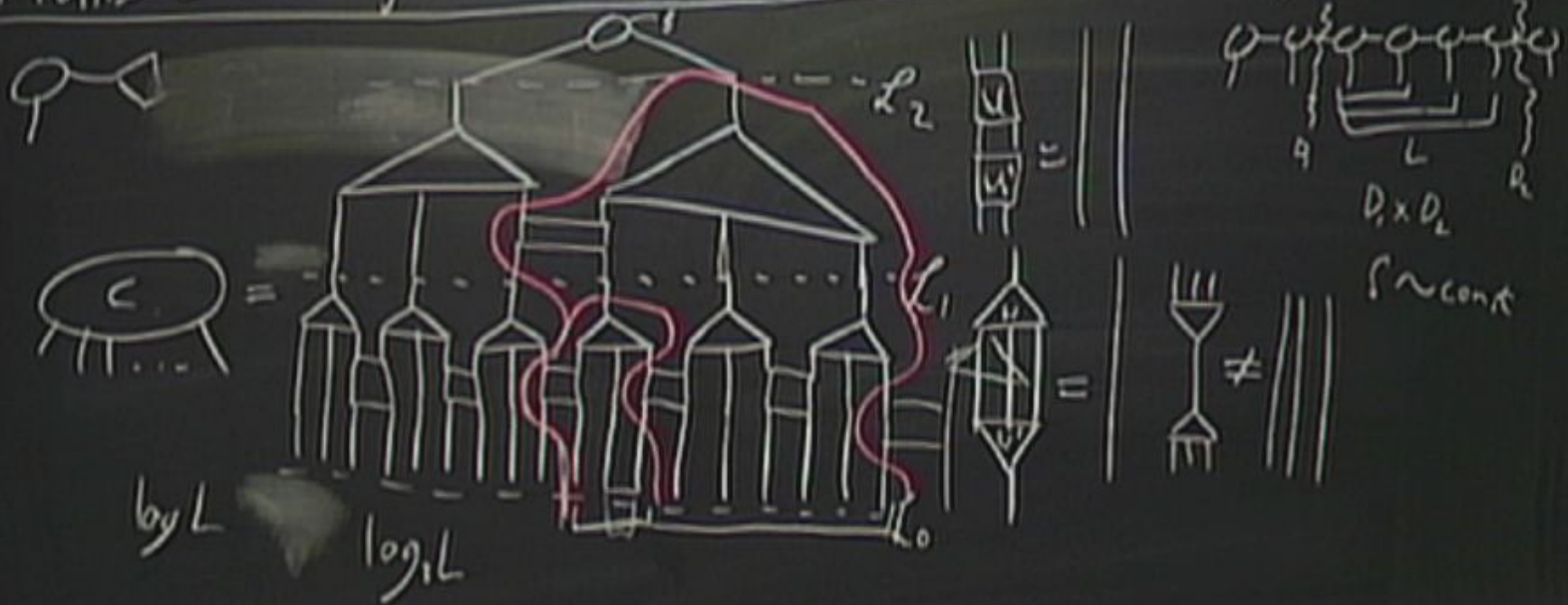
$$R = O_c$$

$\{ \text{recont} \}$

Multiscale Entanglement Renormalisation Ansatz (MERA)



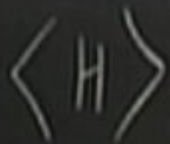
Multiscale Entanglement Renormalisation Ansatz (MERA)



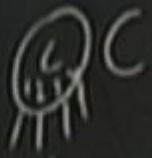
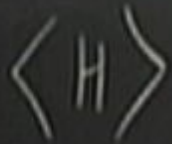
$\langle H \rangle$



CAUTION



CAUTION



CAUTION



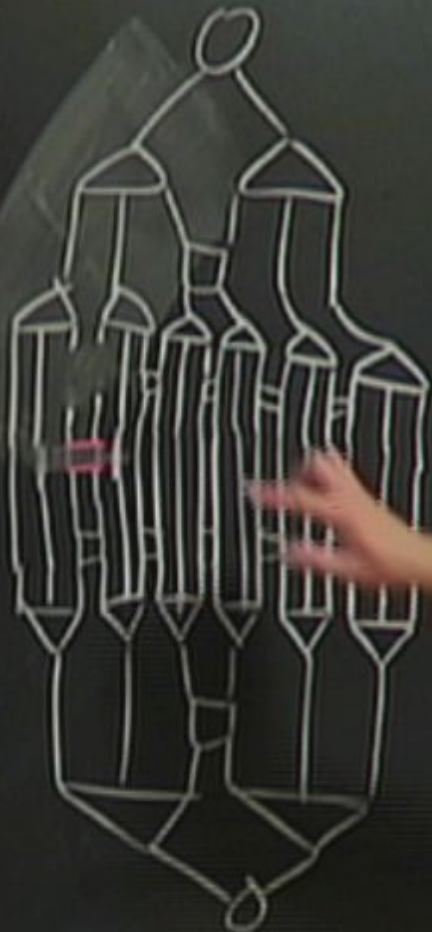
M



CAUTION

$\langle H \rangle$

$$H = \sum_i k_{i,i+1}$$



\sum

$$\langle H \rangle$$

$$H = \sum_i h_{i,i+1}$$

$$= \sum$$



$$\langle H \rangle$$

$$H = \sum_i k_{i,i+1}$$

$$= \sum$$

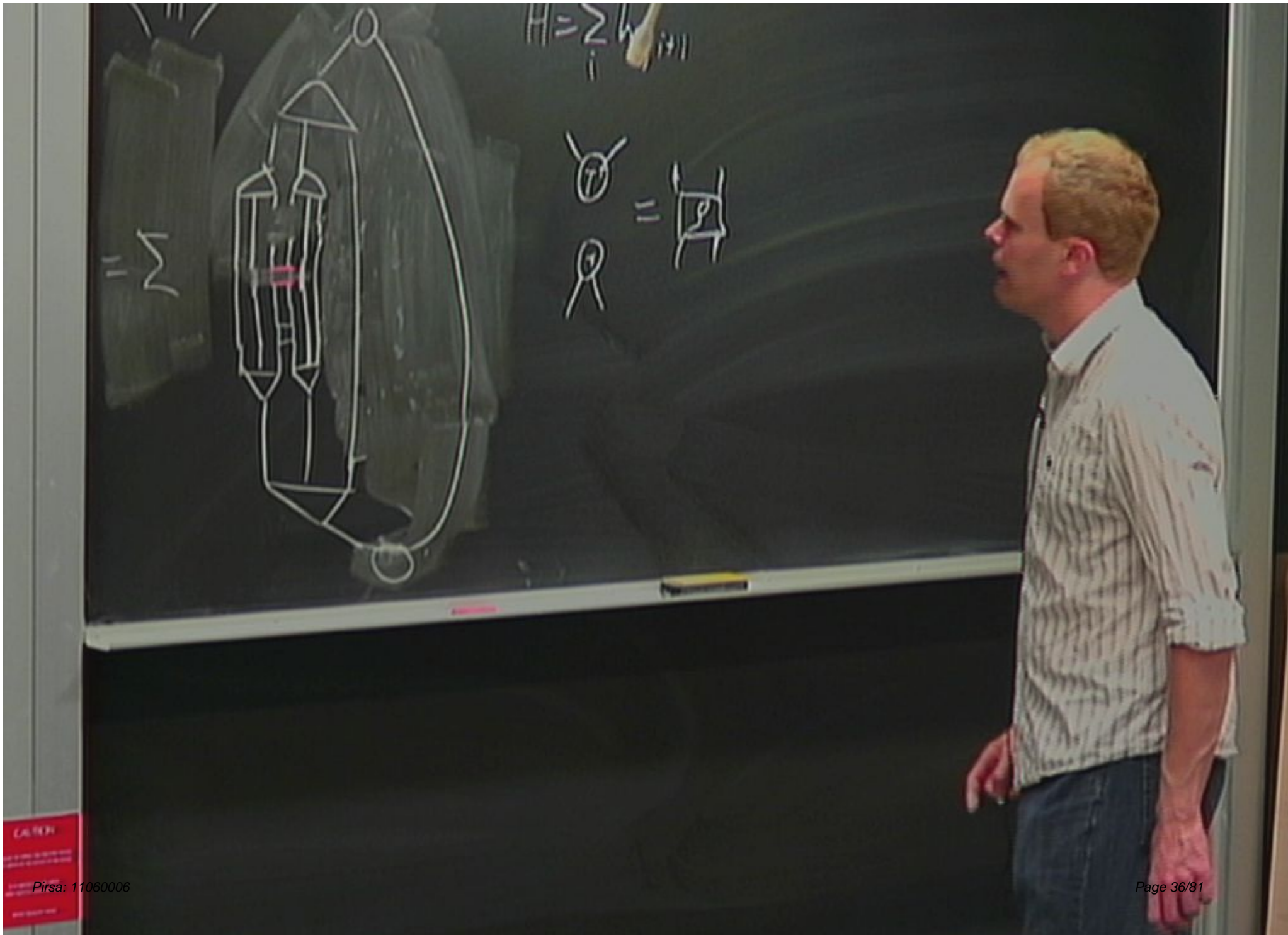


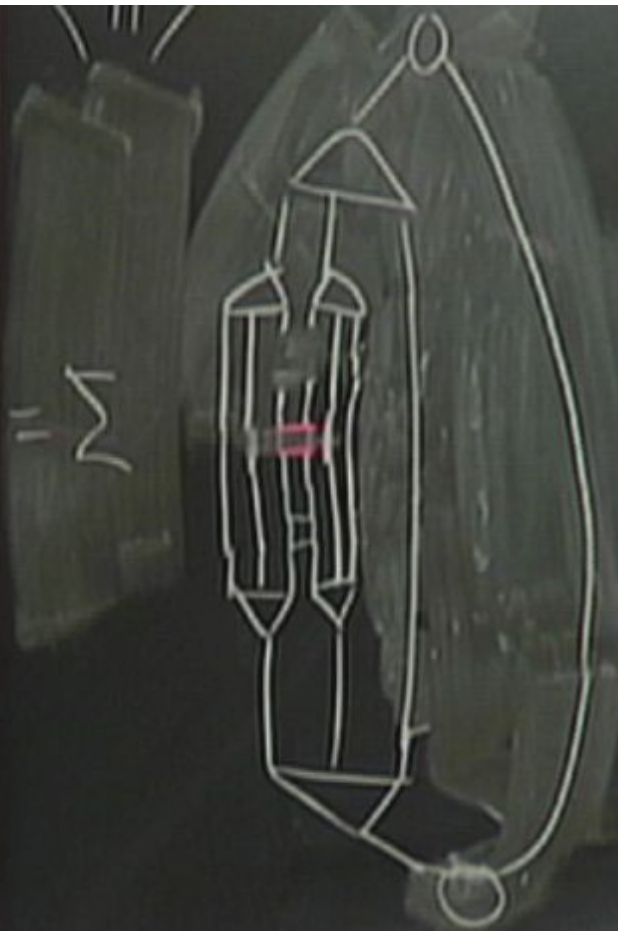
$\langle H \rangle$

$$H = \sum_i k_{i,i+1}$$

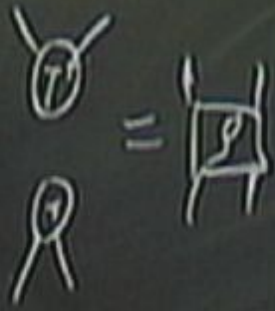


\sum

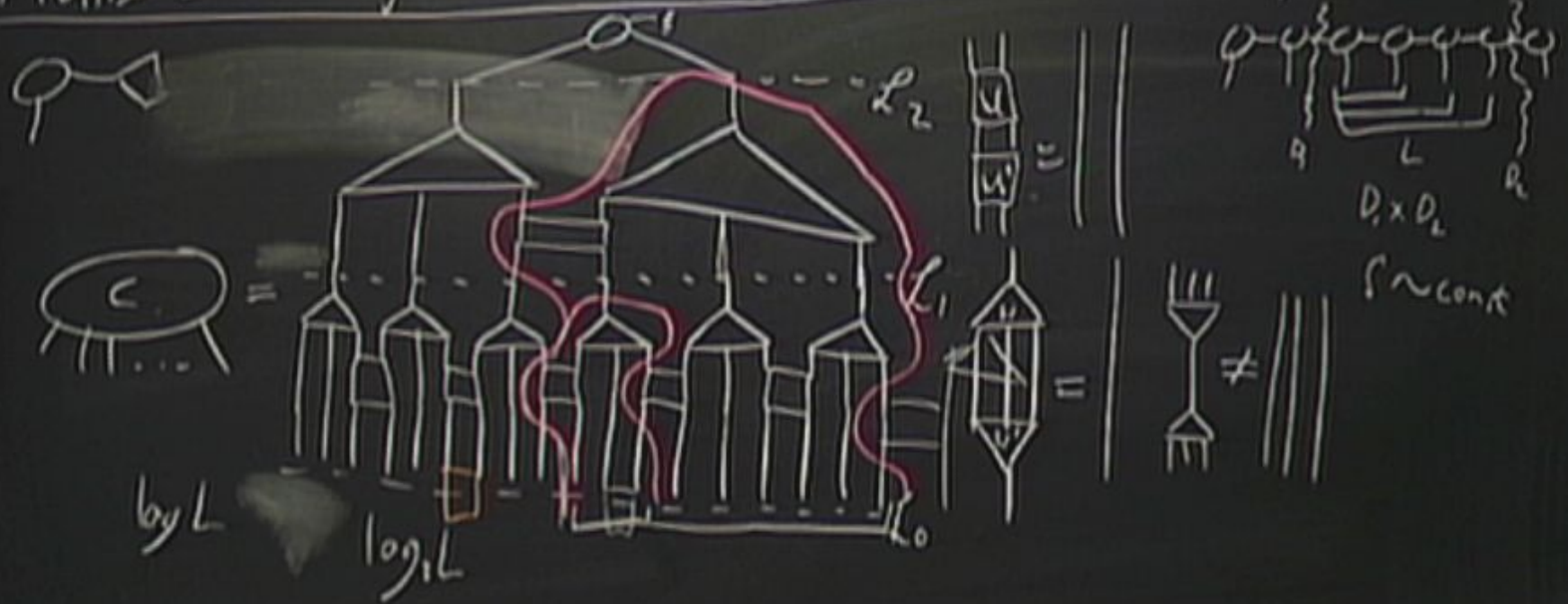


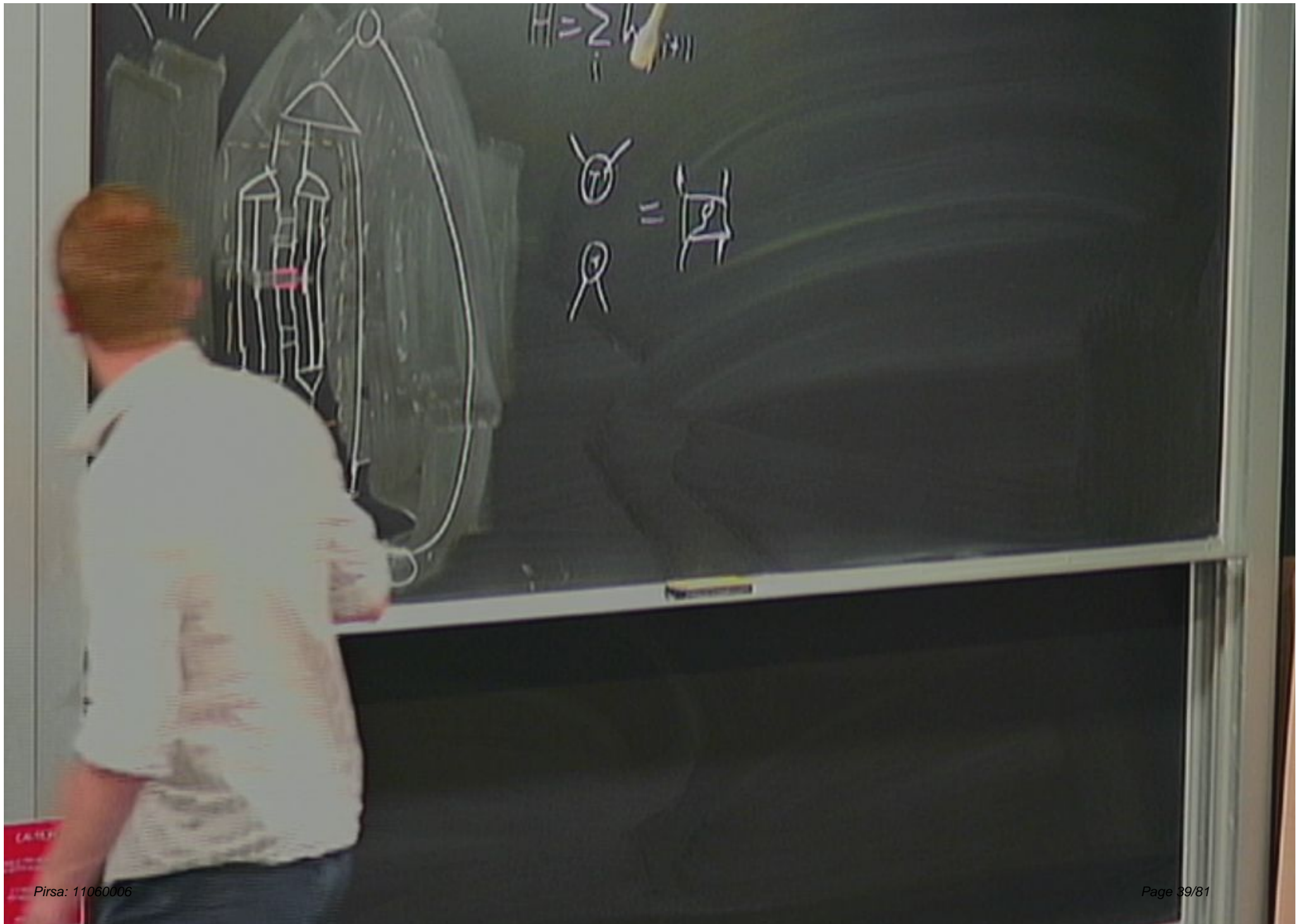


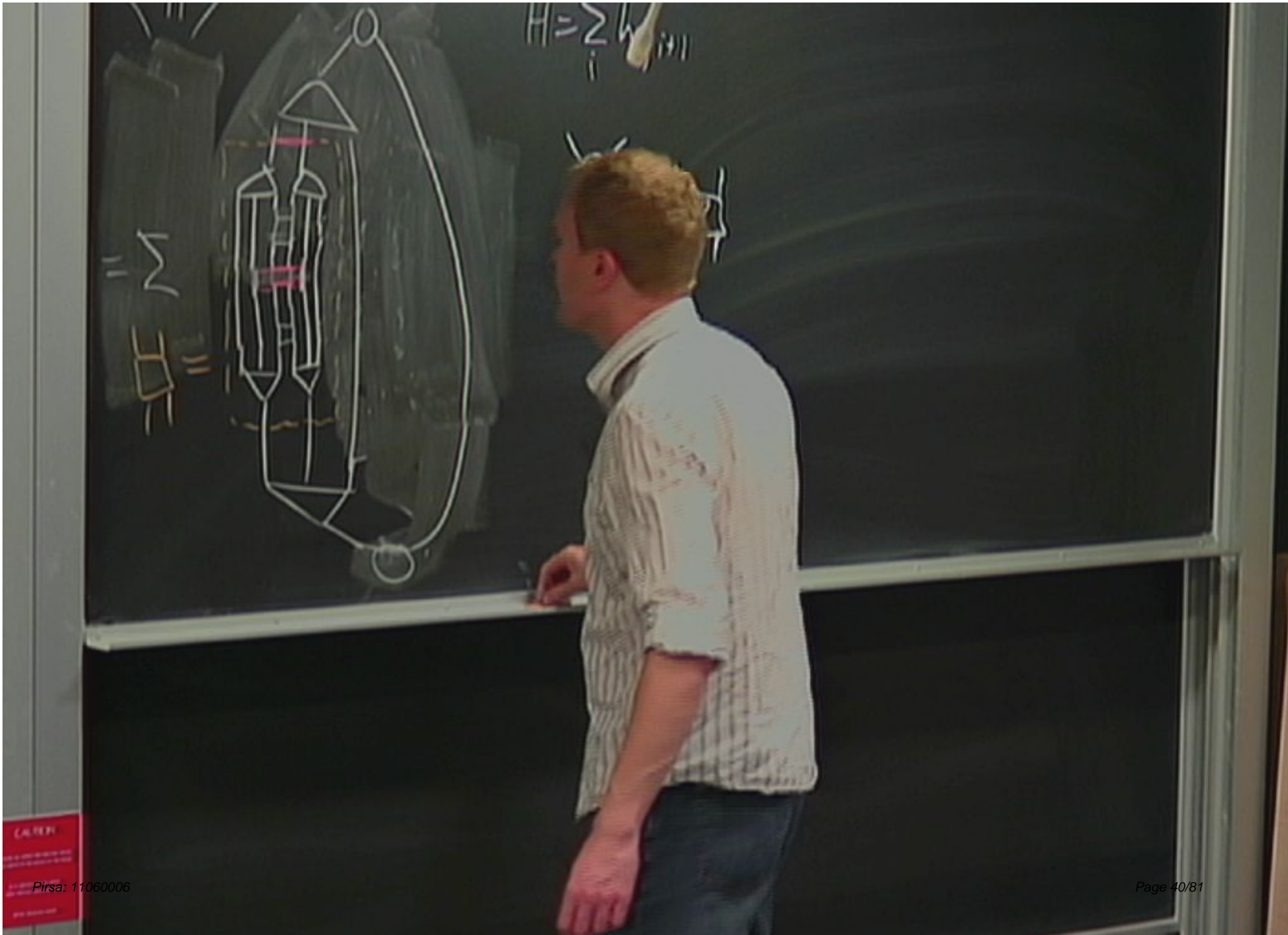
$$H = \sum_i w_i$$

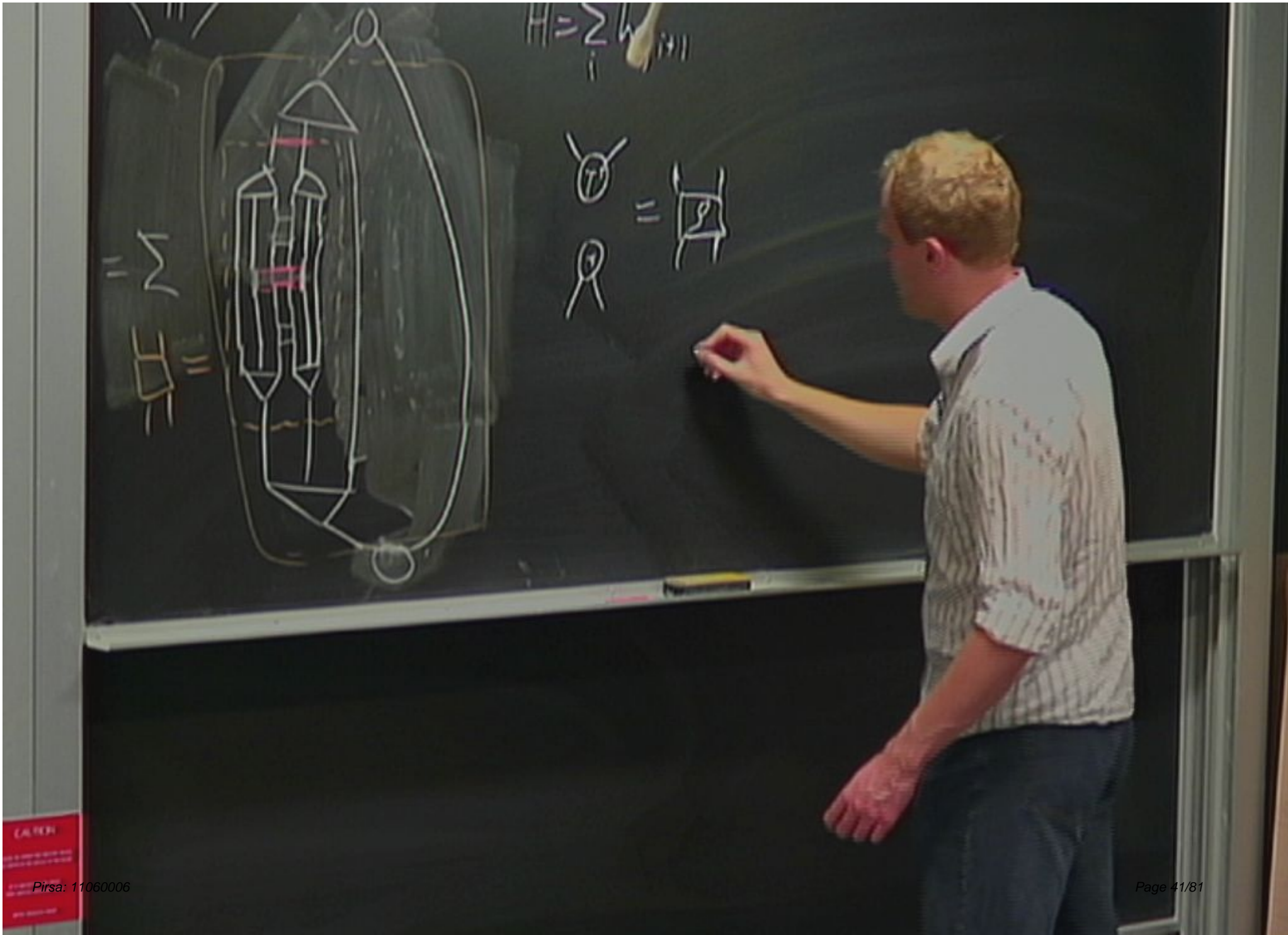


Multiscale Entanglement Renormalisation Ansatz (MERA)

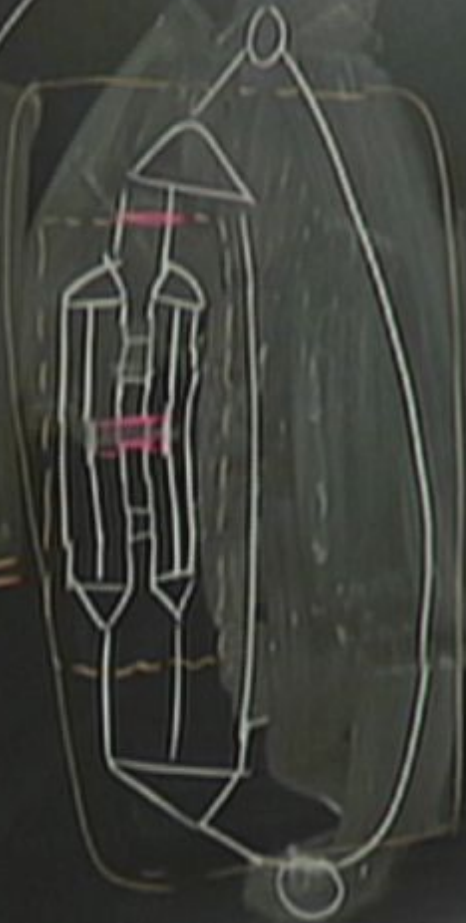
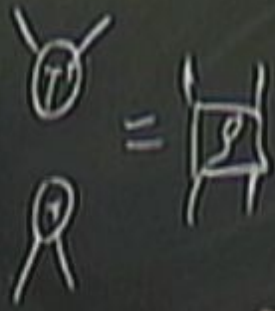


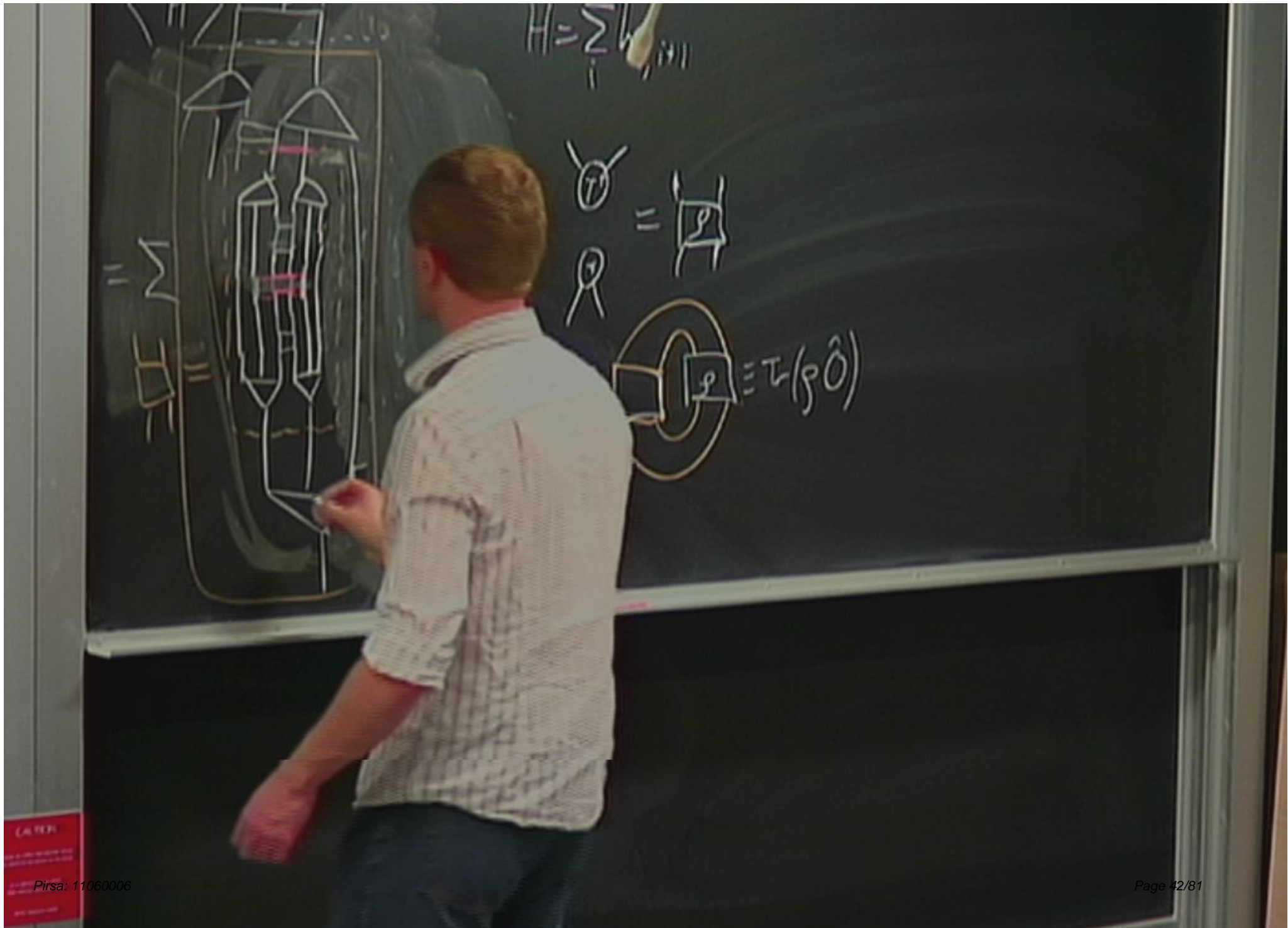






$$H = \sum_i w_i$$



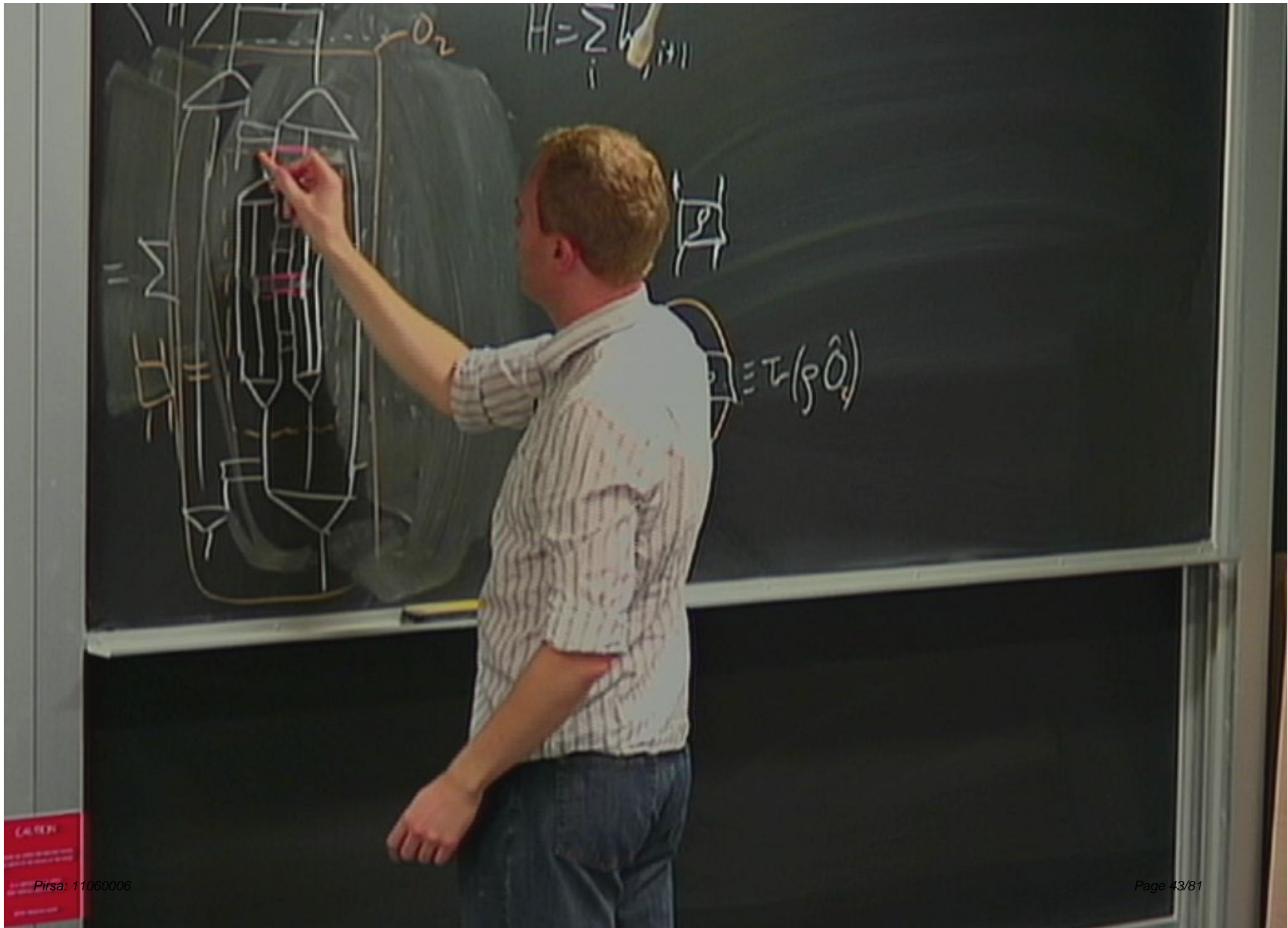


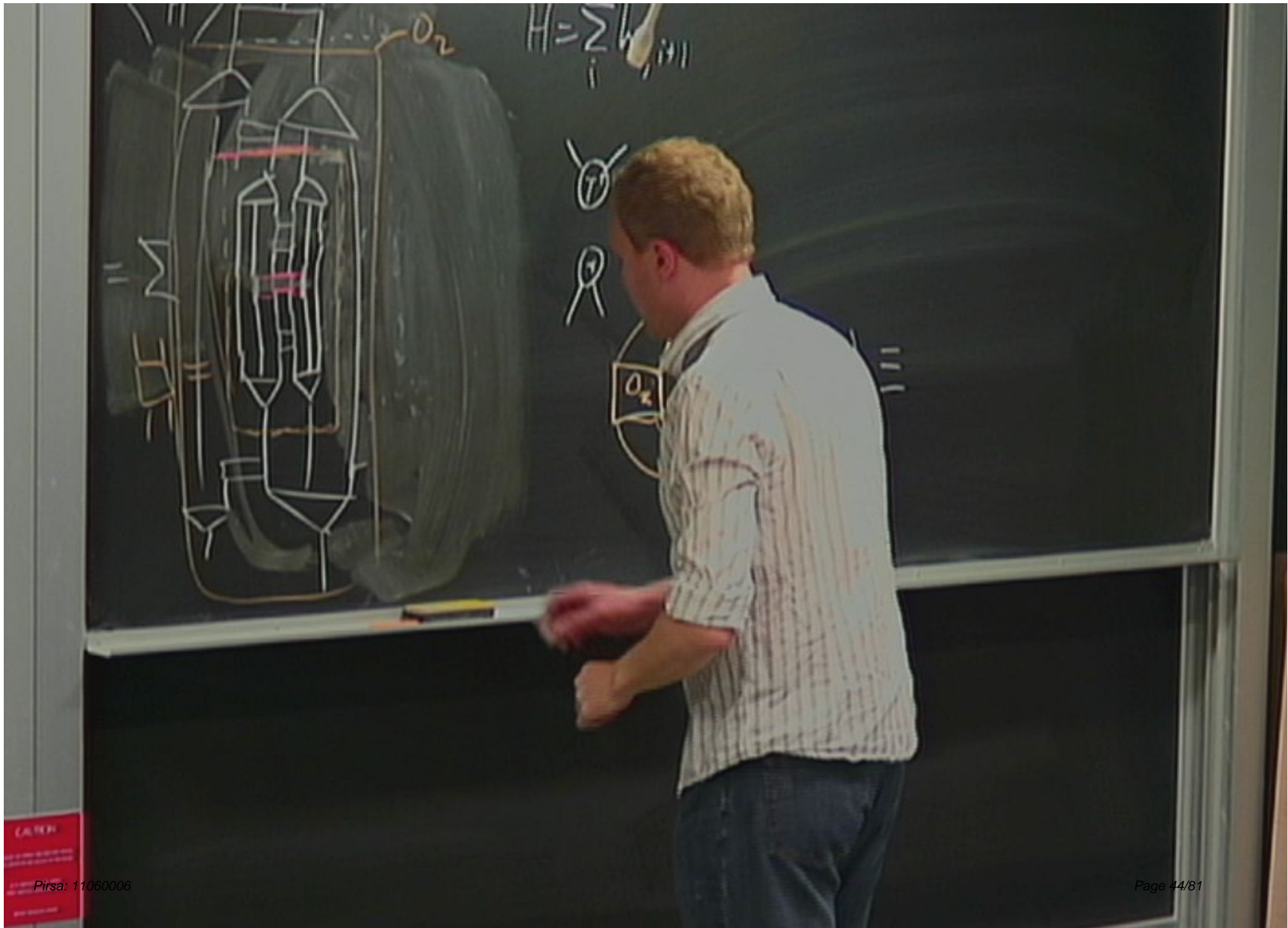
$$H = \sum_i \dots$$

$$\text{Diagram} = \text{Diagram}$$

$$\text{Diagram} = \tau(\rho \hat{O})$$

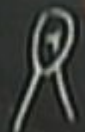
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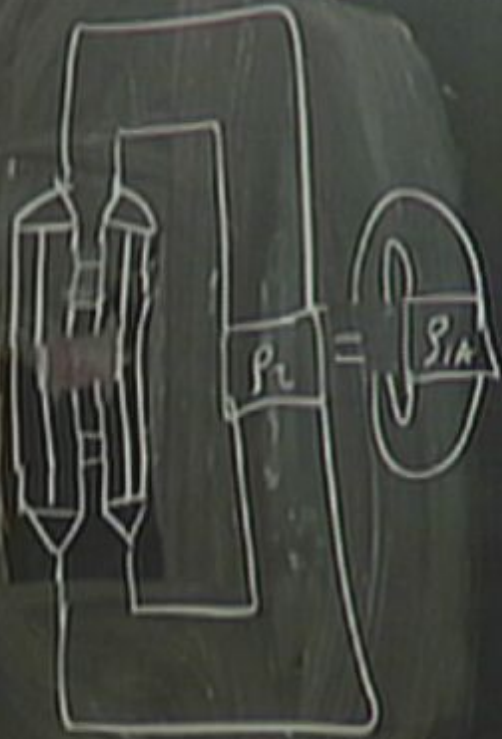


$$H = \sum_i W_i \psi_i$$

O₂



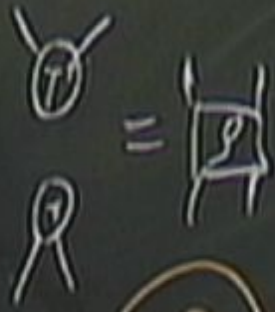
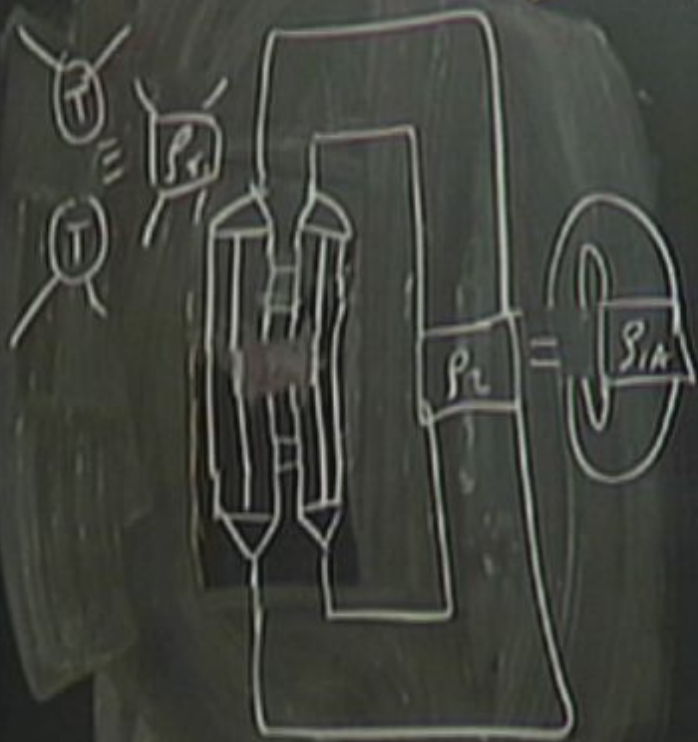
O₂



$$\begin{matrix} \text{---} \circ \text{---} \\ \text{---} \circ \text{---} \end{matrix} = \begin{matrix} \square \\ \square \end{matrix}$$

$$\begin{matrix} \square \\ \square \end{matrix} \equiv \tau(\rho \hat{O}) \equiv$$





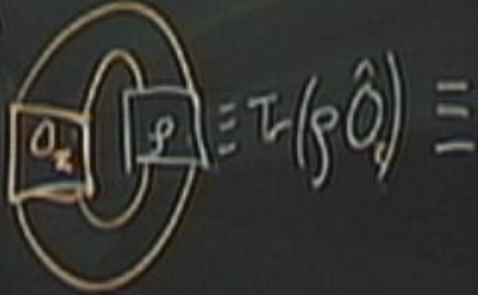
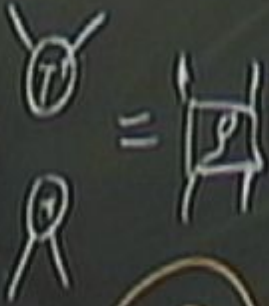
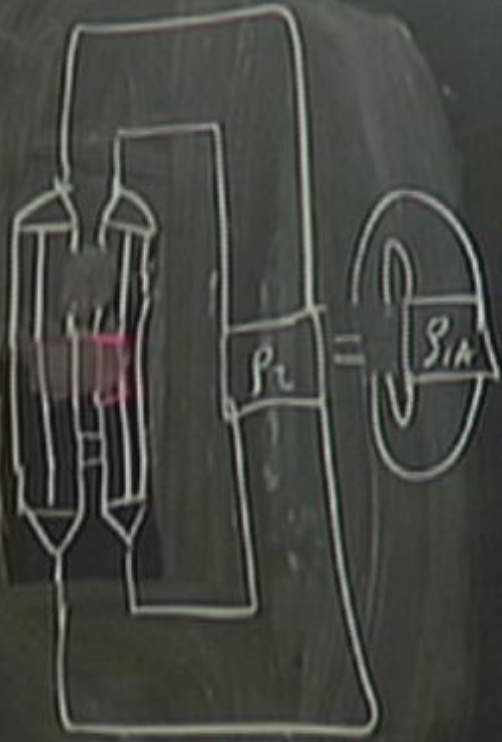
$$\text{[Diagram]} = \tau(\rho \hat{O}_d) =$$

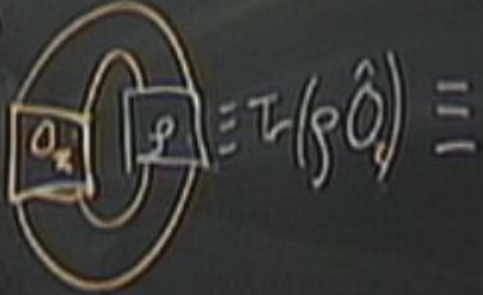
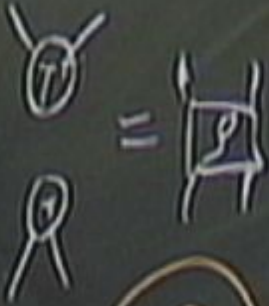
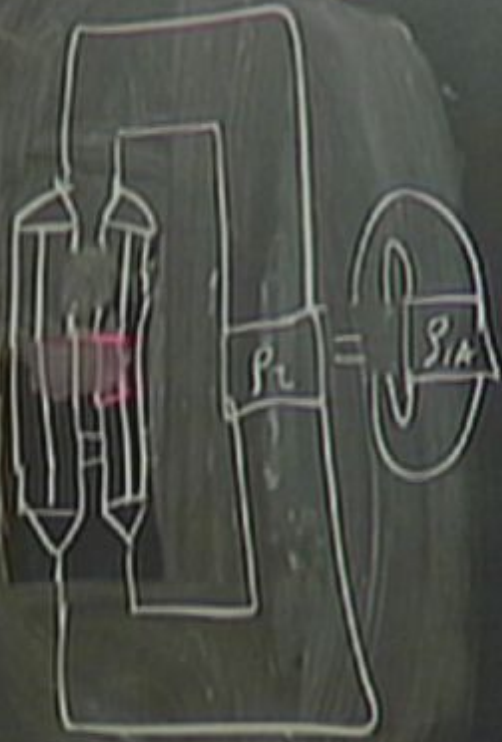


CAUTION
 This is a warning sign with some illegible text below it.



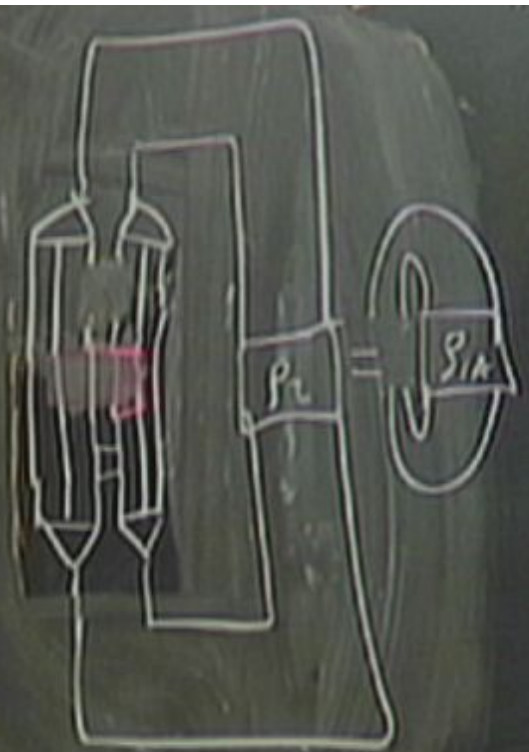
$$= \tau(\hat{\rho}^0) =$$





CAUTION

$$U$$



$$\text{Tr} = \text{Tr}$$

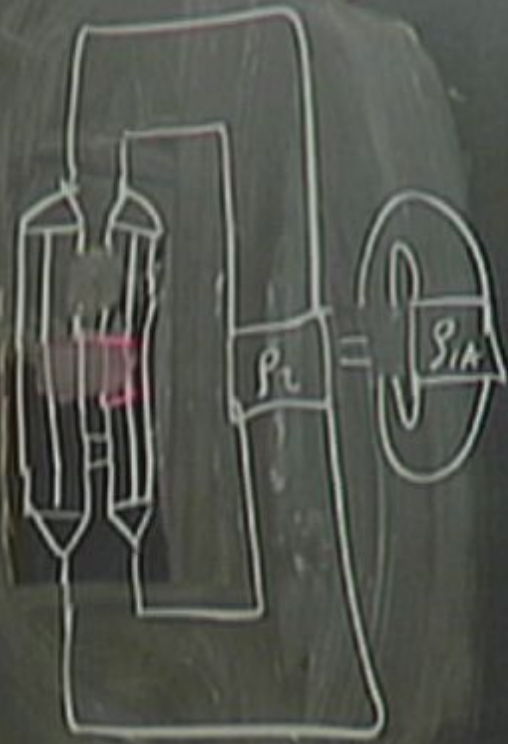
$$\text{Tr}(P \hat{O}) = \text{Tr}(\hat{O} P)$$

$$E = USV^T$$

$$U = -VU^T$$

$$\text{Tr}(UE^T) = \text{Tr}(-VU^T S V^T)$$

$$\begin{bmatrix} 1 \\ 1 \end{bmatrix}$$



$$\begin{matrix} \text{---} \\ \text{---} \end{matrix} = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

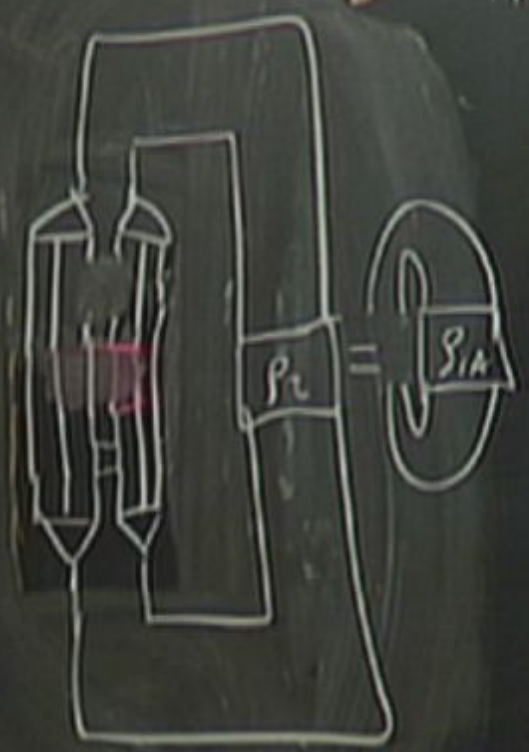
$$\begin{bmatrix} 0 \\ 1 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \text{Tr}(\hat{P} \hat{Q}) =$$

$$\begin{bmatrix} 1 \\ 1 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = USV^T$$

$$\begin{bmatrix} 1 \\ 1 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = -VU^T$$

$$\begin{aligned} \text{Tr}(UE^T) &= \text{Tr}(-X^T Y^T S Y^T X^T) \\ &= \text{Tr}(-S) \end{aligned}$$

$$\rho$$



$-O_2$

$$H = \sum_i h_i$$

$$\text{Tr} = \rho$$

$$\rho = \text{Tr}(\rho \hat{O}_i)$$

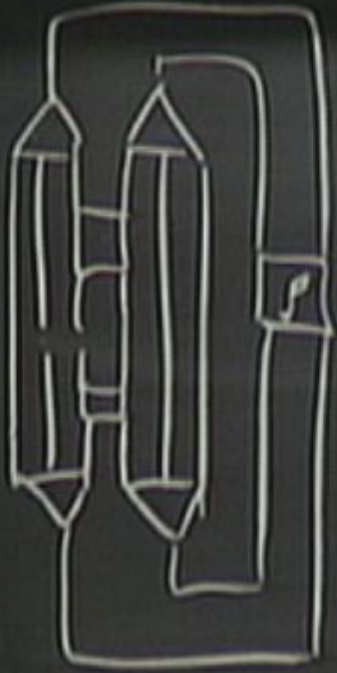
$$E = USV^T$$

$$U = -VU^T$$

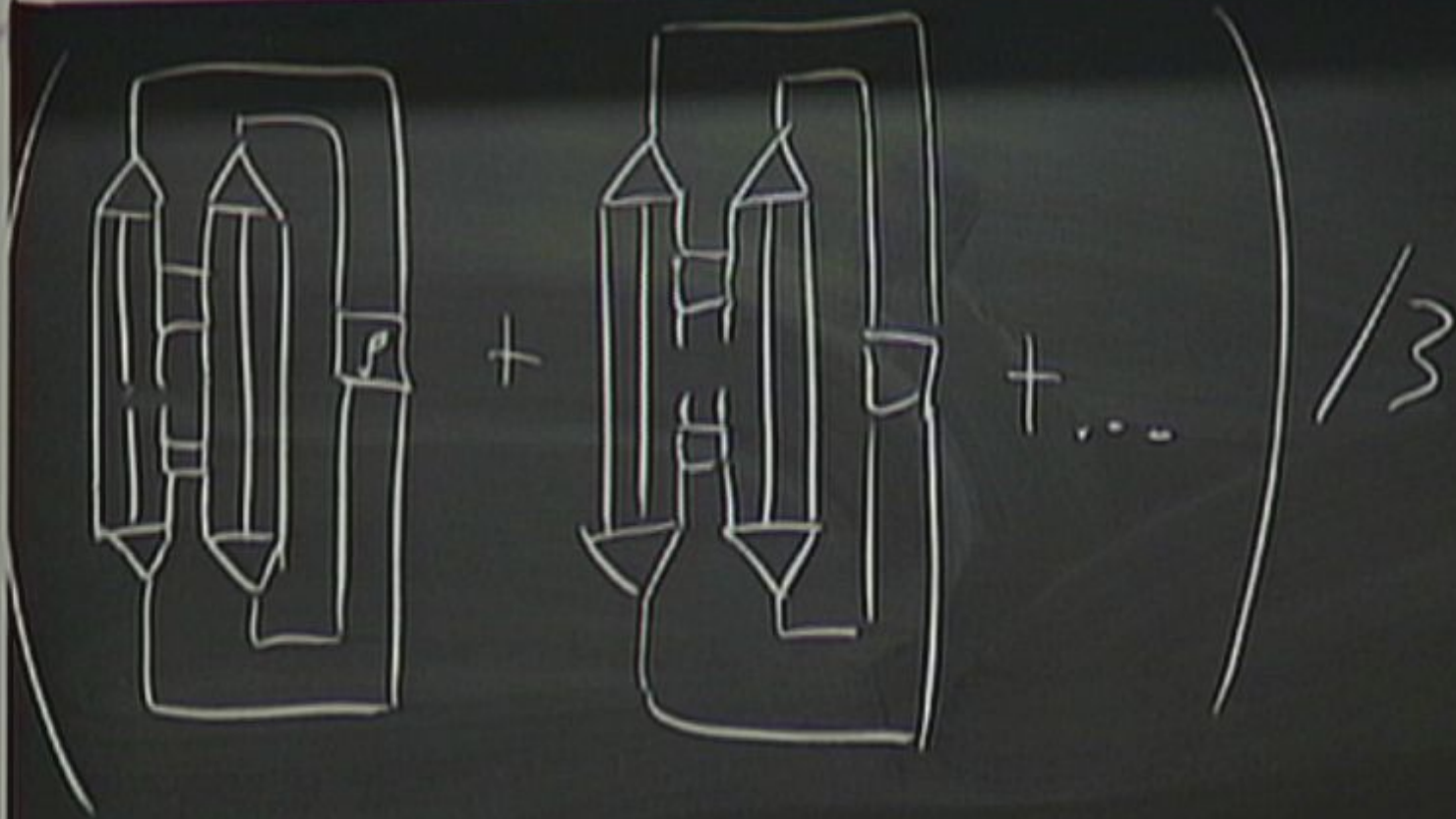
$$\text{Tr}(UE^T) = \text{Tr}(-X^T Y^T S Y^T X^T)$$

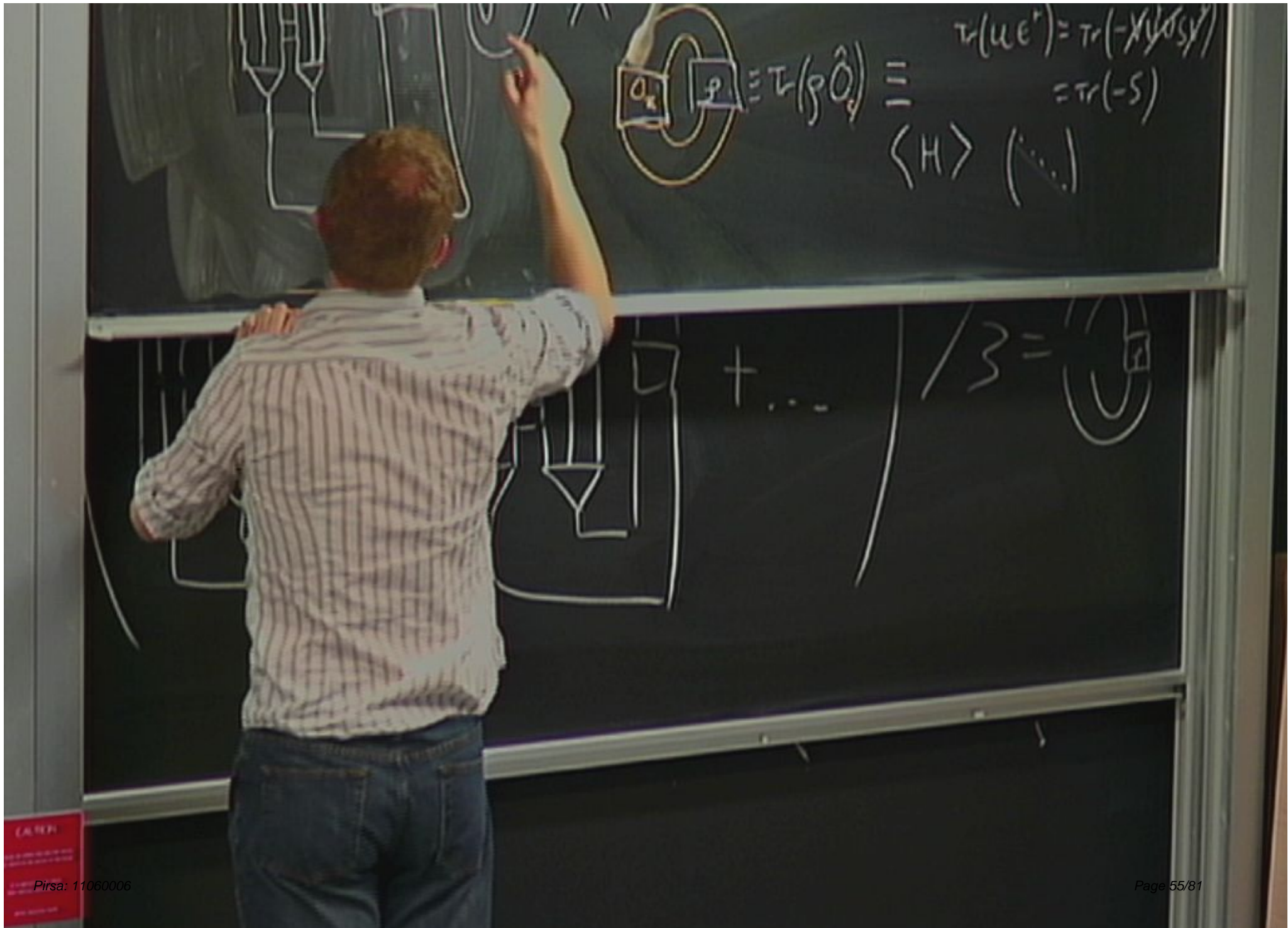
$$= \text{Tr}(-S)$$

$$\langle H \rangle$$



CAUTION

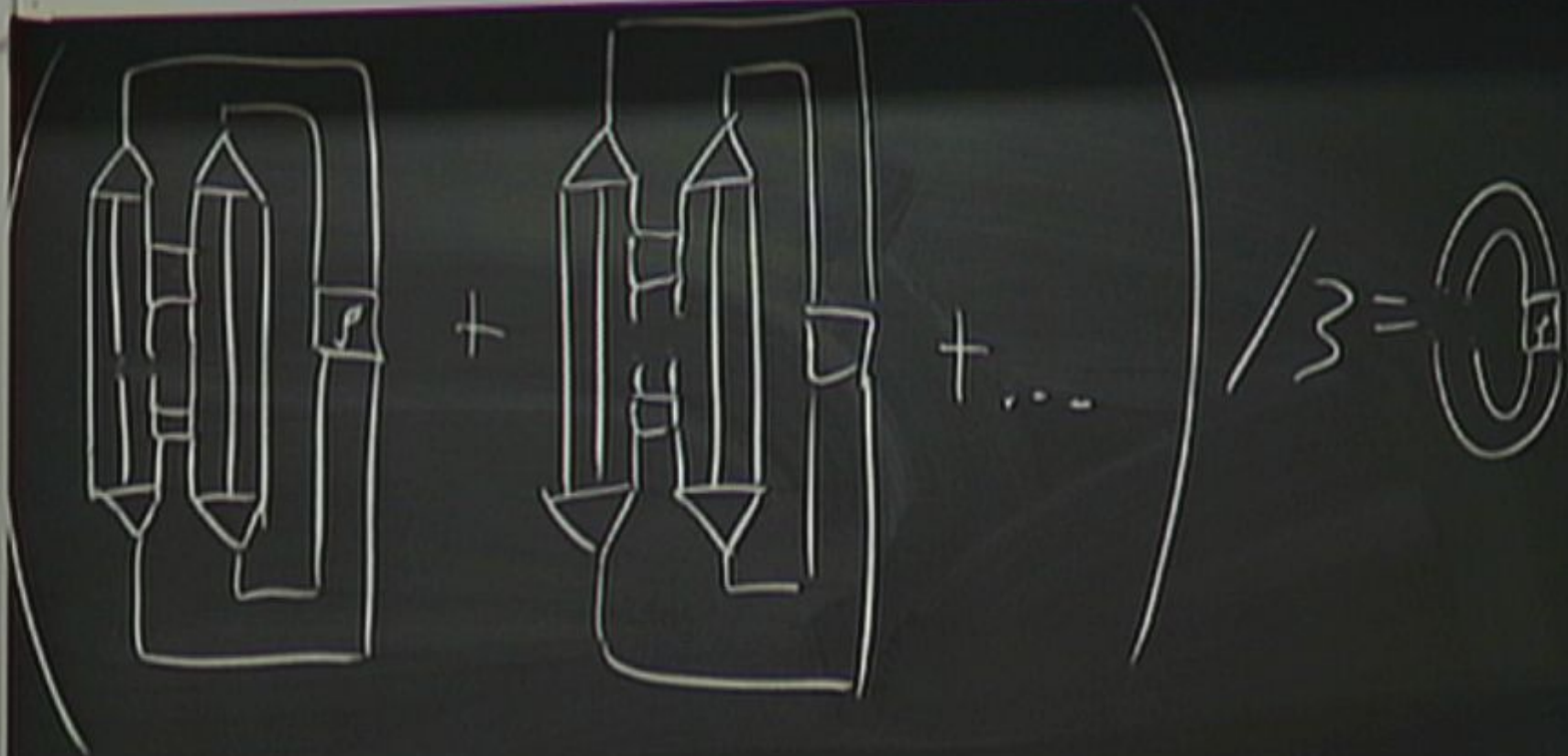


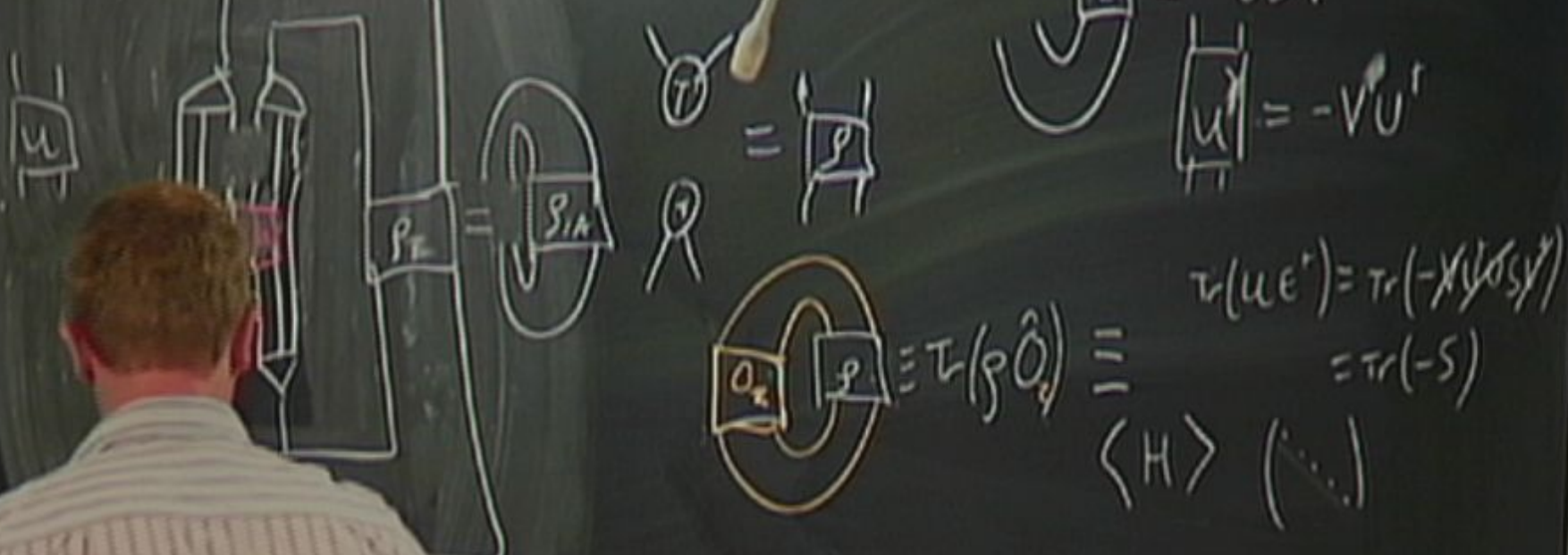


$$\text{Tr}(UE^T) = \text{Tr}(-X^T Y S Y^T)$$
$$= \text{Tr}(-S)$$

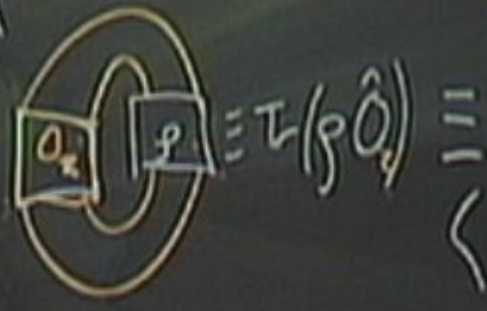
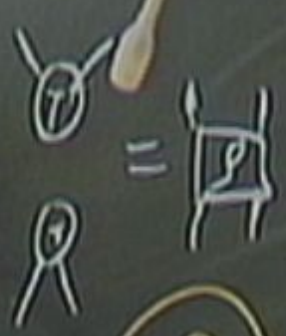
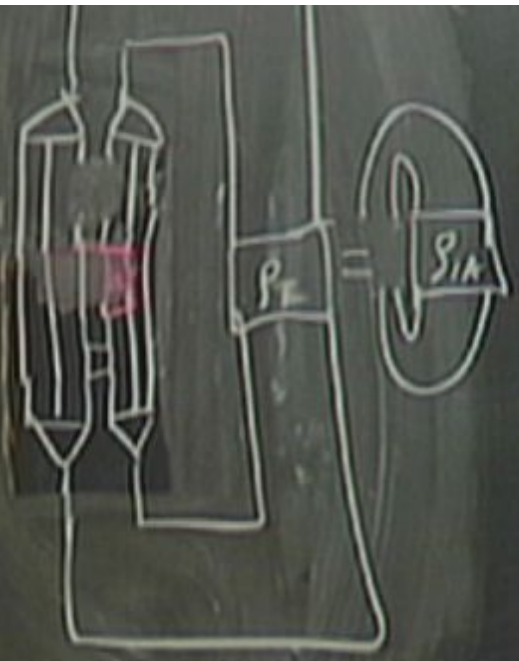
$$\text{Tr}(\rho \hat{O}_i) = \langle H \rangle$$

$$\frac{1}{3} =$$





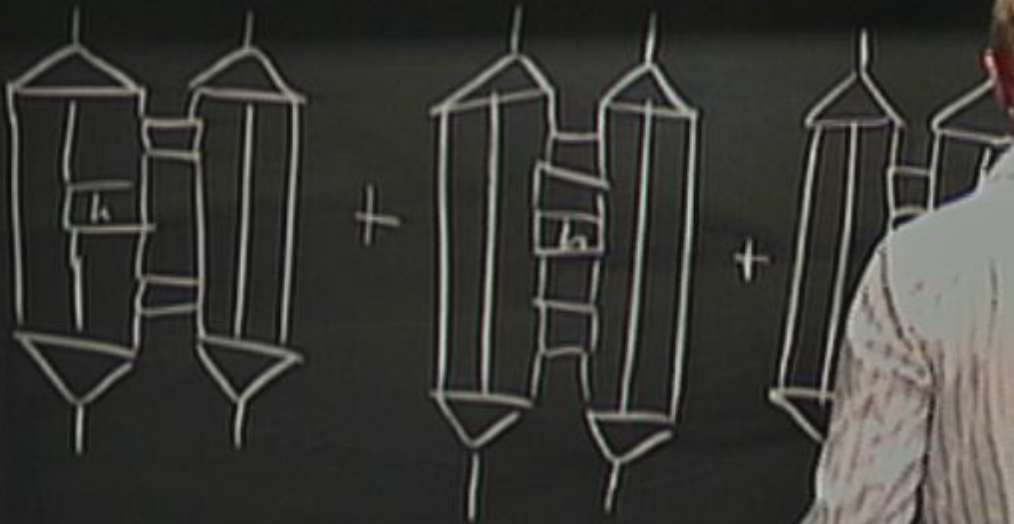
\mathbb{R}^2



$$U^T = -V U^T$$

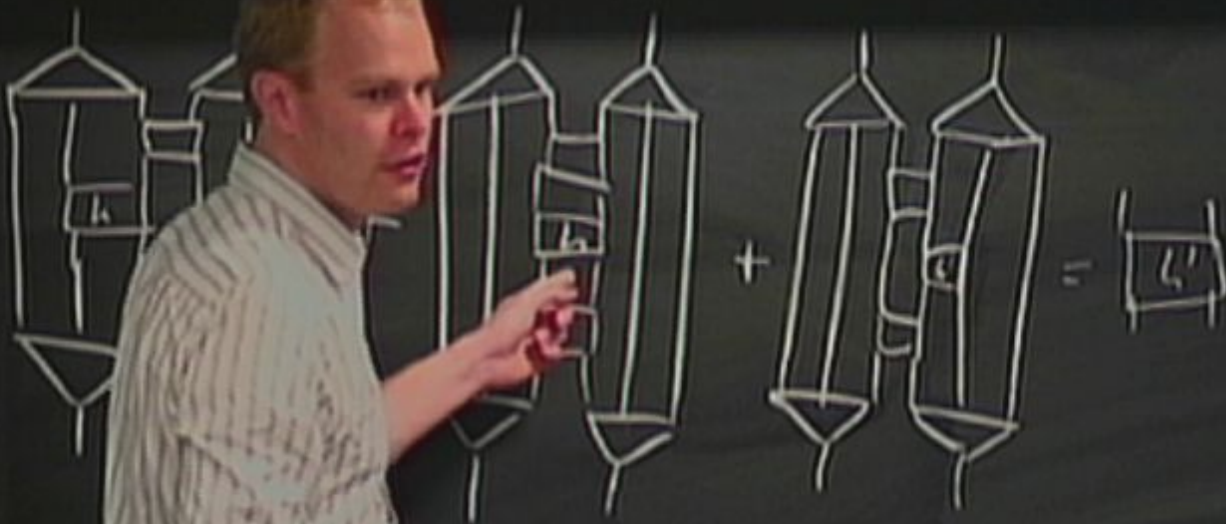
$$\text{Tr}(U E^T) = \text{Tr}(-X Y^T S Y^T) = \text{Tr}(-S)$$

$\langle H \rangle$ ()



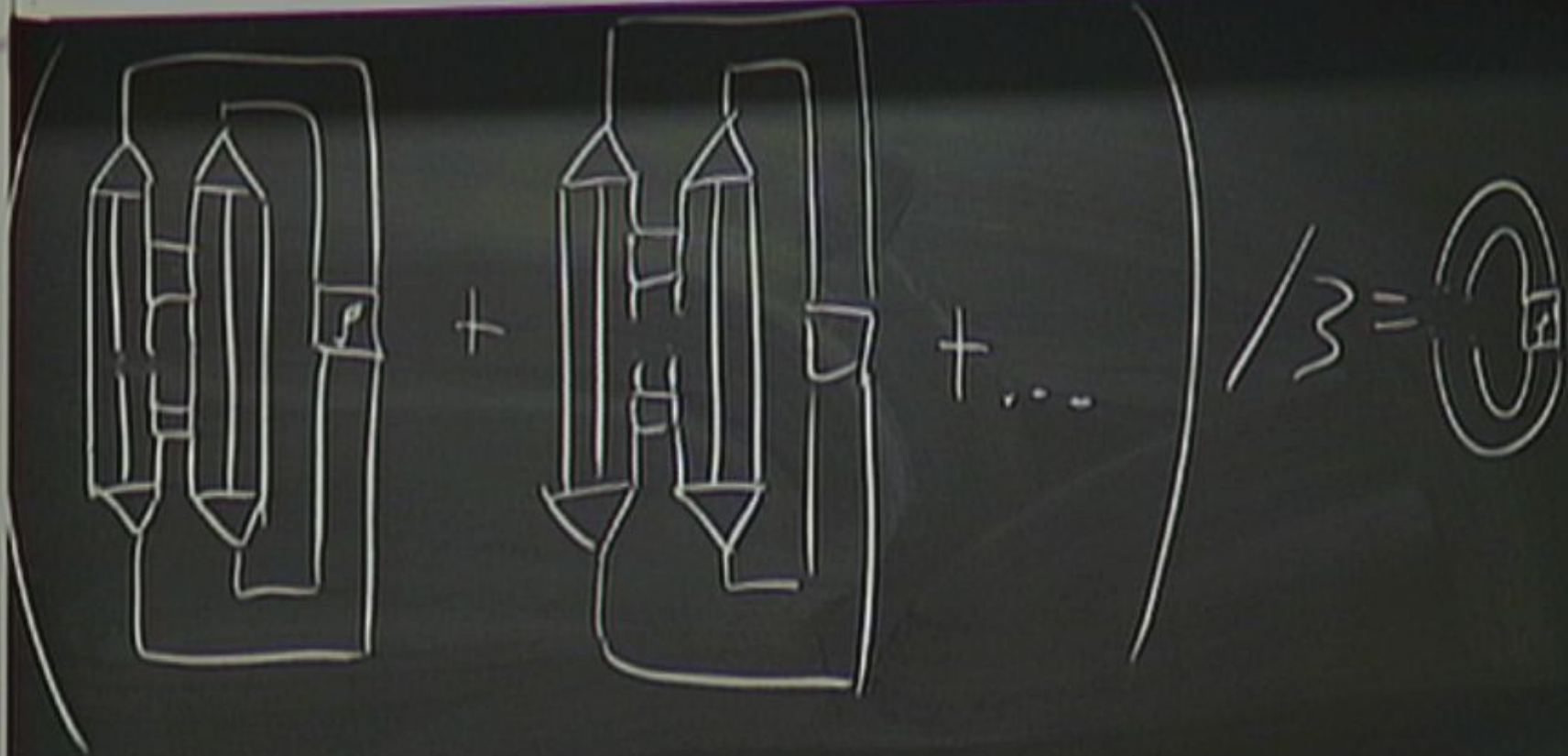
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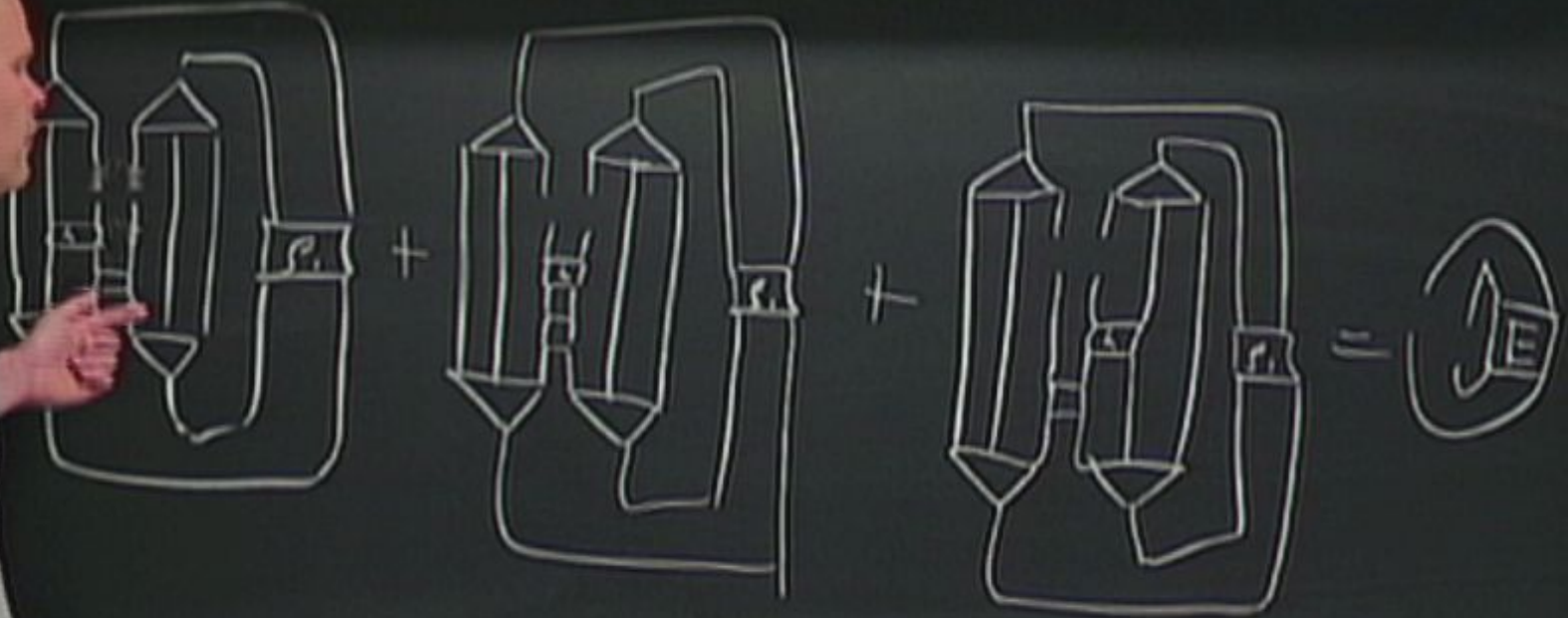


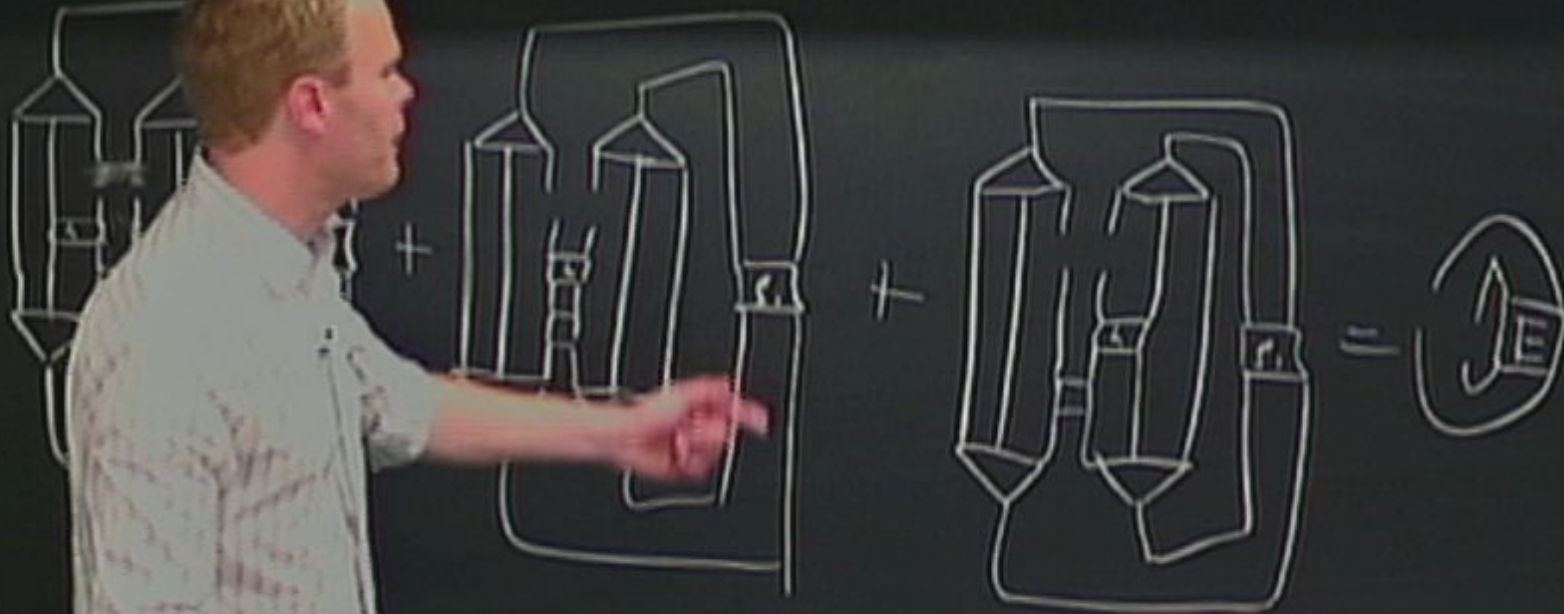
ALPH
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CAUTION
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CAUTION











Algorithms for Entanglement Renormalization
G. Evenbly, R.G. Vidal



Algorithm for Entanglement Renormalization
G. Evenbly, L.S. Vidal

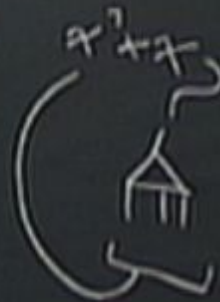


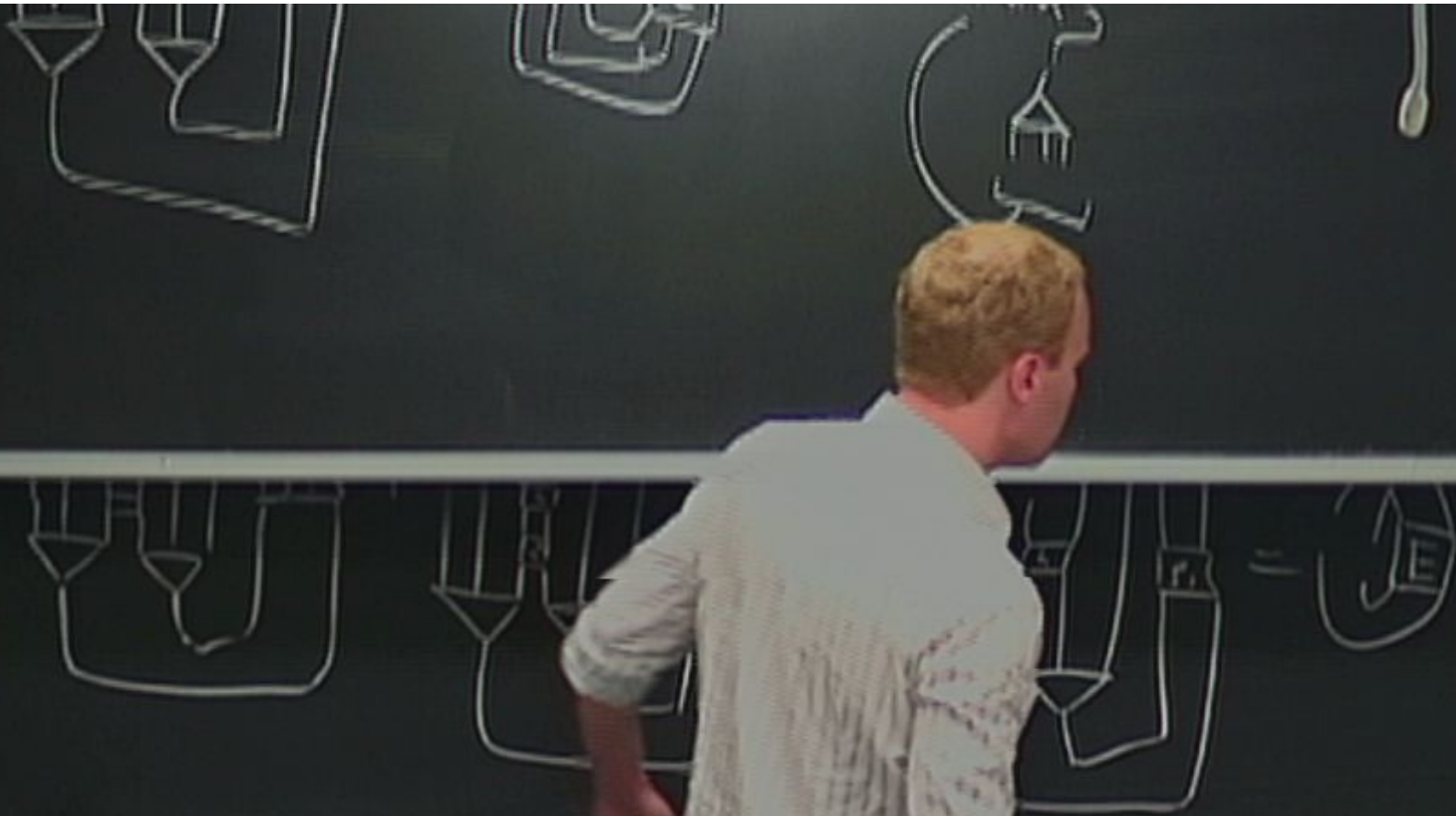
$$-V^{\dagger}U$$

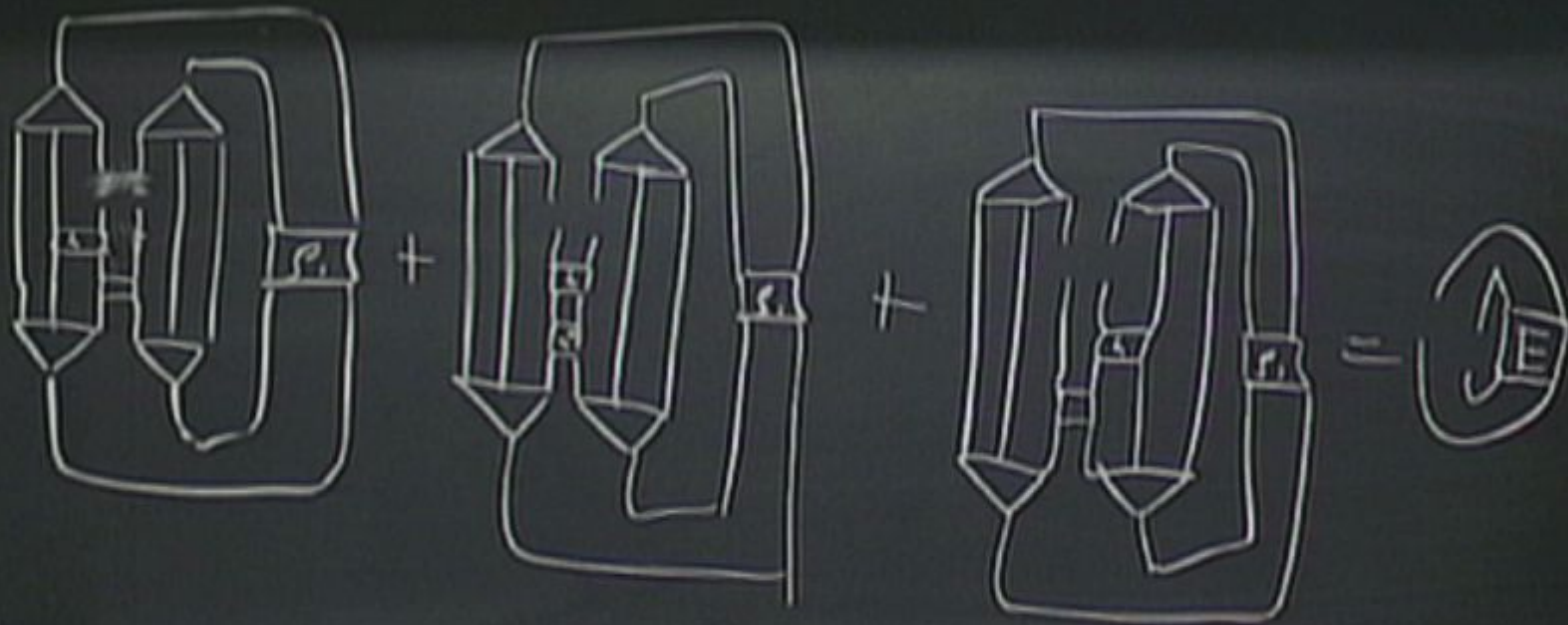
Algorithm for Entanglement Renormalization
G. Evenbly, L.S. Vidal

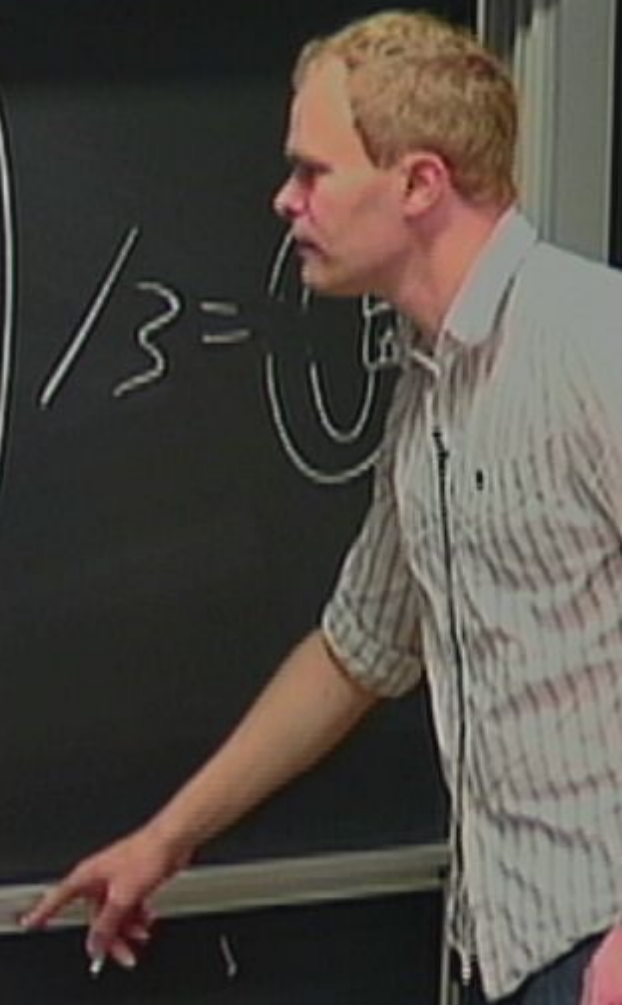
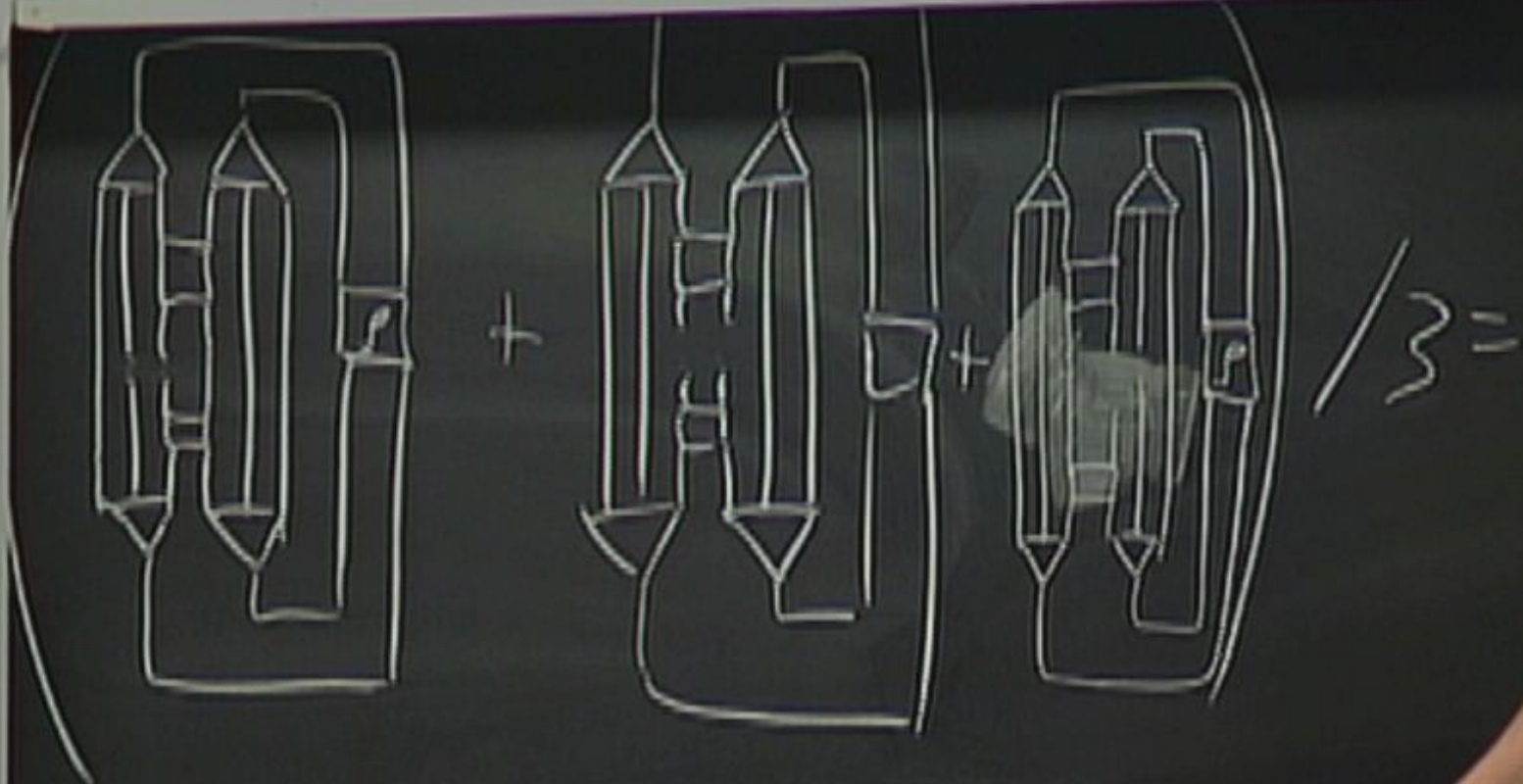


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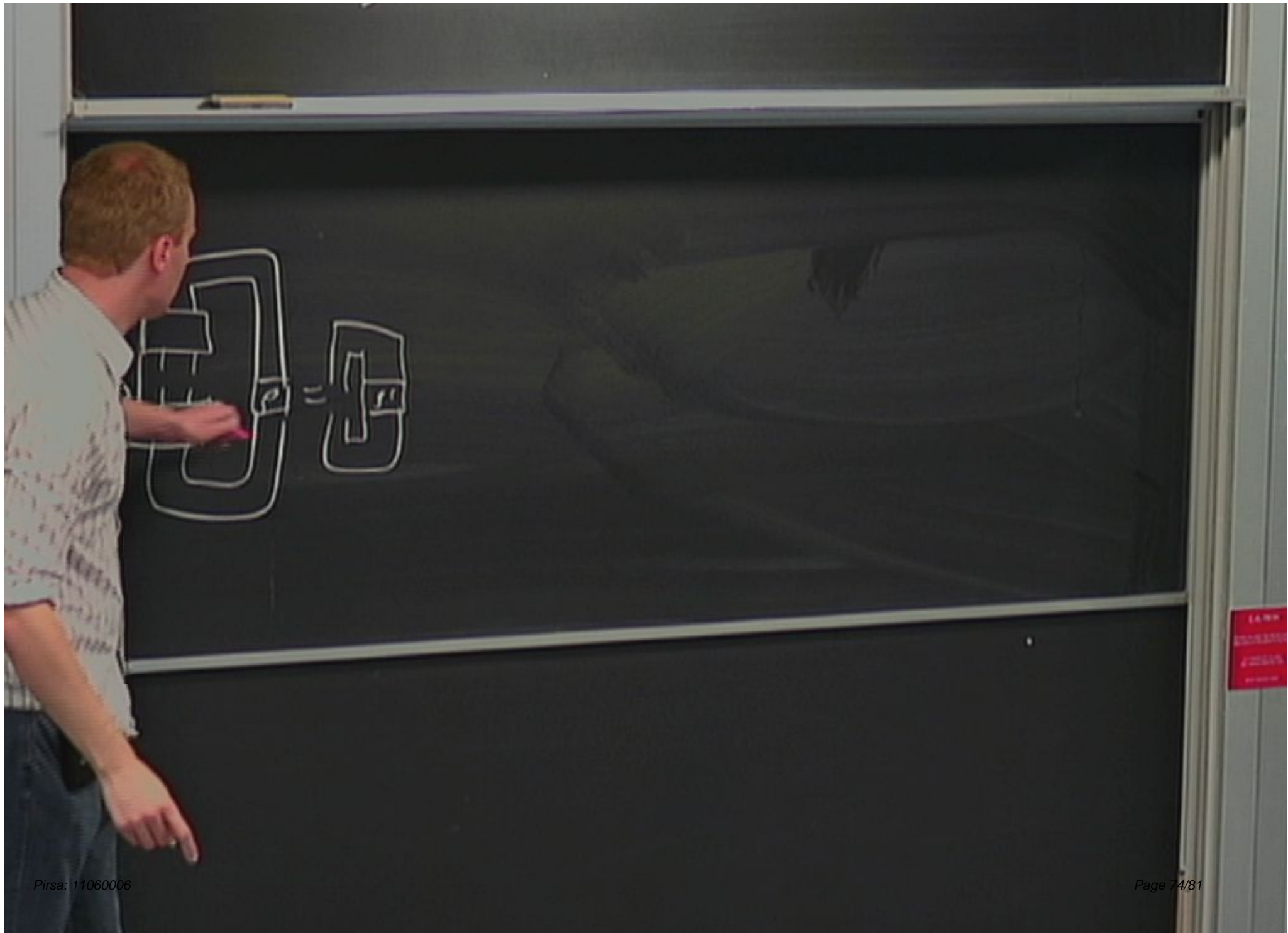


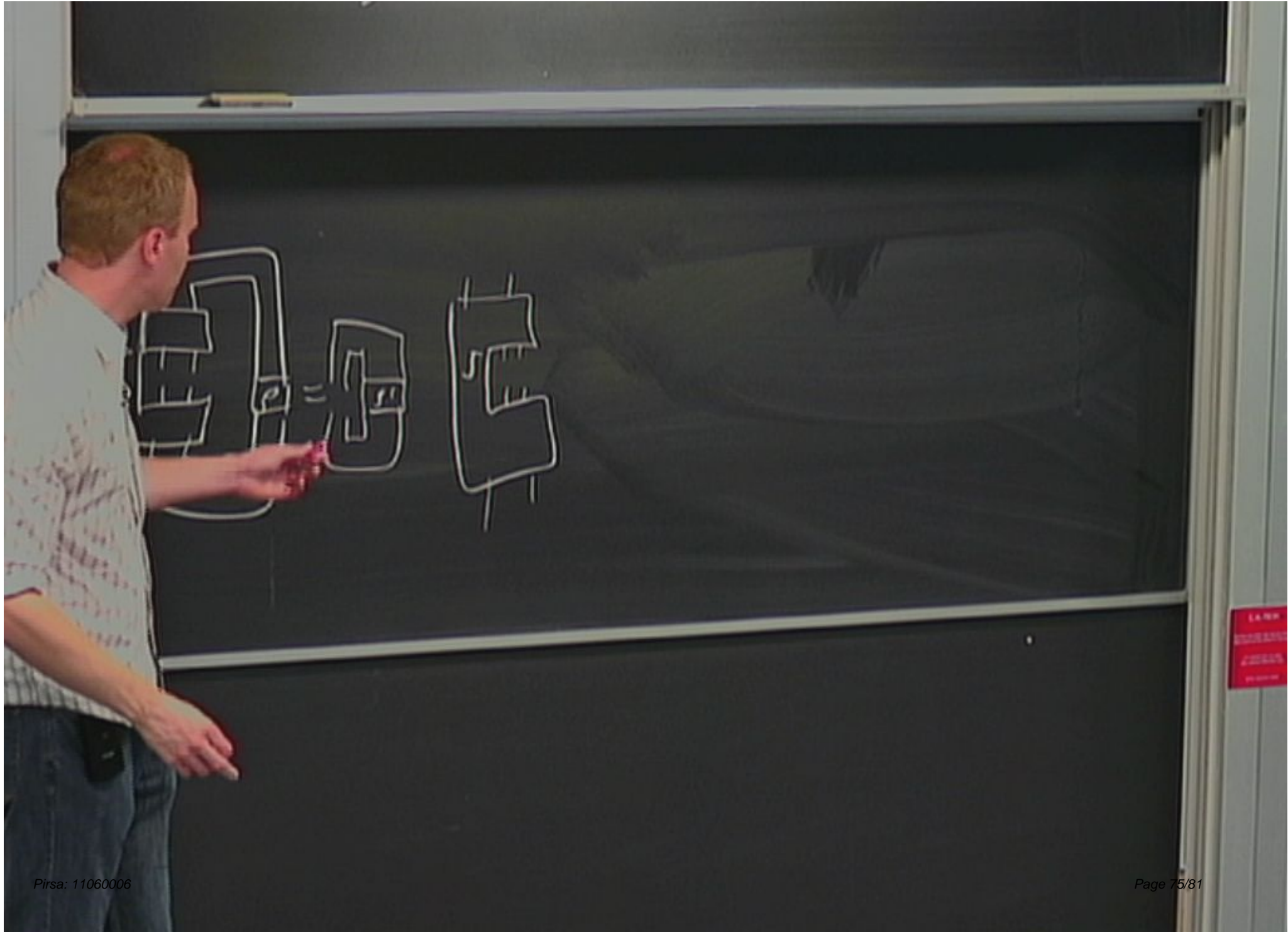


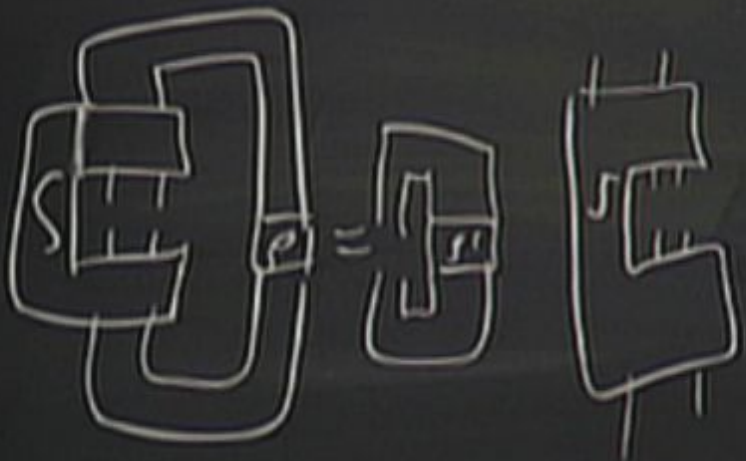


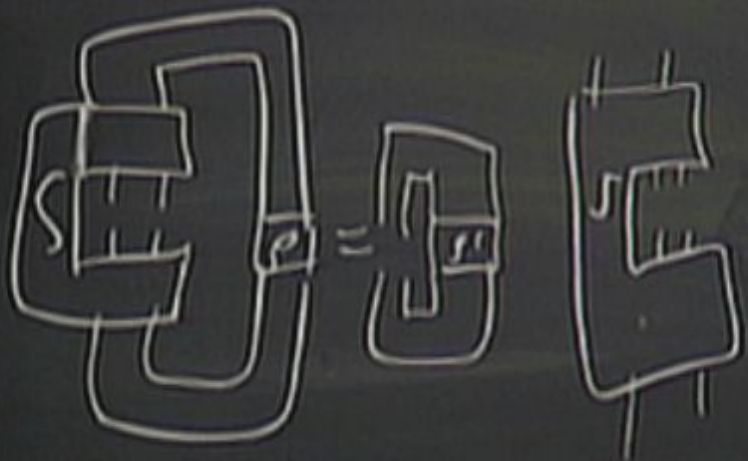


CAUTION
DO NOT TOUCH
THE SURFACE
OF THE BOARD

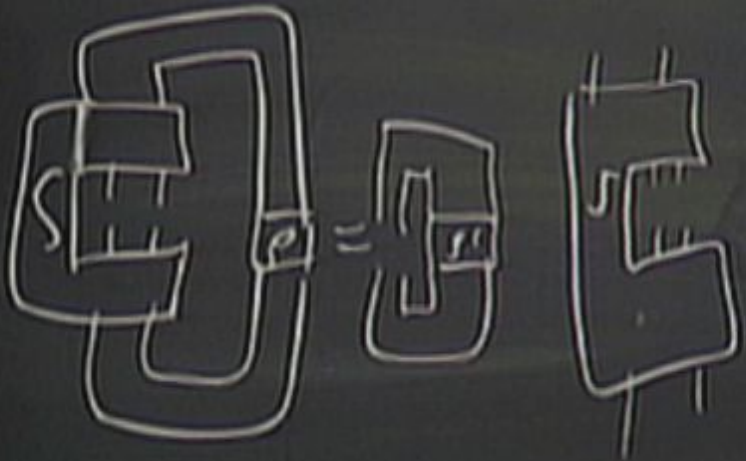


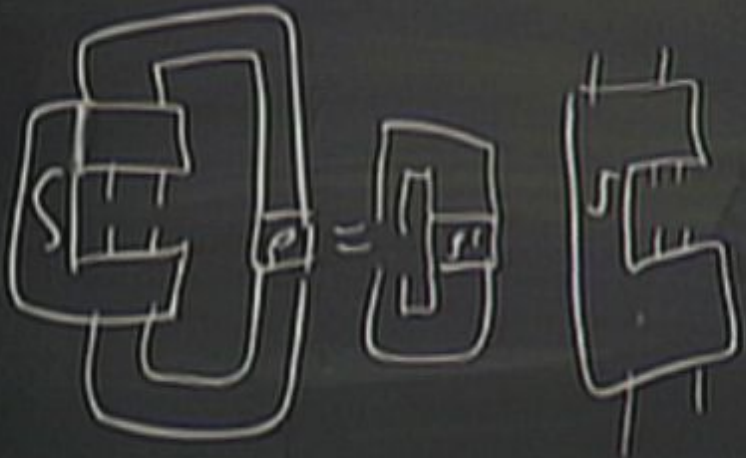




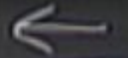


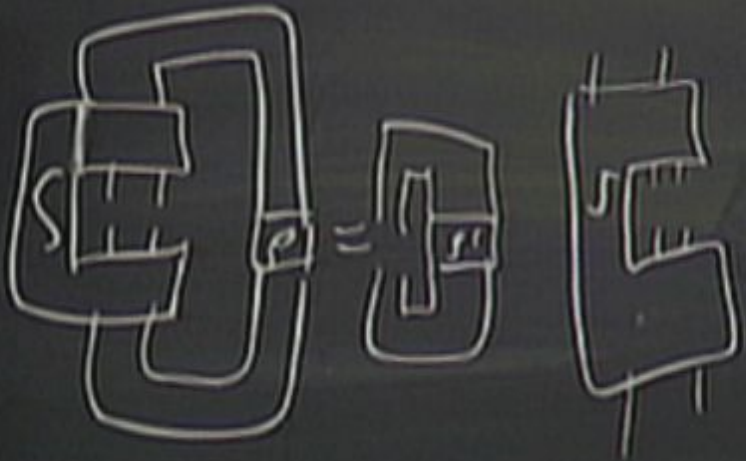
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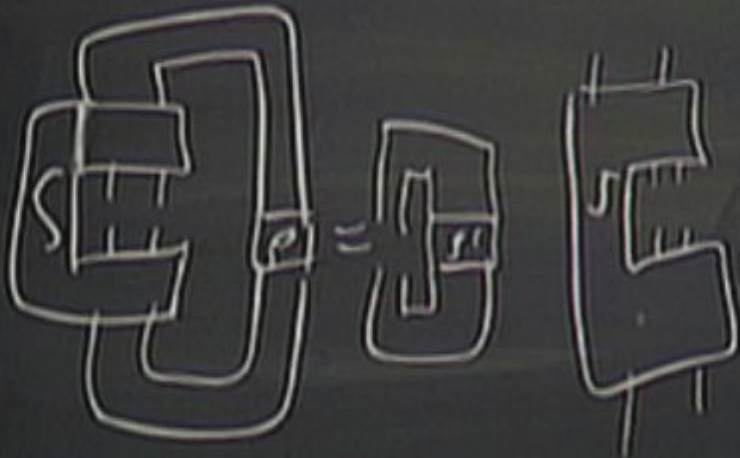
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For more information
 contact us at
 020-26104789

CAUTION
Do not touch the
 equipment
 without the
 instructor's
 permission



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