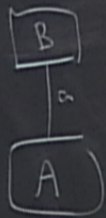


Title: 13/14 PSI - Foundations of Quantum Mechanics - Lecture 14

Date: Jan 23, 2014 11:30 AM

URL: <http://pirsa.org/14010063>

Abstract:

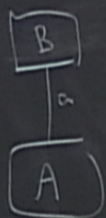


$$\text{prob}(A^{a_1} B_{a_1}) = A^{a_1} B_{a_1}$$

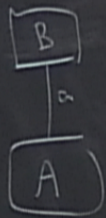
blue $\rightarrow$

$$\text{prob}(A^{a_1} B_{a_1}) = A^{a_1} B_{a_1} = \boxed{A} \xrightarrow{a} \boxed{B}$$

blue $\rightarrow$ white.
 $\backslash \text{mathsf}$ $\rightarrow$ normal math font.

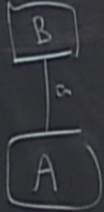


$$\text{prob}(A^{a_1} B_{a_1}) = A^{a_1} B_{a_1} = \boxed{A} \text{---}^a \boxed{B}$$



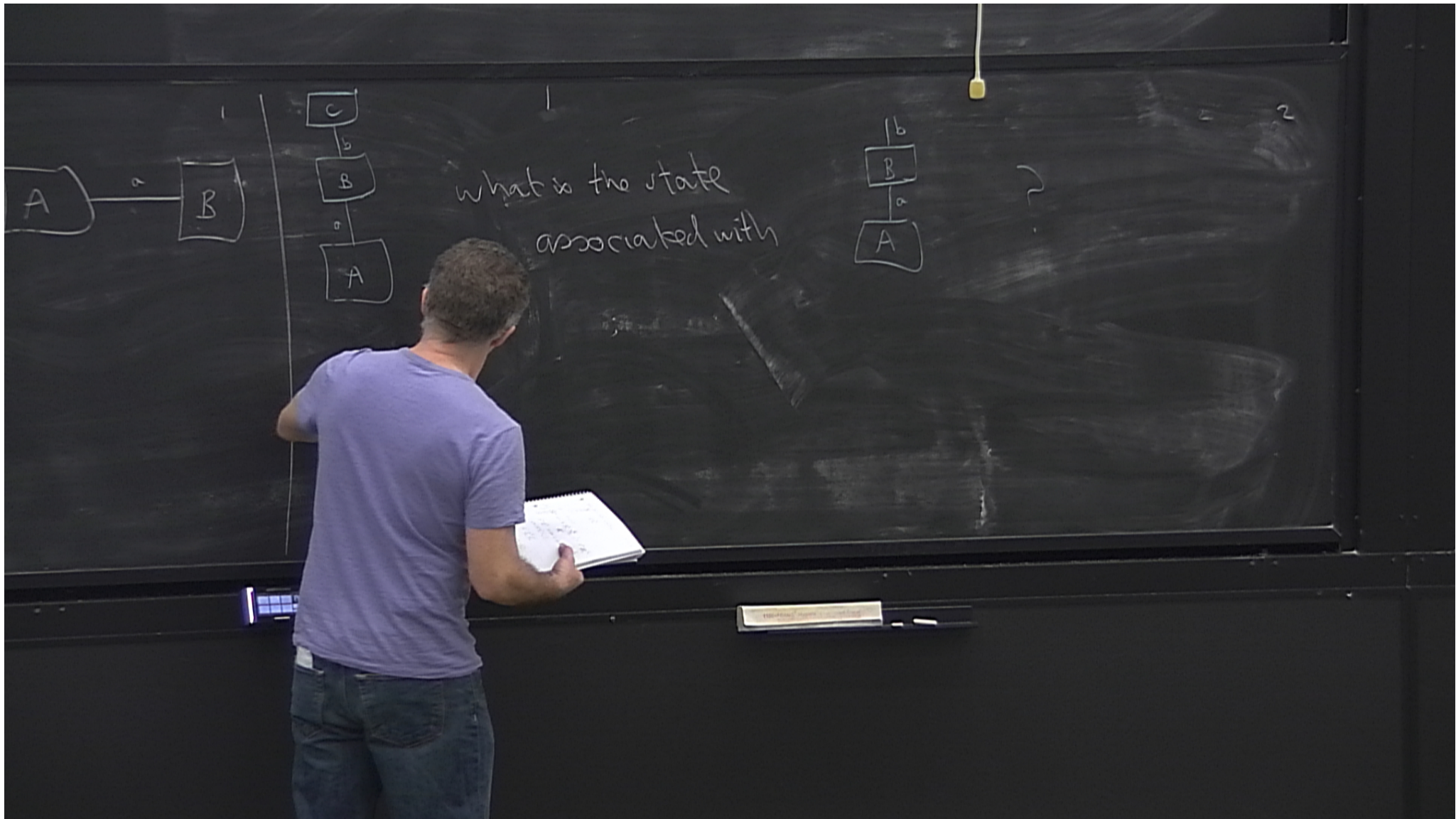
blue $\rightarrow$ white.
 mathsf $\rightarrow$ normal math font.

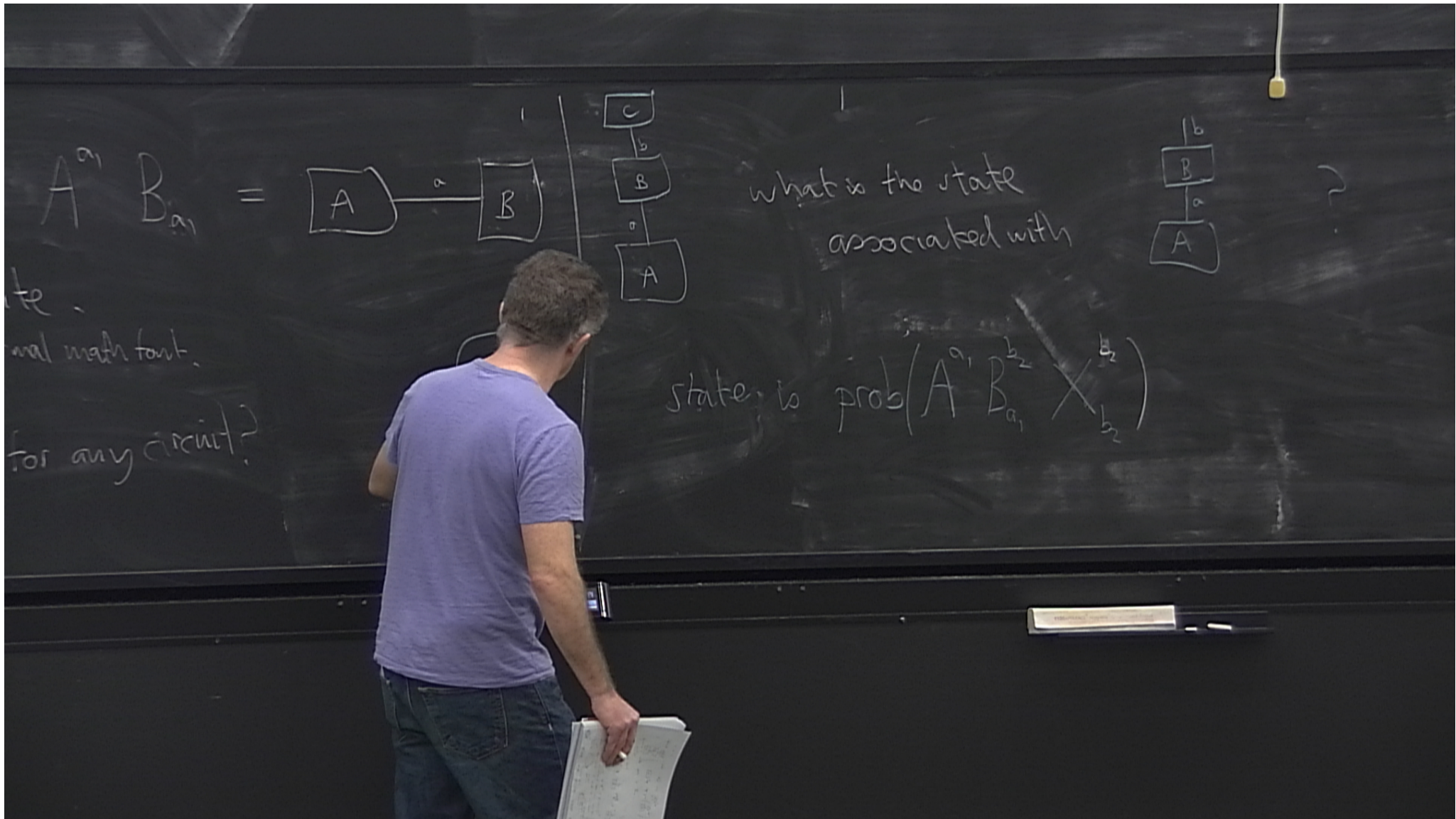
$$\text{prob}(A^{a_1} B_{a_1}) = A^{a_1} B_{a_1} = \boxed{A} \xrightarrow{a} \boxed{B}$$

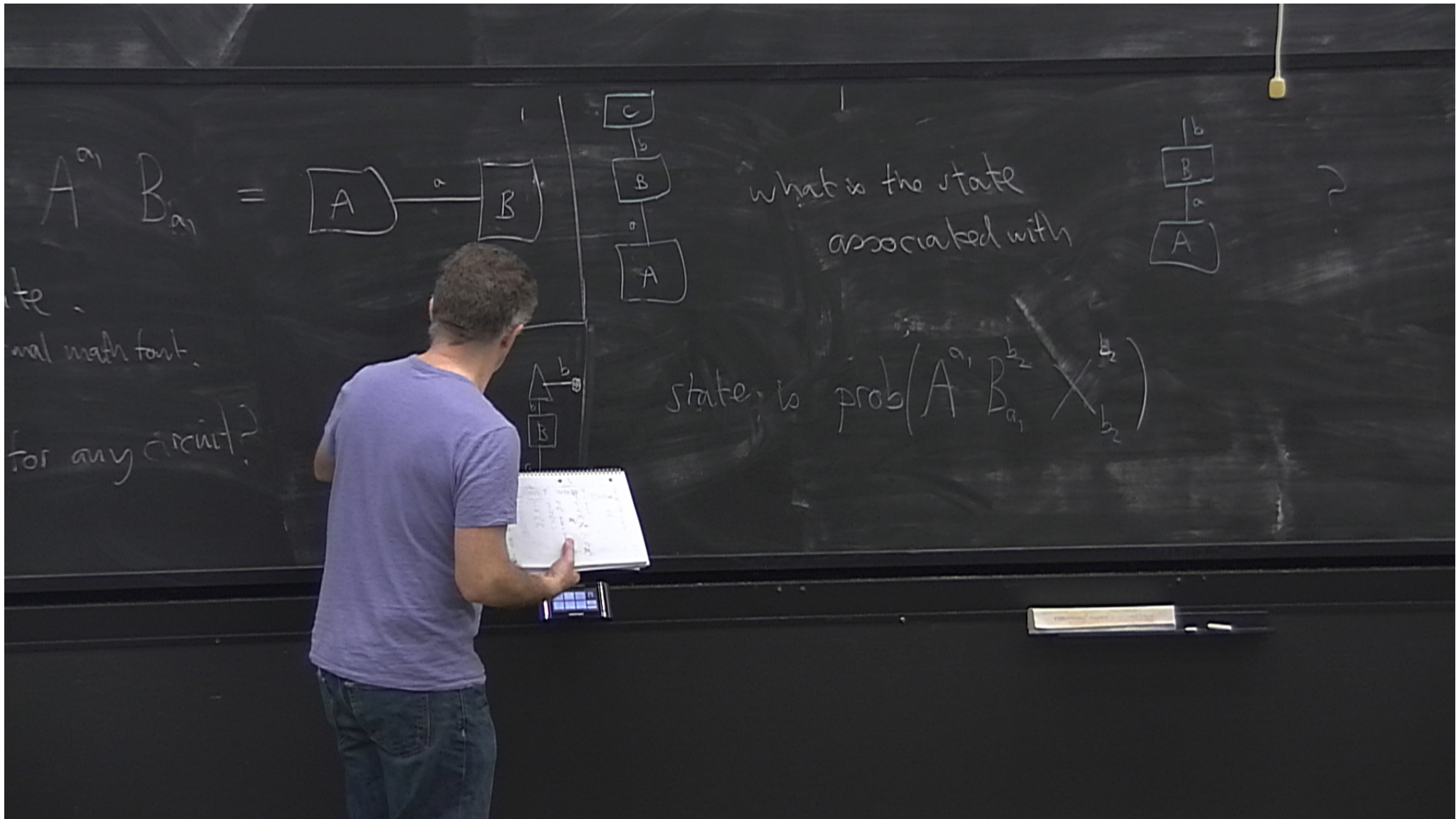


blue $\rightarrow$ white.
 $\backslash$ mathsf $\rightarrow$ normal math font.

does this work for any circuit?







$\rightarrow$ white.
 $\rightarrow$ normal math font.
 is work for any

$$A^{a_1} B_{a_1} = \boxed{A} \xrightarrow{a} \boxed{B}$$

$$\boxed{C} \xrightarrow{b} \boxed{B} \xrightarrow{a} \boxed{A}$$

$$\boxed{B} \xrightarrow{a} \boxed{A}$$

what is the state associated with

$$\boxed{B} \xrightarrow{b} \boxed{A}$$

state is $\text{prob}(A^{a_1} B_{a_1} \times \cancel{B_{b_2}})$

$\rightarrow$ white.
 $\rightarrow$ normal math font.
 is work for any circuit.

$$A^{a_1} B_{a_1} = \boxed{A} \xrightarrow{a} \boxed{B}$$

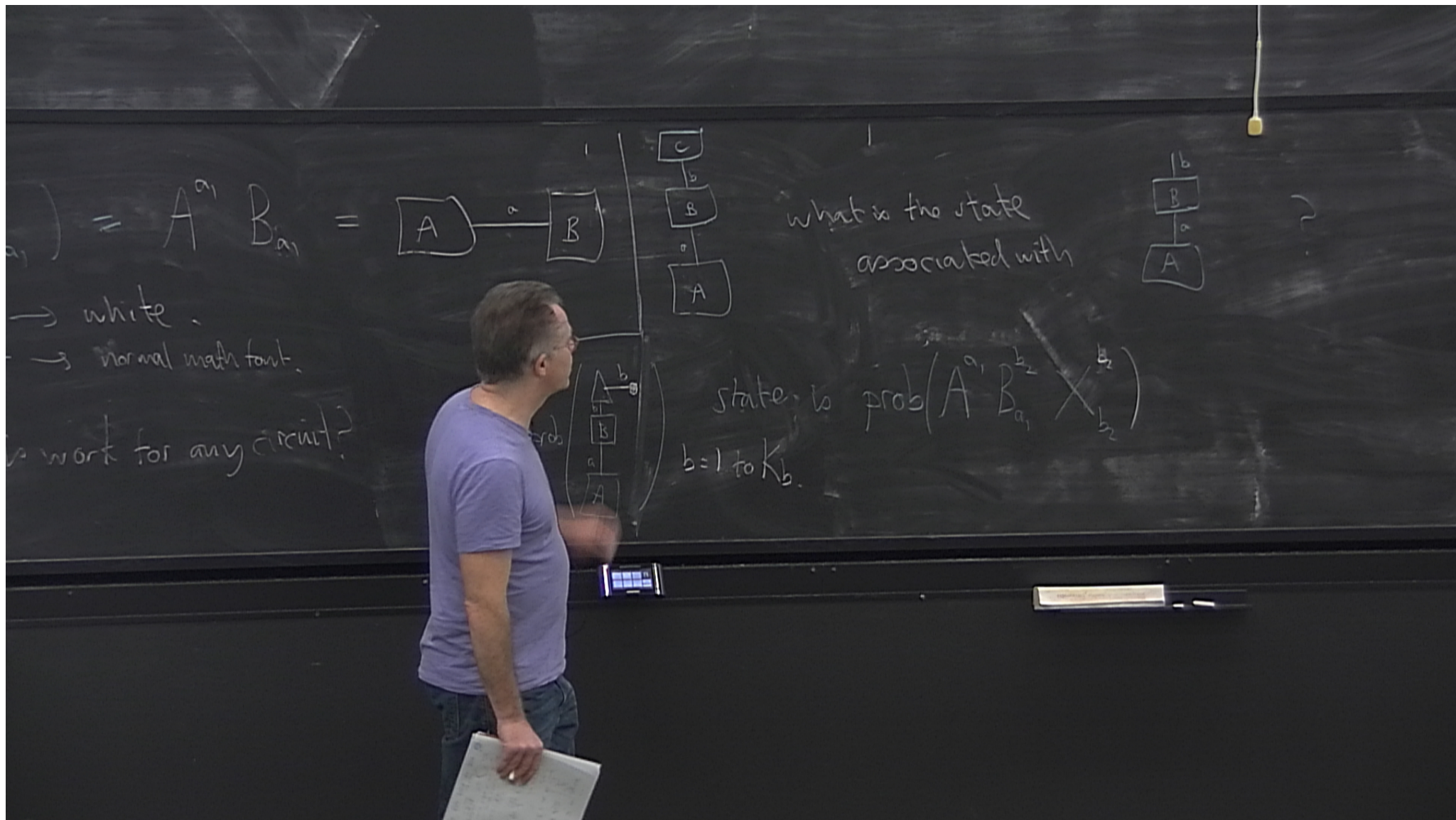
$\boxed{C} \xrightarrow{b} \boxed{B} \xrightarrow{a} \boxed{A}$

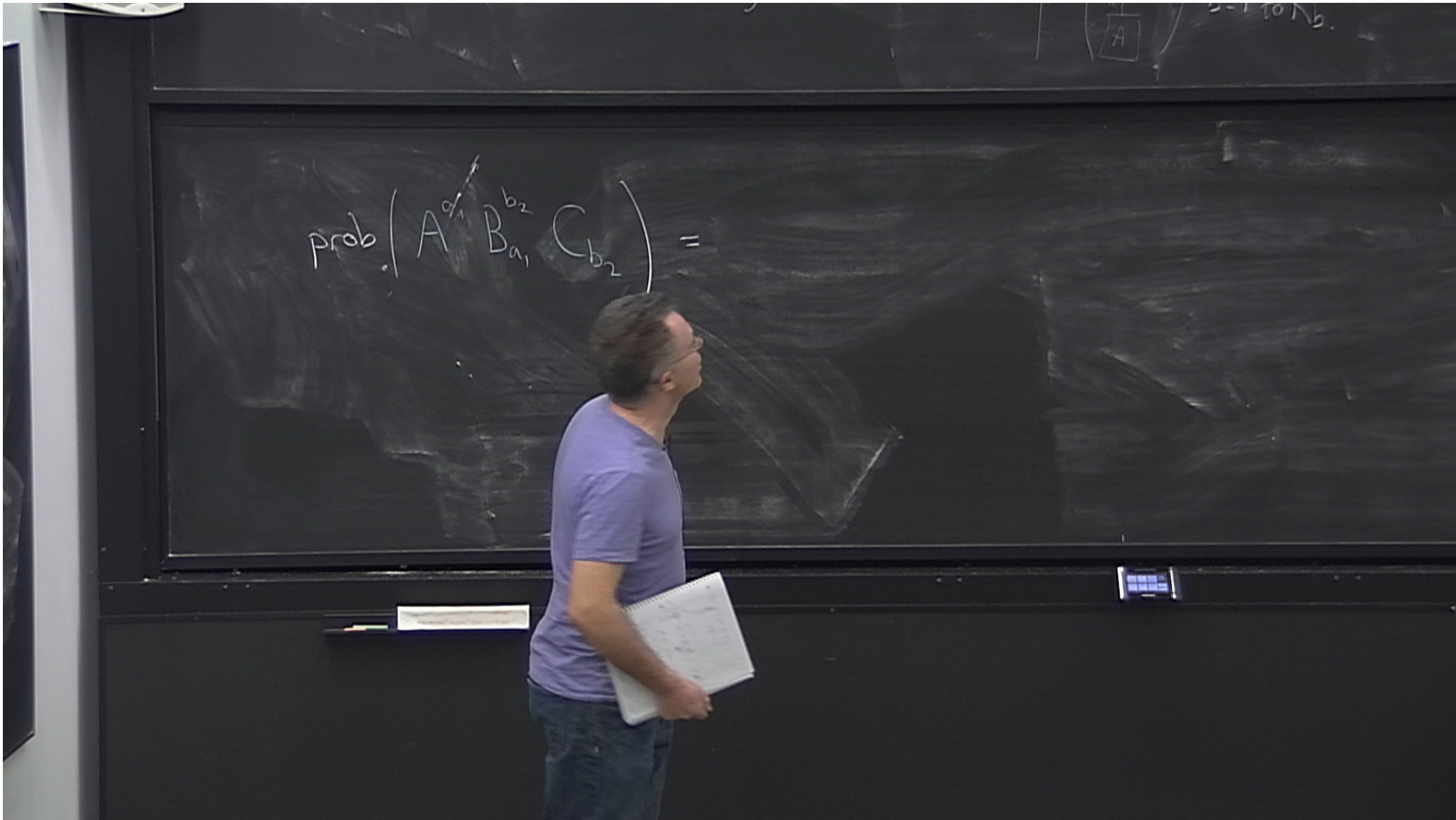
$\boxed{A} \xrightarrow{a} \boxed{B} \xrightarrow{b} \boxed{C}$

what is the state associated with

$\boxed{B} \xrightarrow{b} \boxed{A}$

state is $\text{prob}(A^{a_1} B_{a_1} \times \cancel{B_{b_2}})$

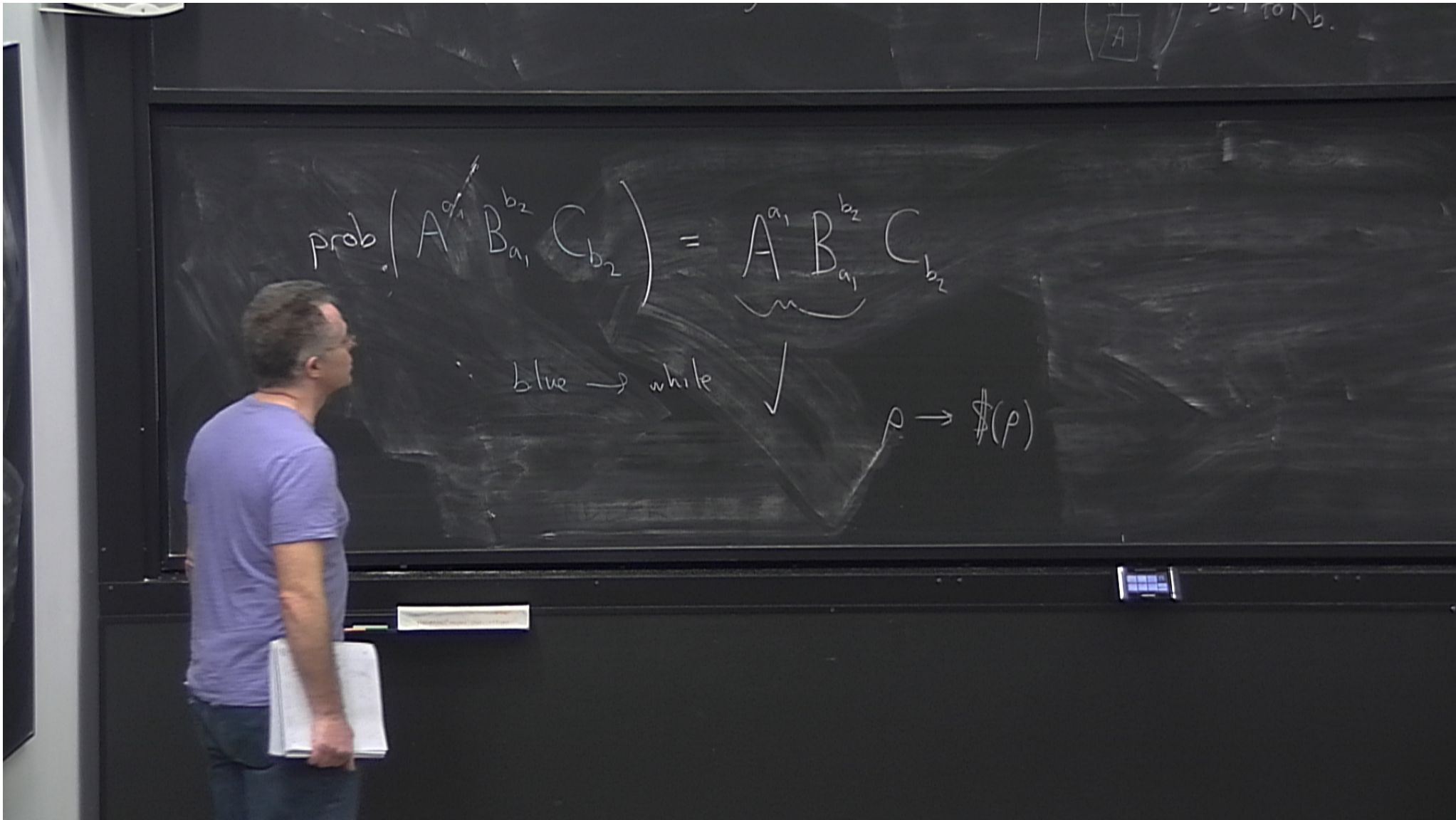


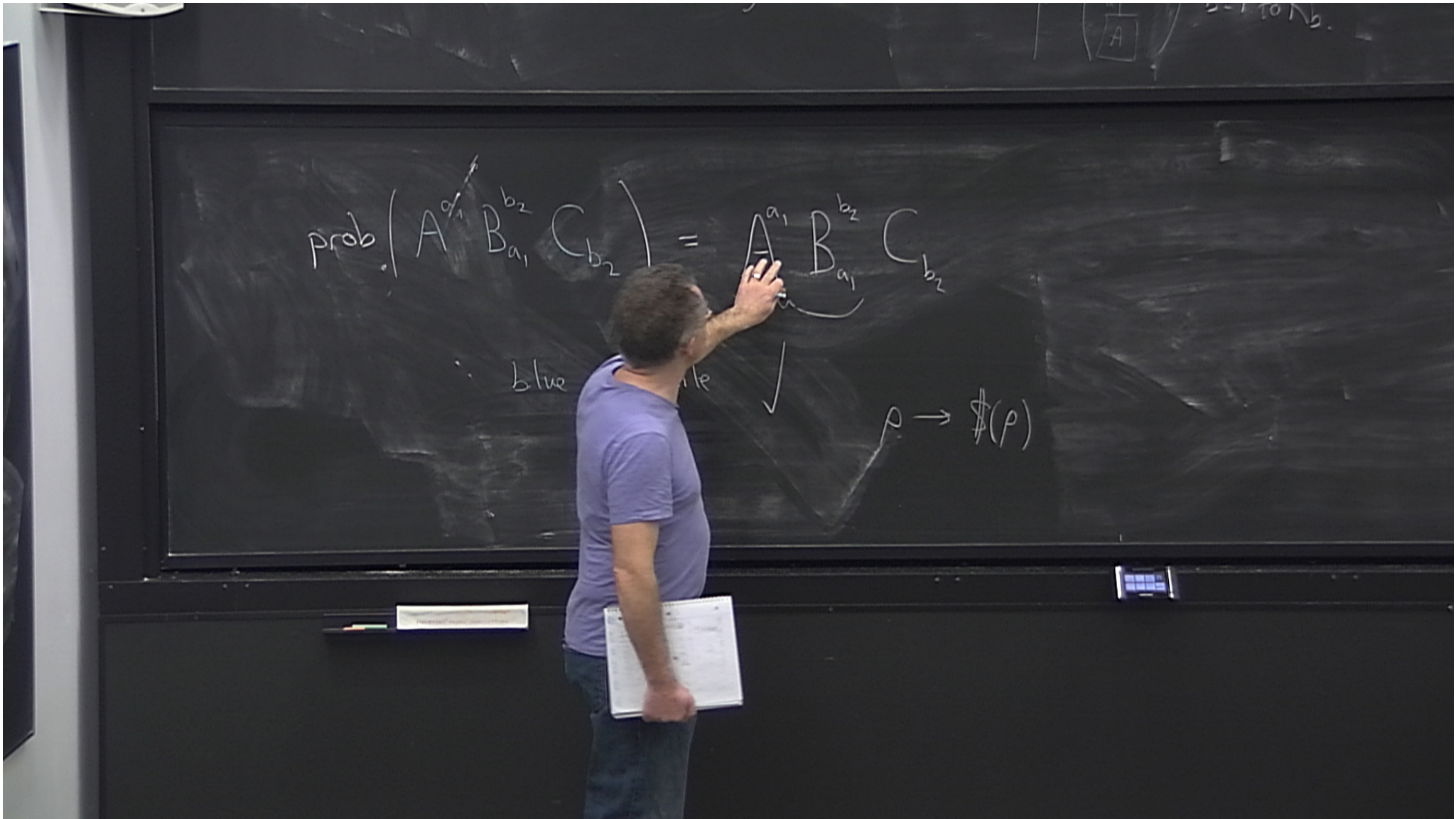


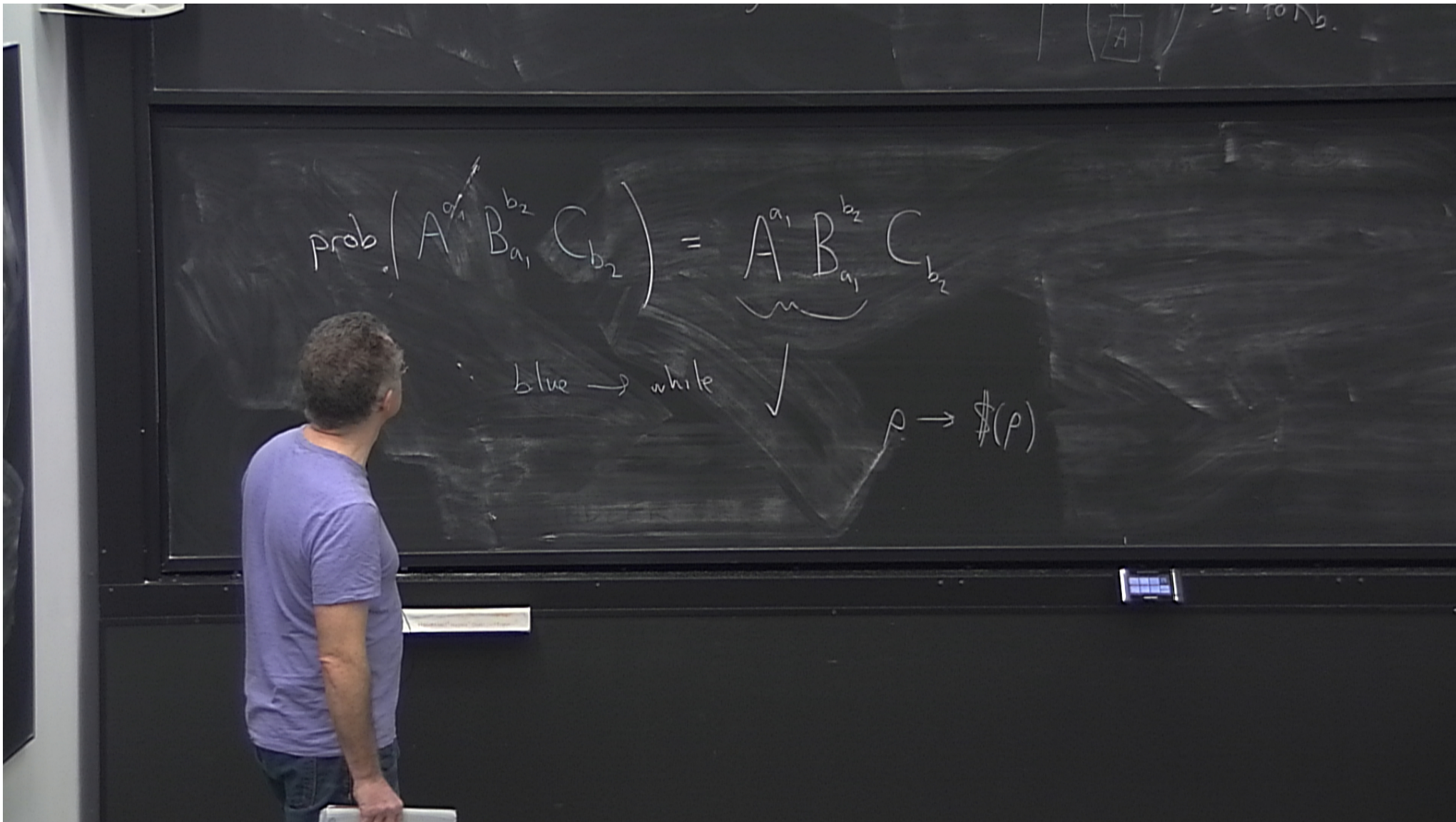
$$\text{prob.} \left(A_{a_1}^{b_2} B_{a_1} C_{b_2} \right) = \underbrace{A_{a_1} B_{a_1}}^{b_2} C_{b_2}$$

$$\text{prob.} \left(A_{a_1}^{b_2} B_{a_1} C_{b_2} \right) = \underbrace{A_{a_1} B_{a_1}}^{b_2} C_{b_2}$$

blue $\rightarrow$ white $\checkmark$







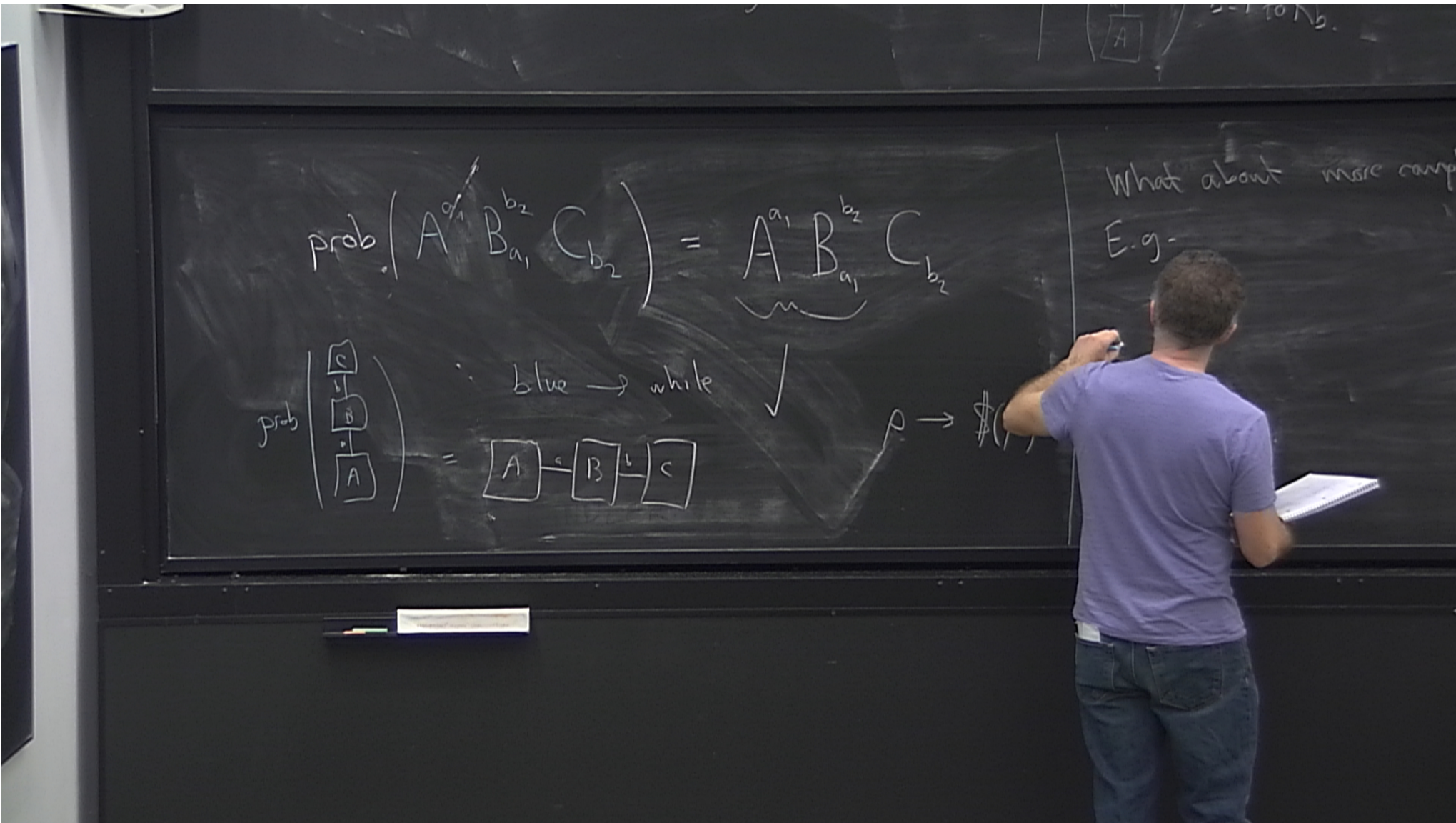
$$\text{prob} \left(A_{a_1}^{b_1} B_{a_1}^{b_2} C_{b_2} \right) = \underbrace{A_{a_1}^{b_1} B_{a_1}^{b_2}}_{\text{blue} \rightarrow \text{white}} C_{b_2}$$

$\rho \rightarrow \$(\rho)$

$$\text{prob} \left(A^{a_1} B^{b_2}_{a_1} C_{b_2} \right) = \underbrace{A^{a_1} B^{b_2}_{a_1}}_{\text{blue} \rightarrow \text{white}} C_{b_2}$$

$$\text{prob} \left(\begin{array}{c} \boxed{C} \\ \downarrow \\ \boxed{B} \\ \downarrow \\ \boxed{A} \end{array} \right) = \boxed{A} \text{---} \boxed{B} \text{---} \boxed{C}$$

$\rho \rightarrow \$(\rho)$



(A) 1 to N_b .

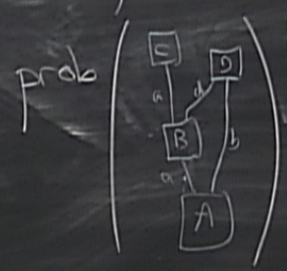
$A^{a_1} B^{b_2} C^{b_2}$
 $A_{a_1} B_{a_1}$

$\rho \rightarrow \$(\rho)$

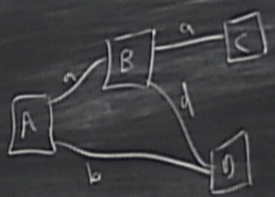
What about more complicated circuits?

E.g.

Can we say



=



$\text{prob}(A^{a_1 b_2} B^{a_2 d_1} C^{d_1 e_2})$

(A) 1 to Nb.

$A^{a_1} B^{b_2}_{a_1} C^{b_2}$

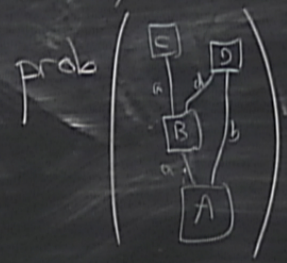
✓

$\rho \rightarrow \$(\rho)$

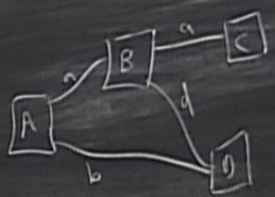
What about more complicated circuits?

E.g.

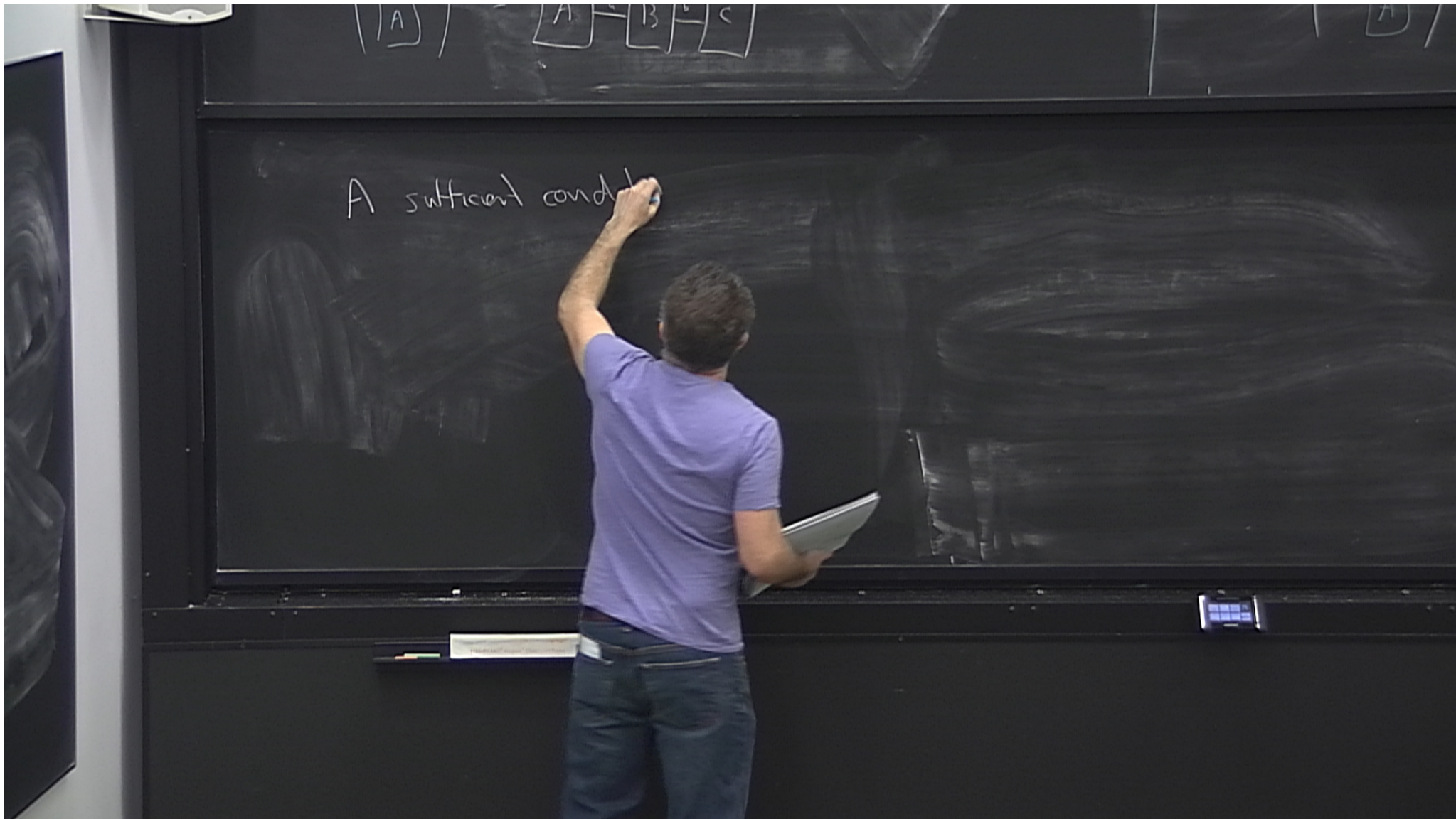
Can we say



=



$$\text{prob}(A^{a_1 b_2} B^{a_3 d_1}_{a_1} C^{a_3} D^{d_1 b_2}_{d_1}) = A^{a_1 b_2} B^{a_3 d_1}_{a_1} C^{a_3} D^{d_1 b_2}_{d_1}$$



$|A\rangle$ $A \rightarrow B \rightarrow C$ $|A\rangle$

A sufficient condition for this is
tomographic locality

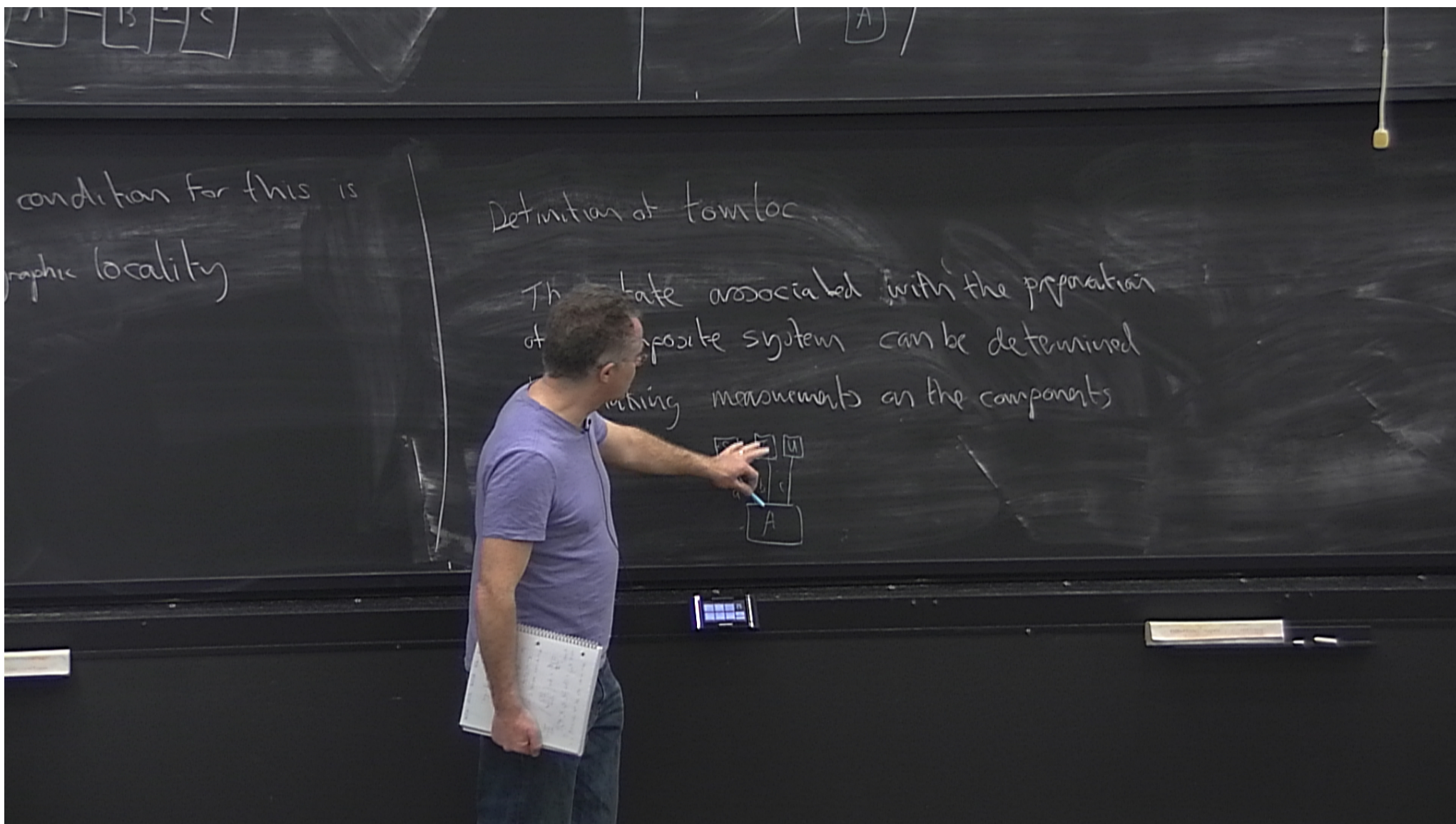
Definition of tomloc.

$|A\rangle$ $|A\rangle|B\rangle|C\rangle$ $|A\rangle$

A sufficient condition for this is
tomographic locality

Definition of tomoloc.

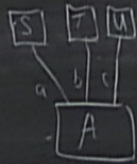
The state associated with the preparation
of a composite system



15

Definition of tomloc.

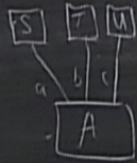
The state associated with the preparation of a composite system can be determined by making measurements on the components



15

Definition of tomloc.

The state associated with the preparation of a composite system can be determined by making measurements on the components



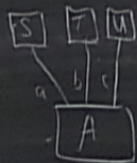
because of linearity this means

state =

15

Definition of tomloc.

The state associated with the preparation of a composite system can be determined by making measurements on the components

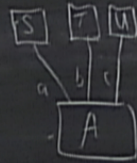


because of linearity this means

$$\text{state} = \text{prob} \left(\begin{array}{c} \uparrow \\ \uparrow \\ \uparrow \\ \boxed{A} \end{array} \right)$$

15
Definition of tomloc.

The state associated with the preparation of a composite system can be determined by making measurements on the components

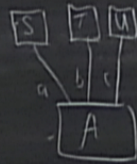


because of linearity this means

$$\text{state} = \text{prob} \left| \begin{array}{c} \uparrow \\ \uparrow \\ \uparrow \\ \uparrow \end{array} \right\rangle = A_{a,b,c}$$

15
Definition of tomloc.

The state associated with the preparation of a composite system can be determined by making measurements on the components



because of linearity this means

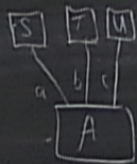
$$\text{state} = \text{prob} \left(\begin{array}{c} \uparrow \\ \uparrow \\ \uparrow \\ \boxed{A} \end{array} \right) = A^{a,b,c}$$

$K_a K_b K_c$

15

Definition of tomloc.

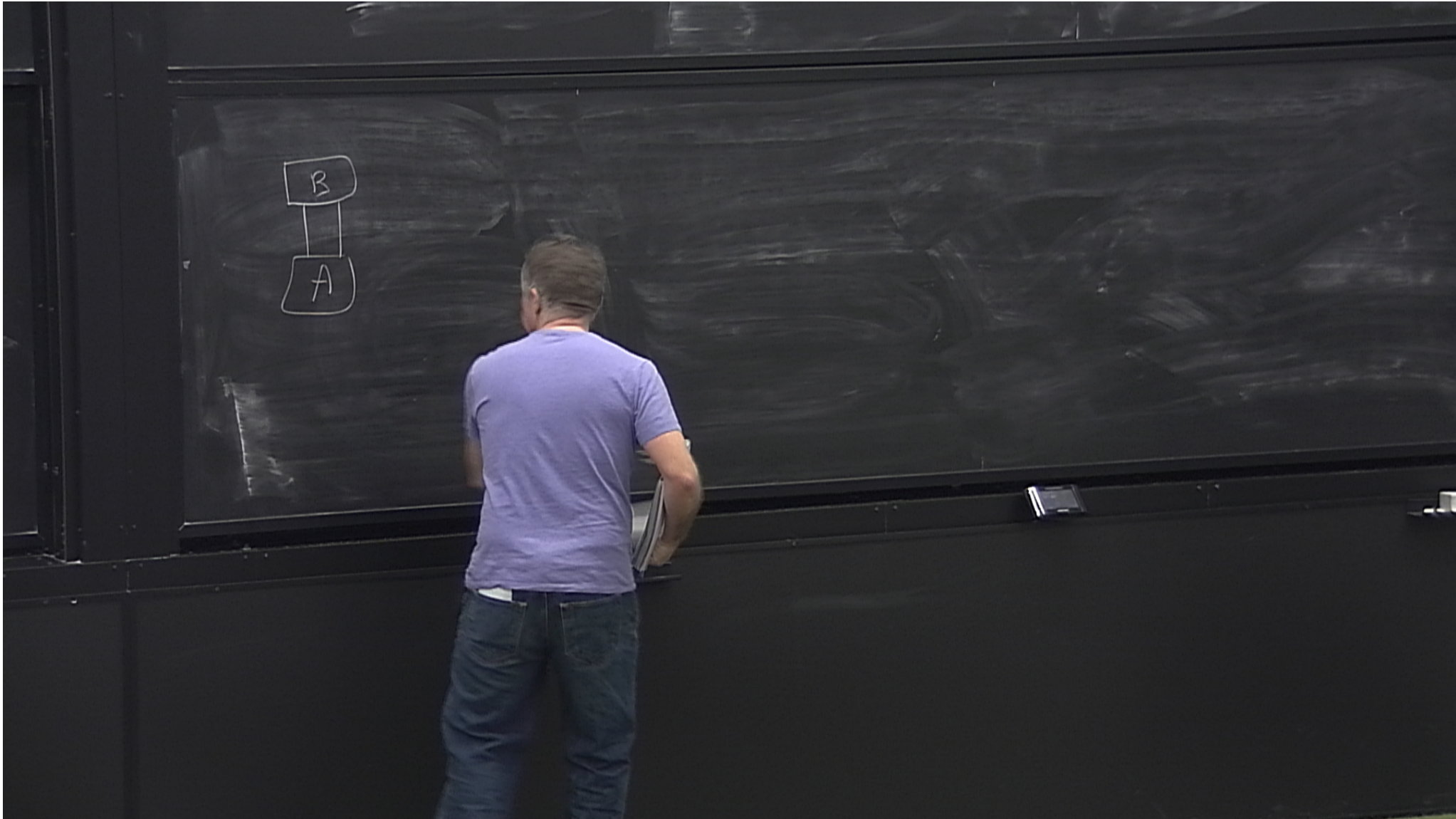
The state associated with the preparation of a composite system can be determined by making measurements on the components

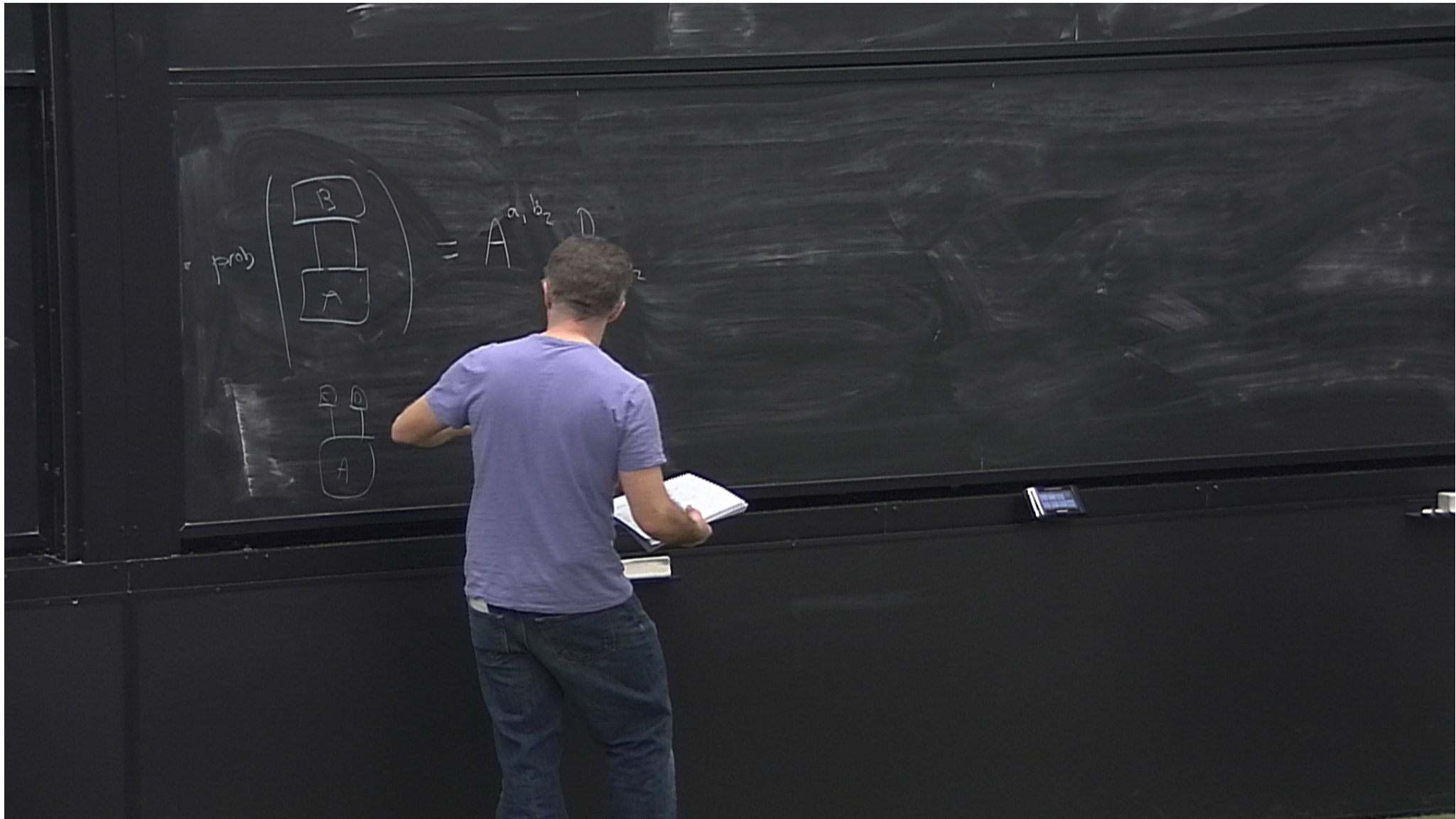


because of linearity this means

$$\text{state} = \text{prob} \left(\begin{array}{c} \uparrow \\ \uparrow \\ \uparrow \\ \boxed{A} \end{array} \begin{array}{c} a \\ b \\ c \end{array} \right) = A^{a,b,c}$$

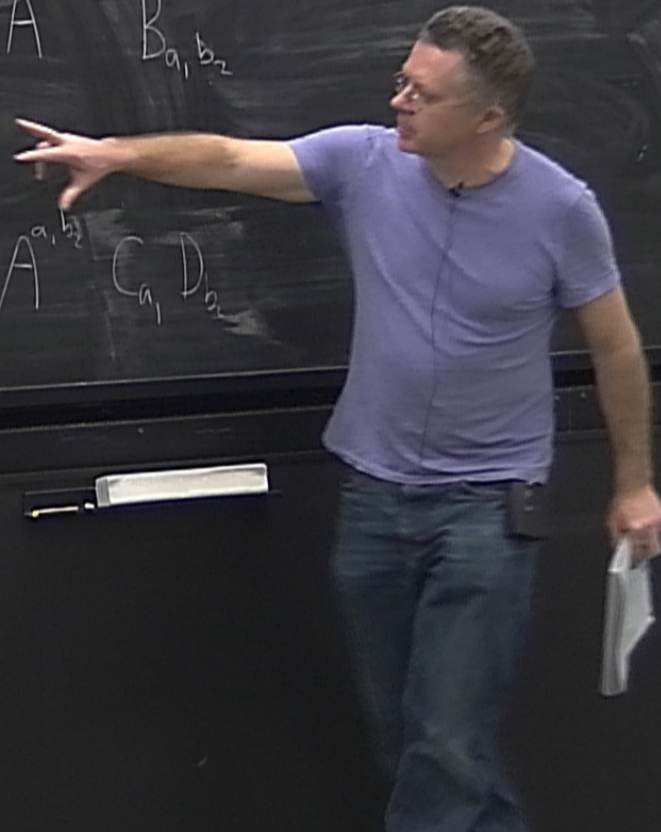
$K_a K_b K_c$

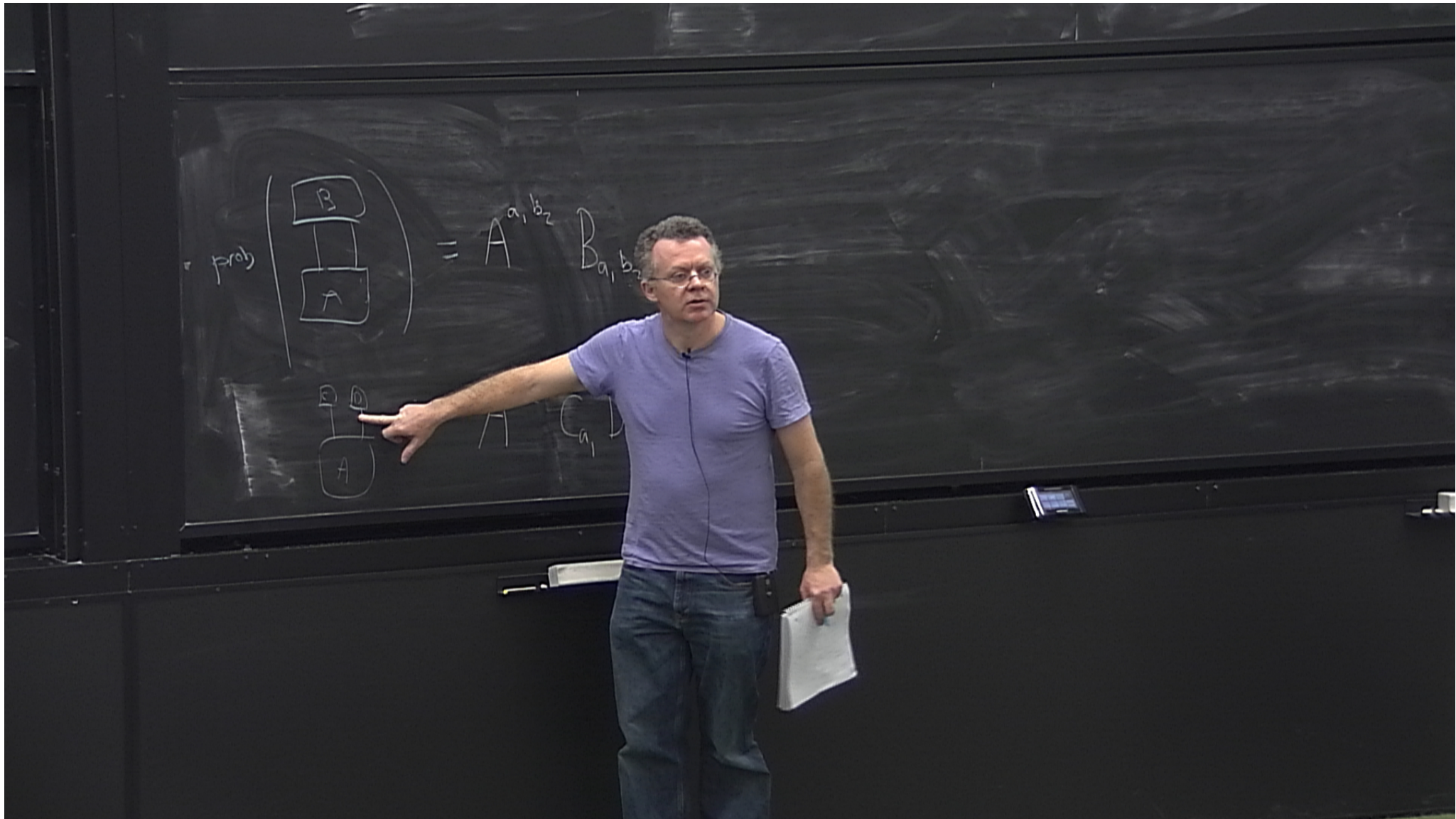




$$\text{prob} \left(\begin{array}{c} \boxed{B} \\ \boxed{A} \end{array} \right) = A_{a_1 b_2} B_{a_1 b_2}$$

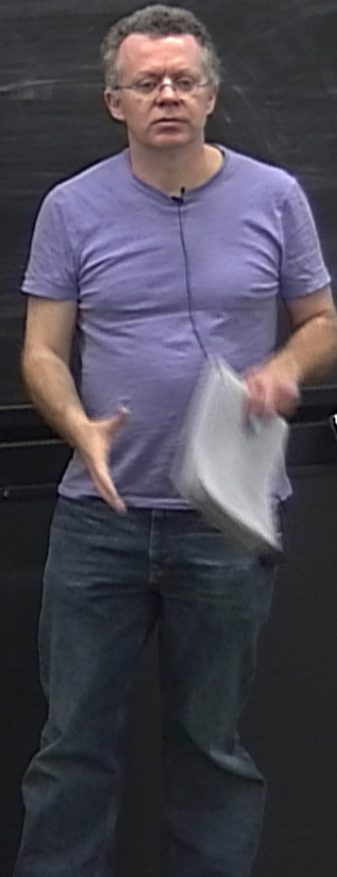
$$\begin{array}{c} \boxed{B} \quad \boxed{D} \\ | \quad | \\ \boxed{A} \end{array} \quad A_{a_1 b_2} C_{a_1 D_{b_2}}$$

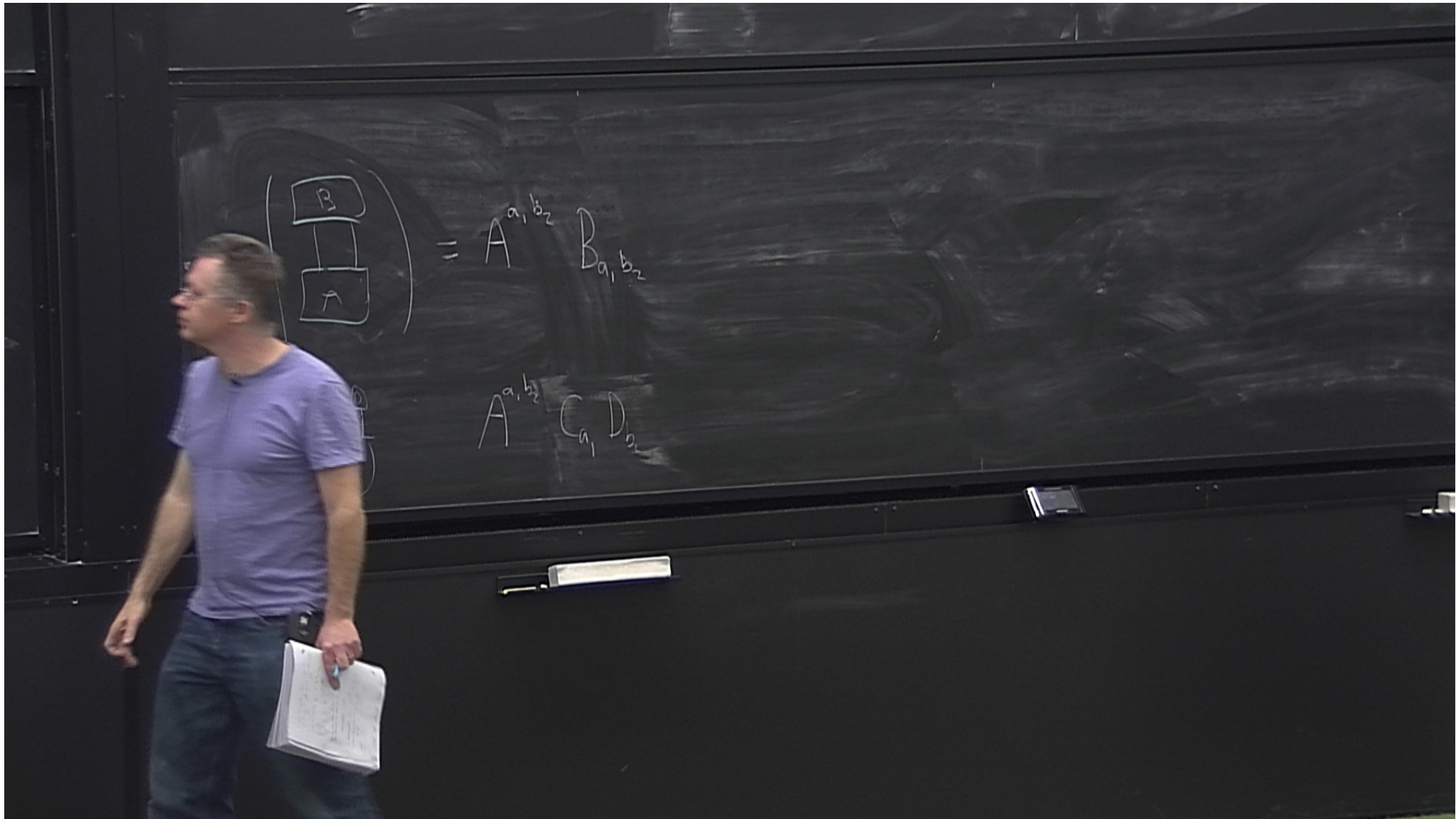




$$\text{prob} \left(\begin{array}{c} B \\ A \end{array} \right) = A^{a_1 b_2} B_{a_1 b_2}$$

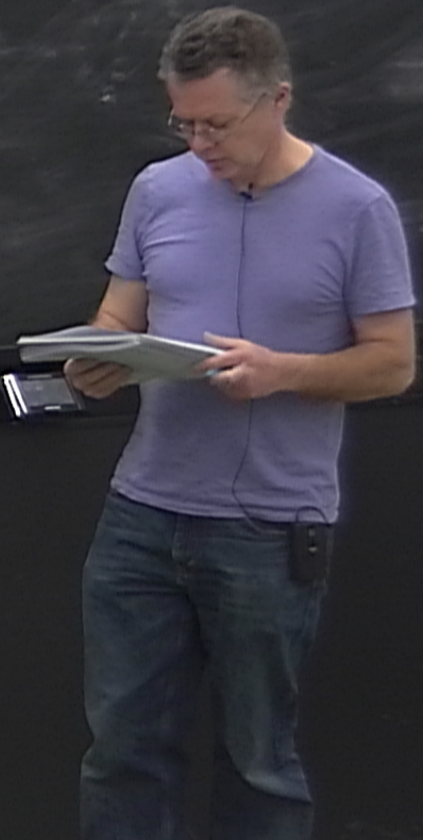
$$\begin{array}{c} E \quad D \\ | \quad | \\ A \end{array} \quad A^{a_1 b_2} C_{a_1} D_{b_2}$$

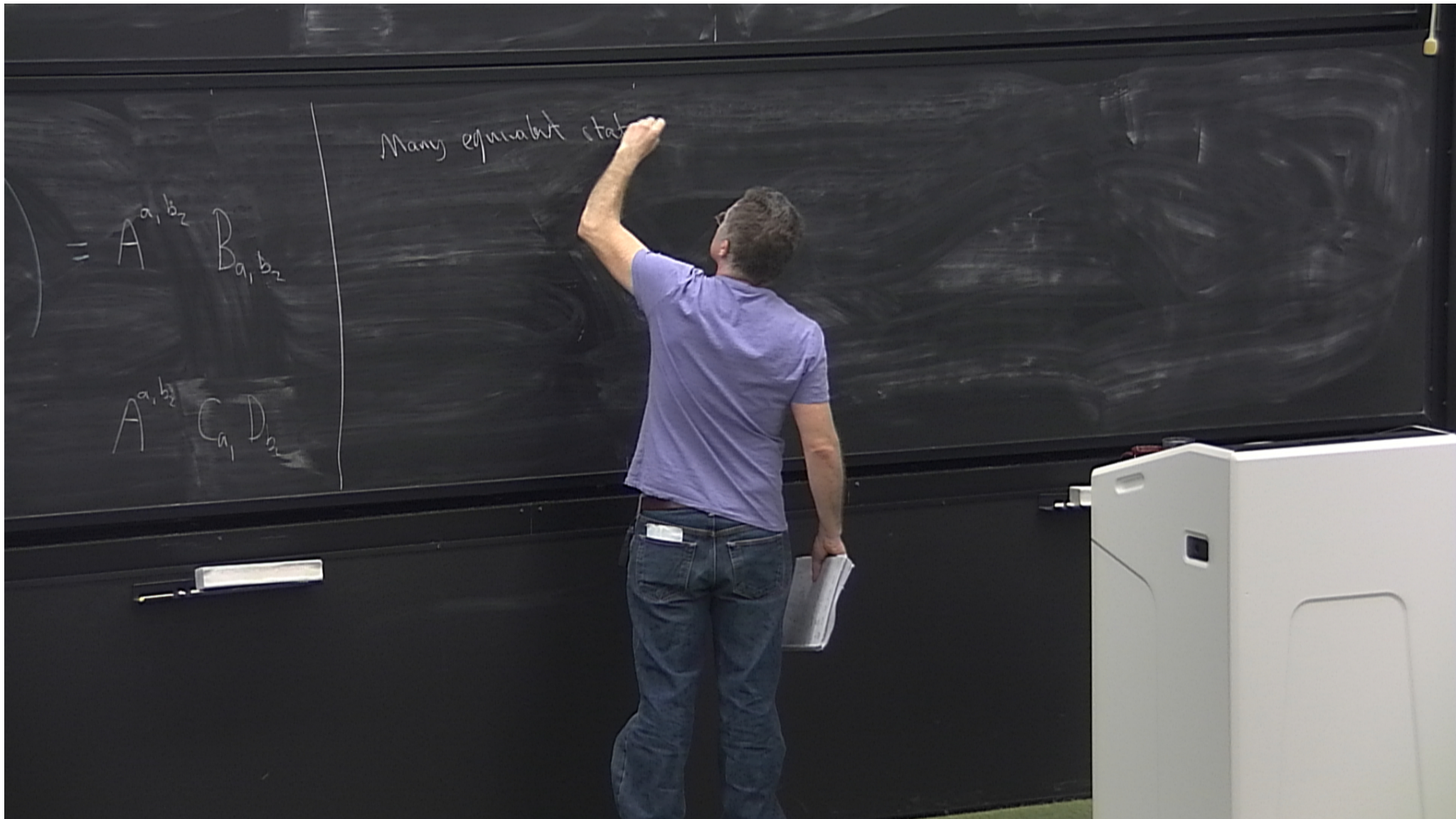


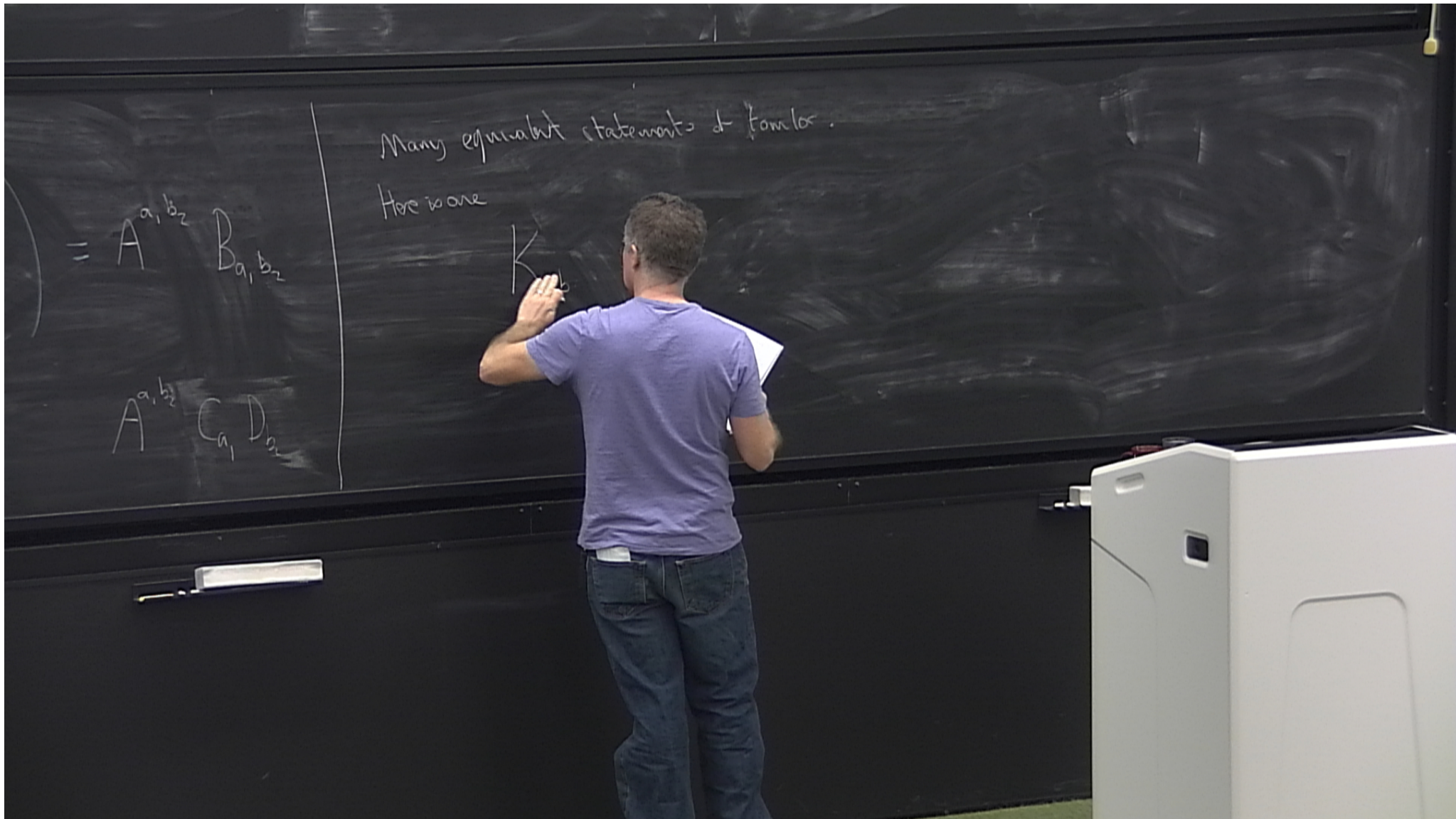


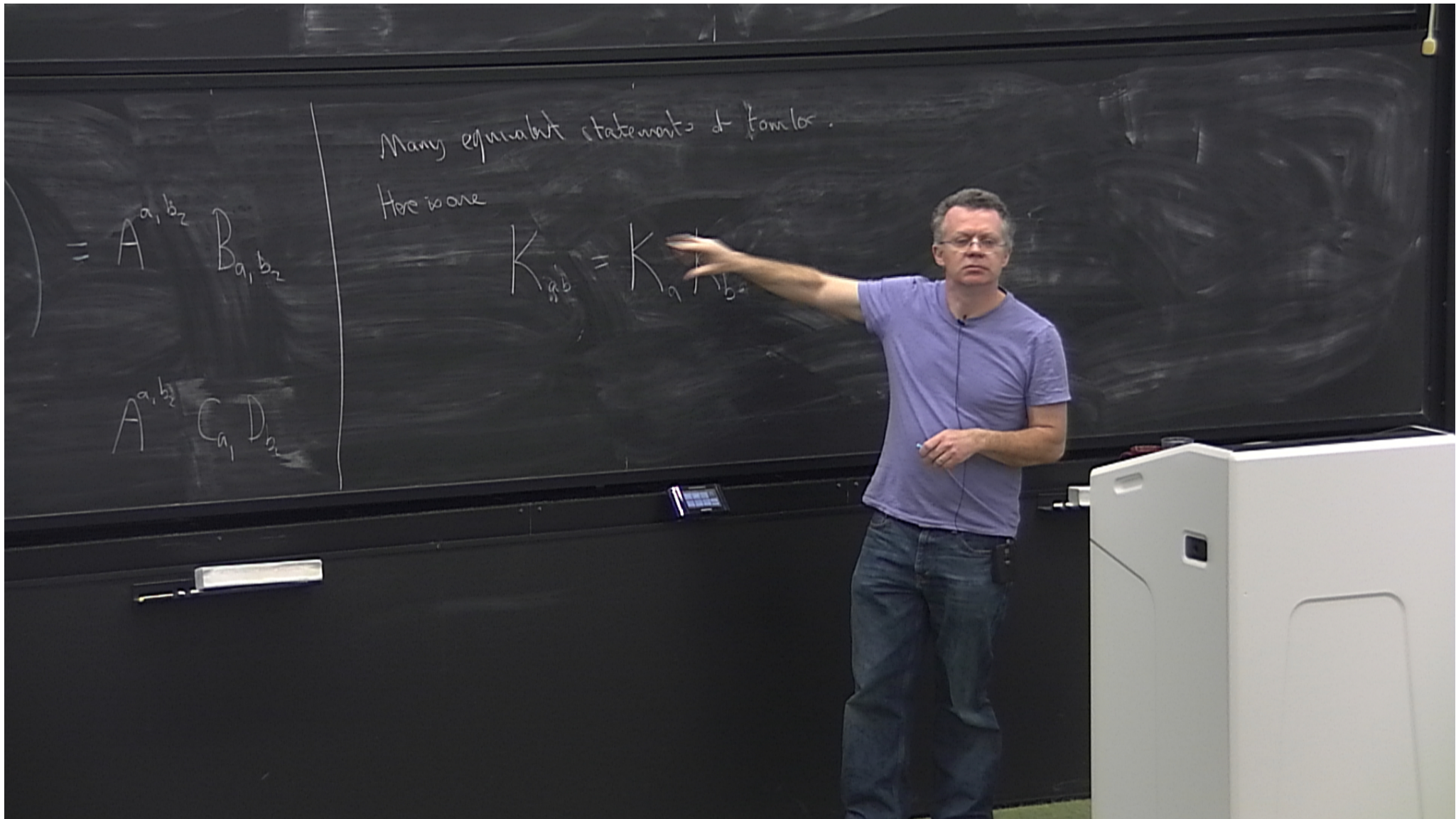
$$\text{prob} \left(\begin{array}{|c|} \hline B \\ \hline A \\ \hline \end{array} \right) = A^{a_1 b_2} B_{a_1 b_2}$$

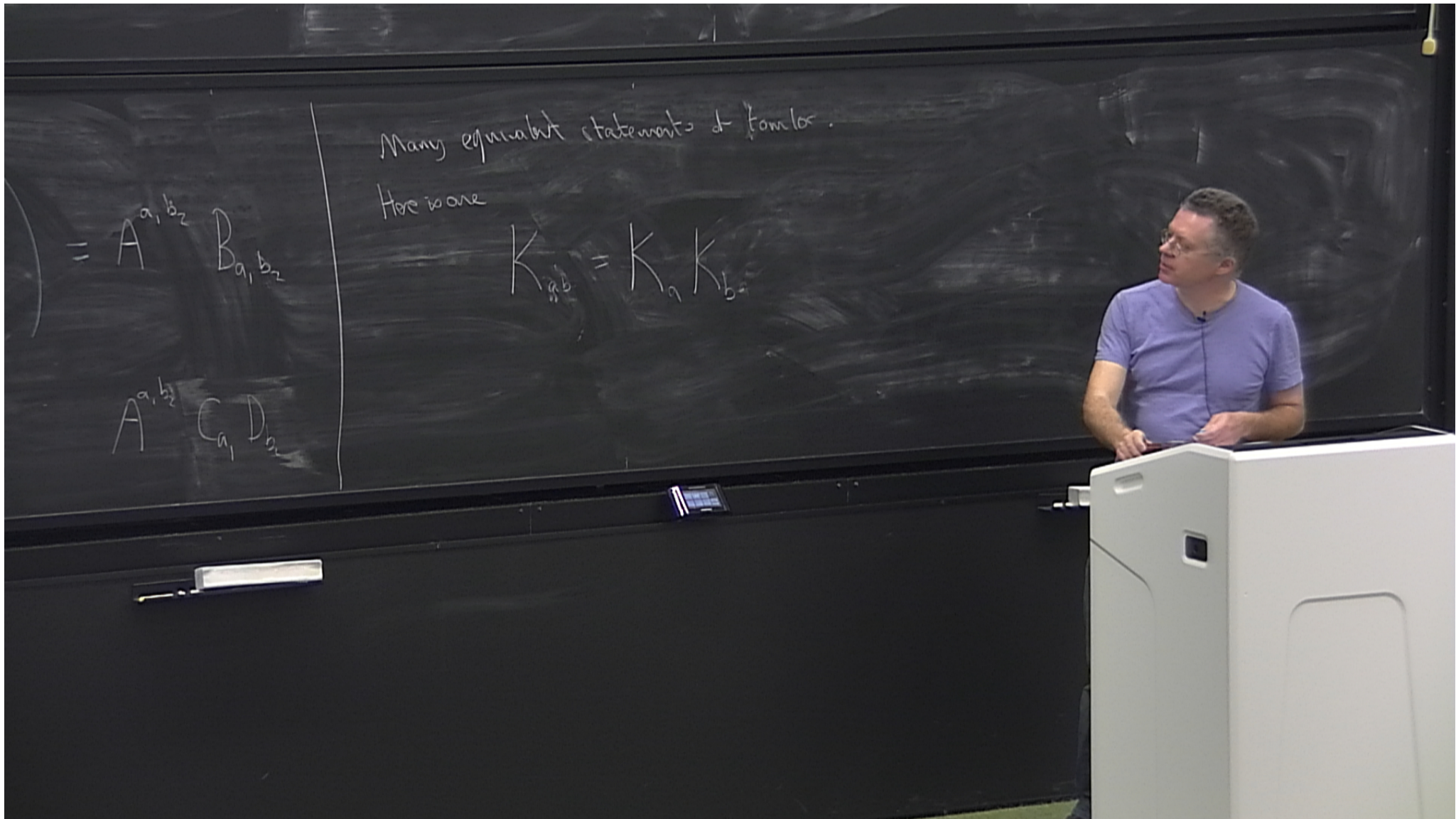
$$\begin{array}{|c|c|} \hline E & D \\ \hline \end{array} \quad A^{a_1 b_2} C_{a_1} D_{b_2}$$

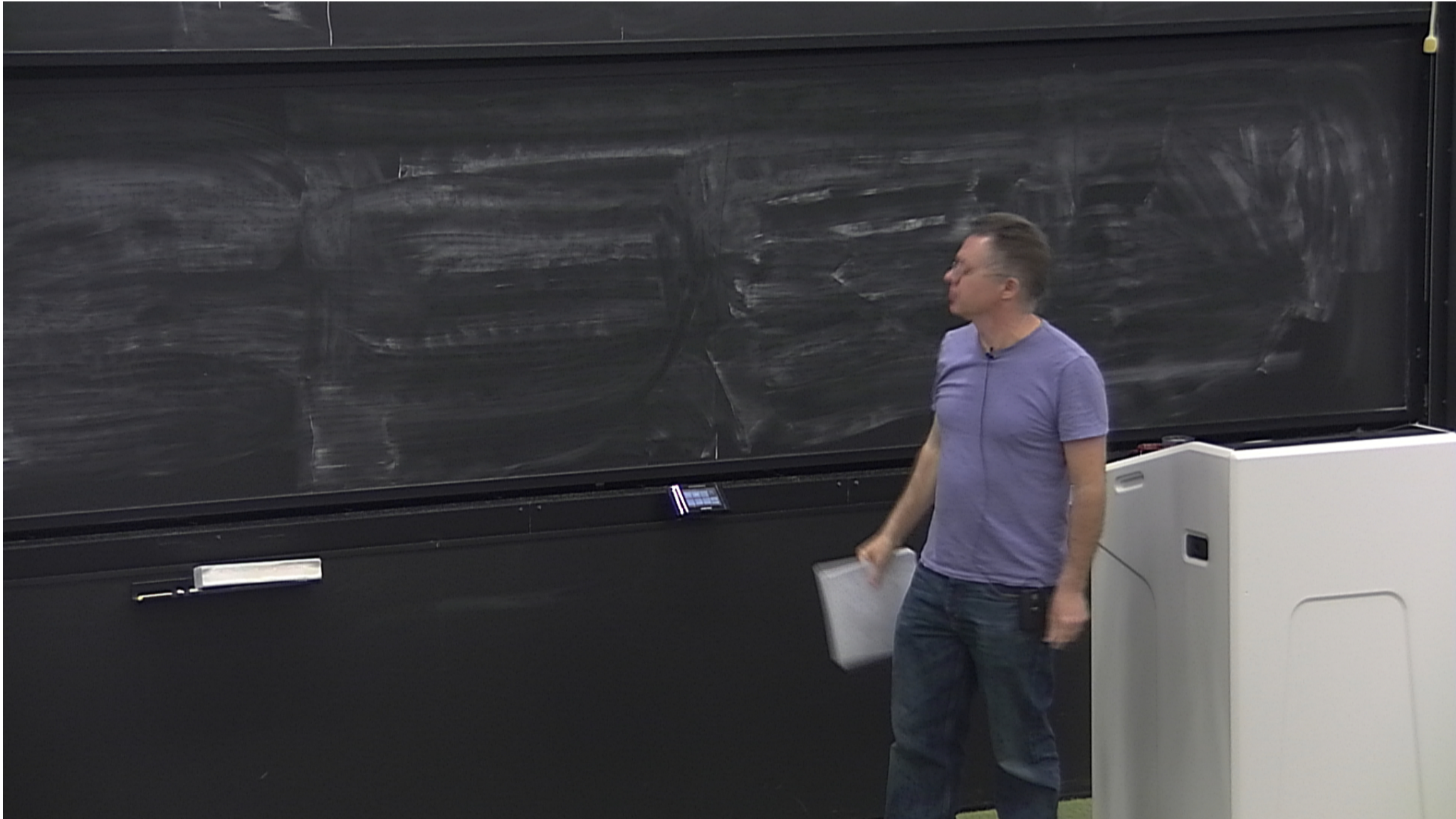


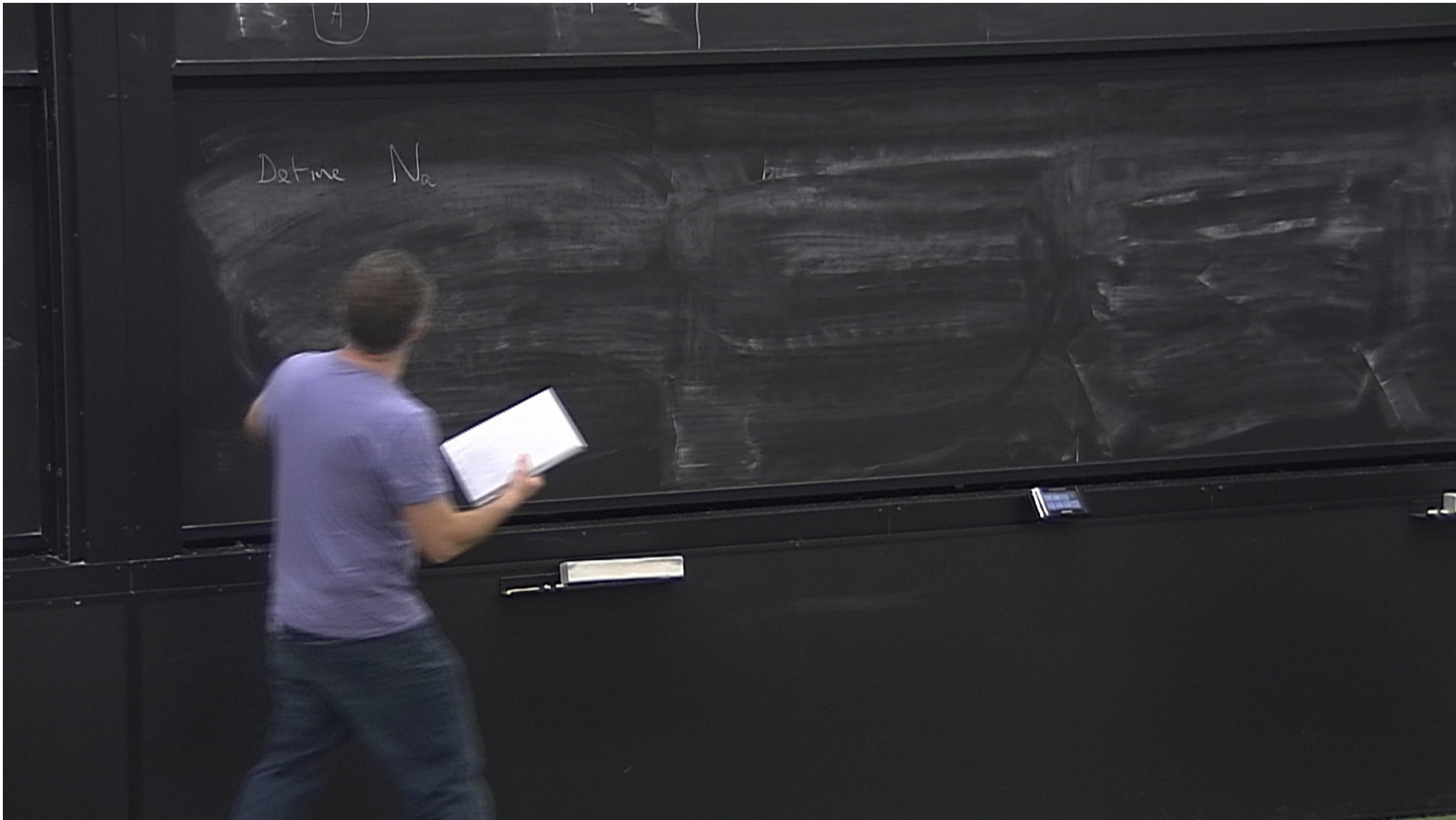


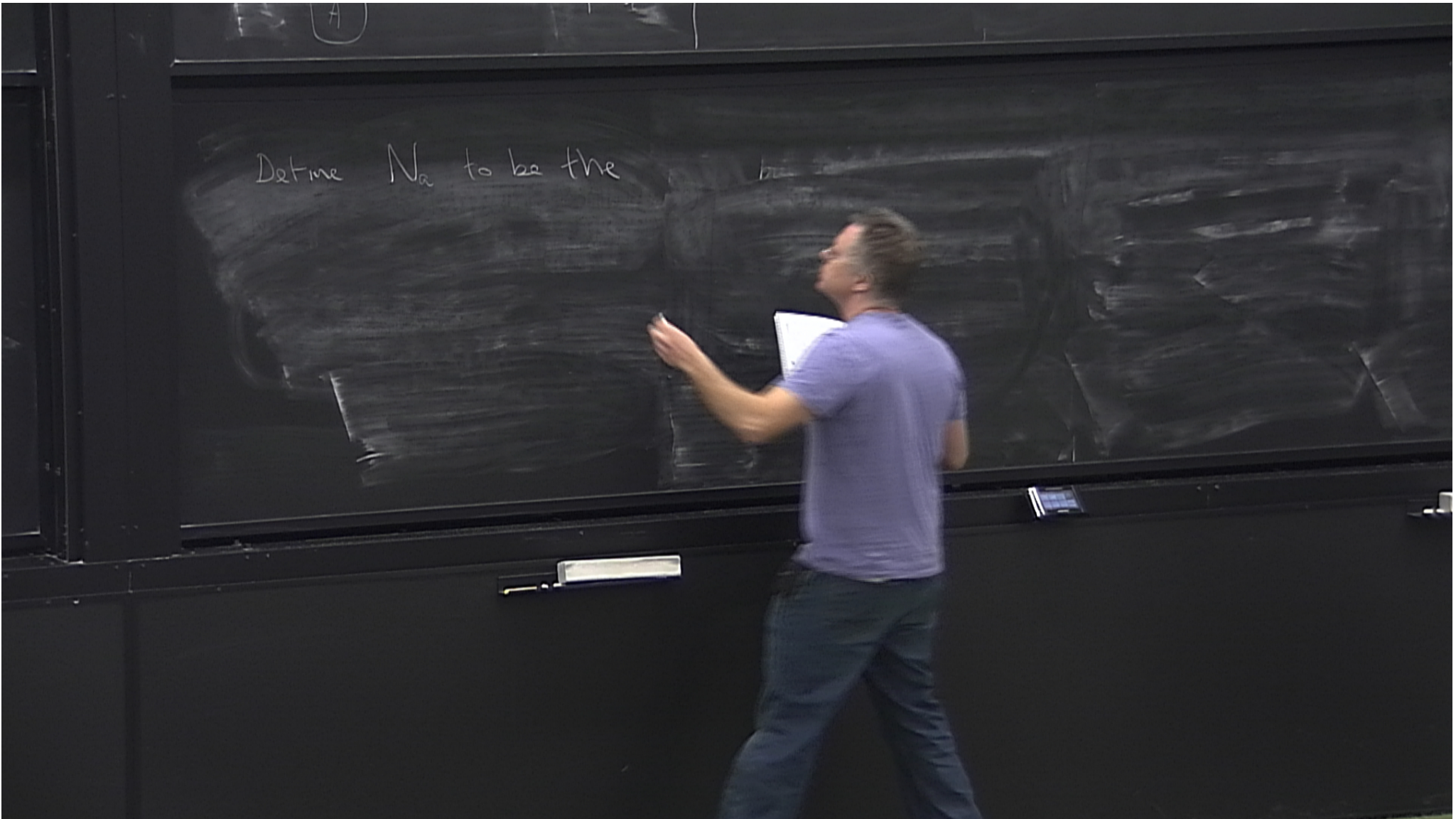












Define N_a to be the maximum number of preparations that
can be perfectly distinguished in a single run, for

Define N_a to be the maximum number of preparations that
can be perfectly distinguished in a single run for a system of type a .

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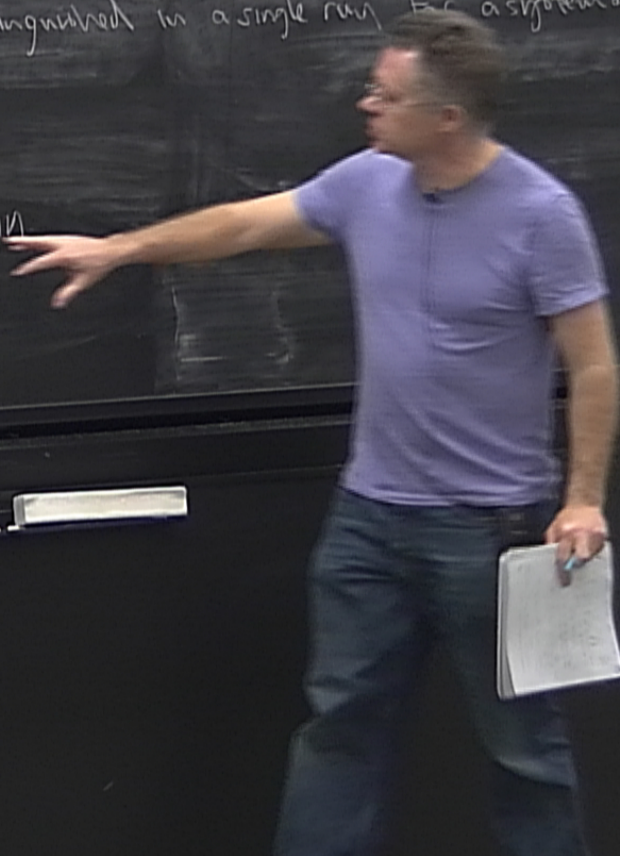


Define N_a to be the maximum number of preparations that
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Define N_a to be the maximum number of preparations that
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$$\text{prob} \left(\begin{array}{c} \boxed{B|A} \\ \downarrow \\ \boxed{A|A} \end{array} \right) = \int_{mn}$$



Define N_a to be the maximum number of preparations that
can be perfectly distinguished in a single run for a system of type a .

$$\text{prob} \left(\begin{array}{c} \boxed{B|a} \\ \downarrow \\ \boxed{A|a} \end{array} \right) = \sum_{mn}$$

Define N_a to be the maximum number of preparations that
can be perfectly distinguished in a single run for a system of type a .

$$\text{prob} \left(\begin{array}{c} \boxed{B|n} \\ \downarrow \\ \boxed{A|m} \end{array} \right) = \sum_{mn}$$

to be the maximum number of preparations that
can be distinguished in a single run for a system of type a .

$$= \sum_{mn}$$

Let us assume
information locality,

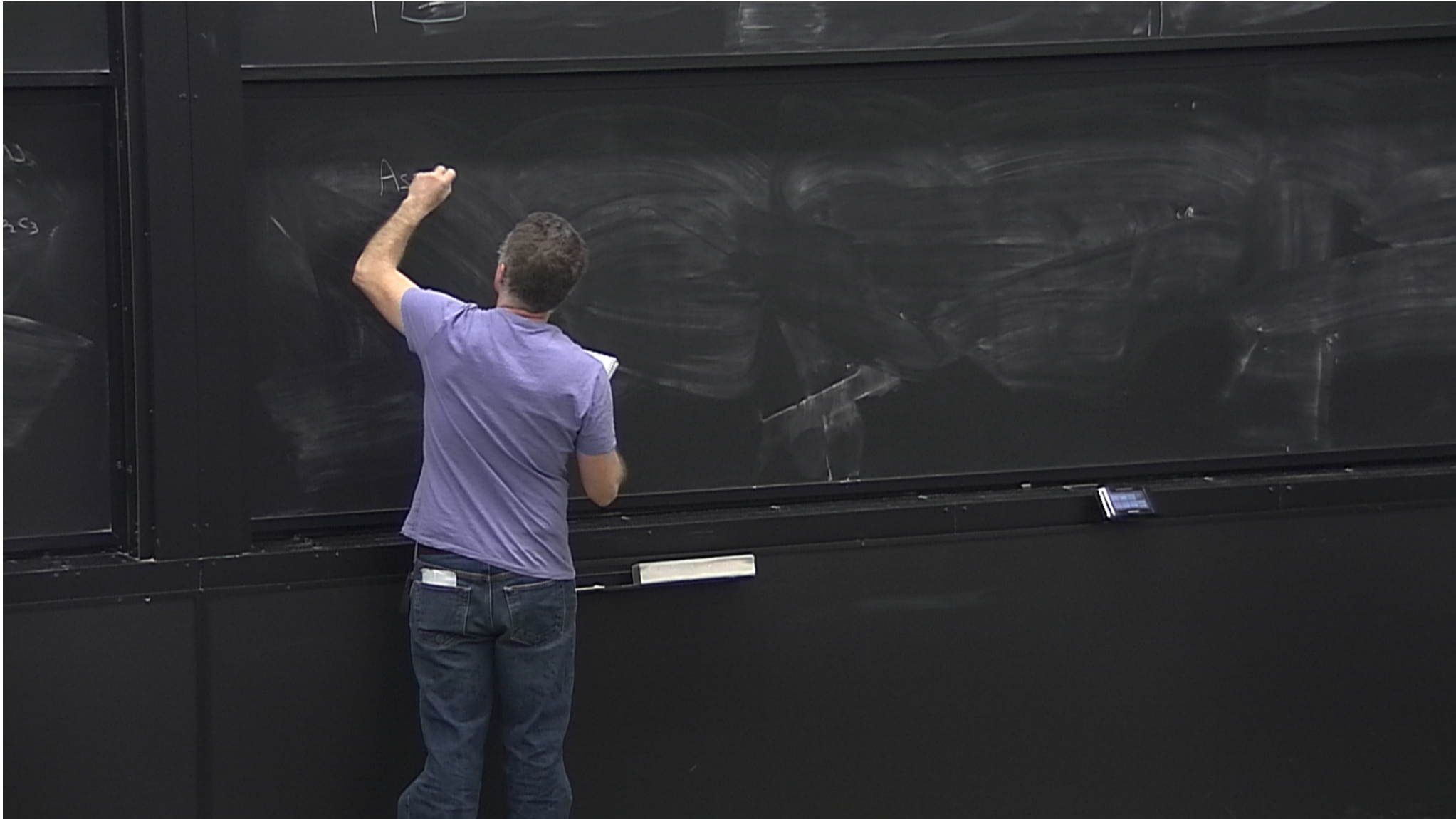
$$N_{ab} = N_a N_b$$

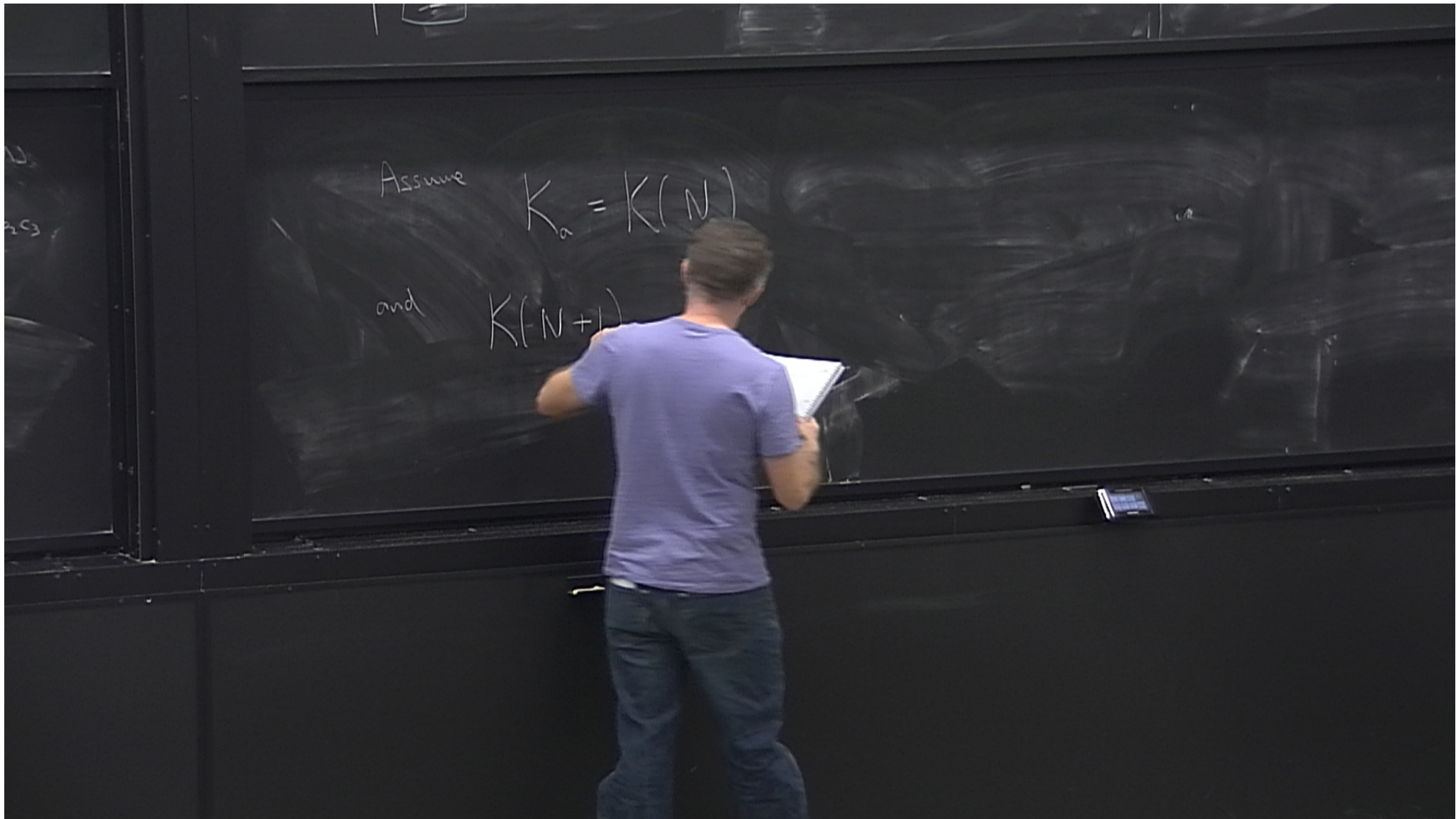
to be the maximum number of preparations that
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$$= \sum_{mn}$$

Let us assume
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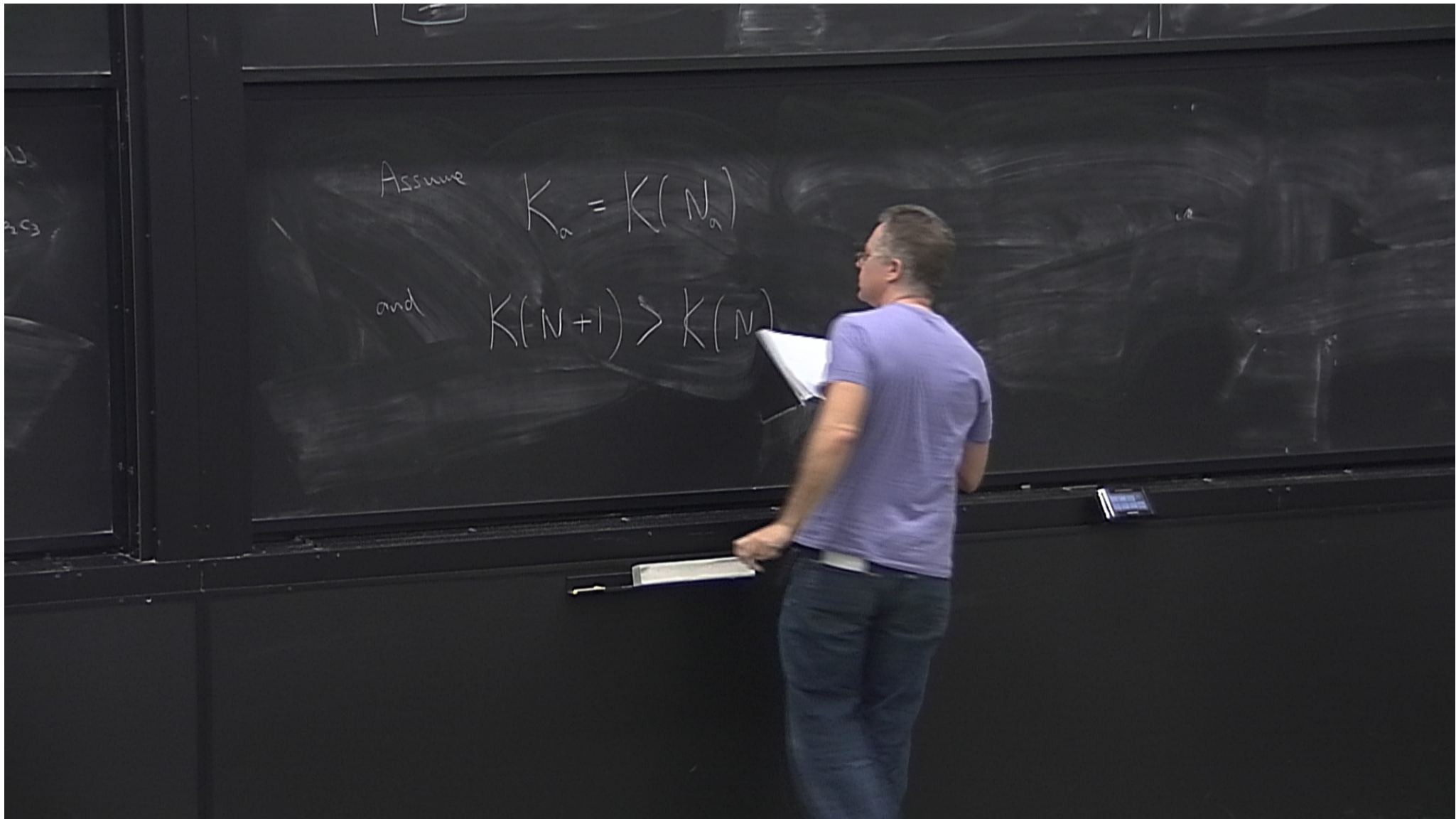
$$N_{ab} = N_a N_b$$





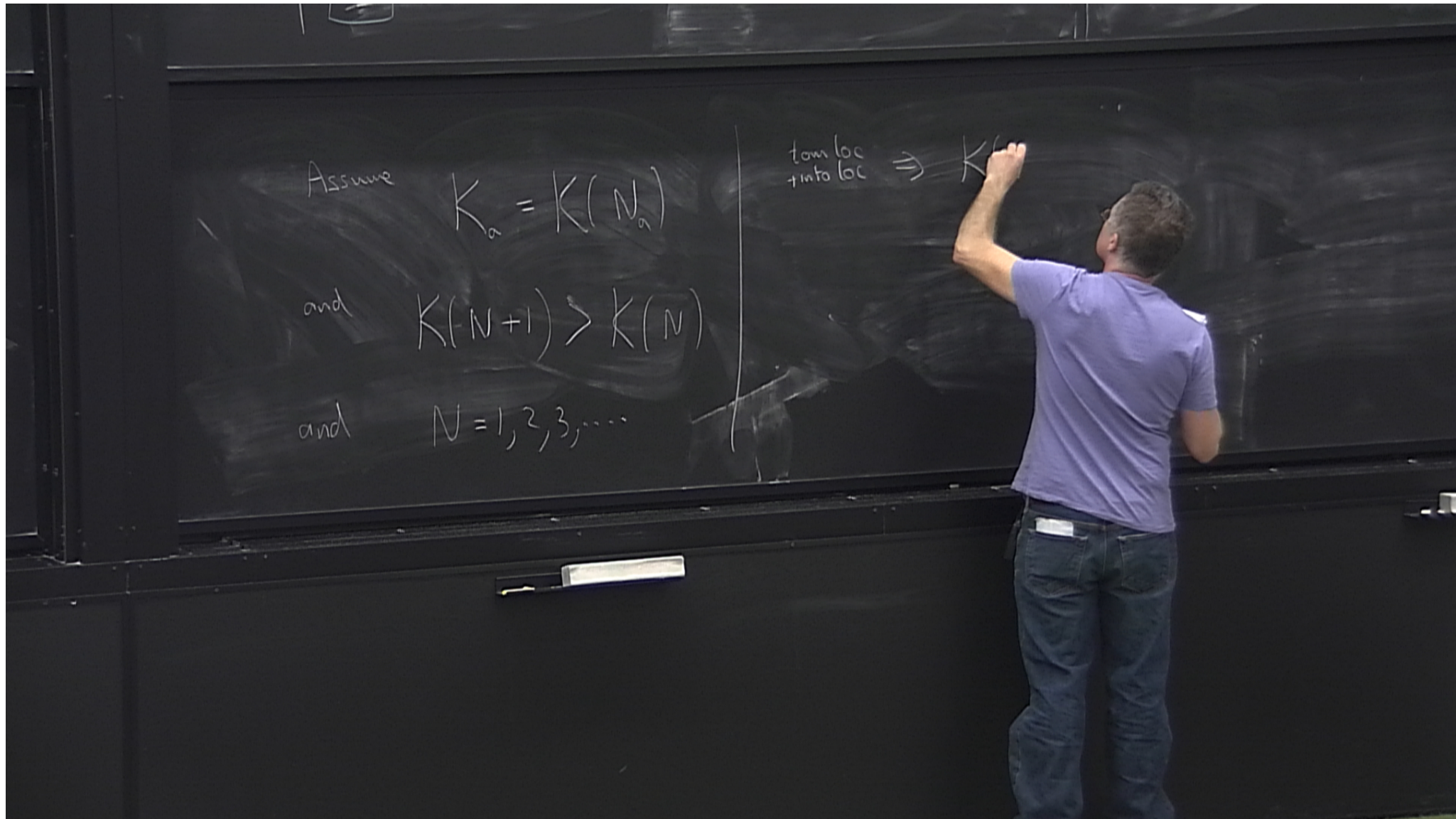
Assume $K_a = K(N)$

and $K(N+1)$



Assume $K_a = K(N_a)$

and $K(N+1) > K(N)$



Assume $K_a = K(N_a)$

and $K(N+1) > K(N)$

and $N = 1, 2, 3, \dots$

low loc
+ into loc $\Rightarrow K(N_a N_b) = K(N_a) K(N_b)$

Assume $K_a = K(N_a)$

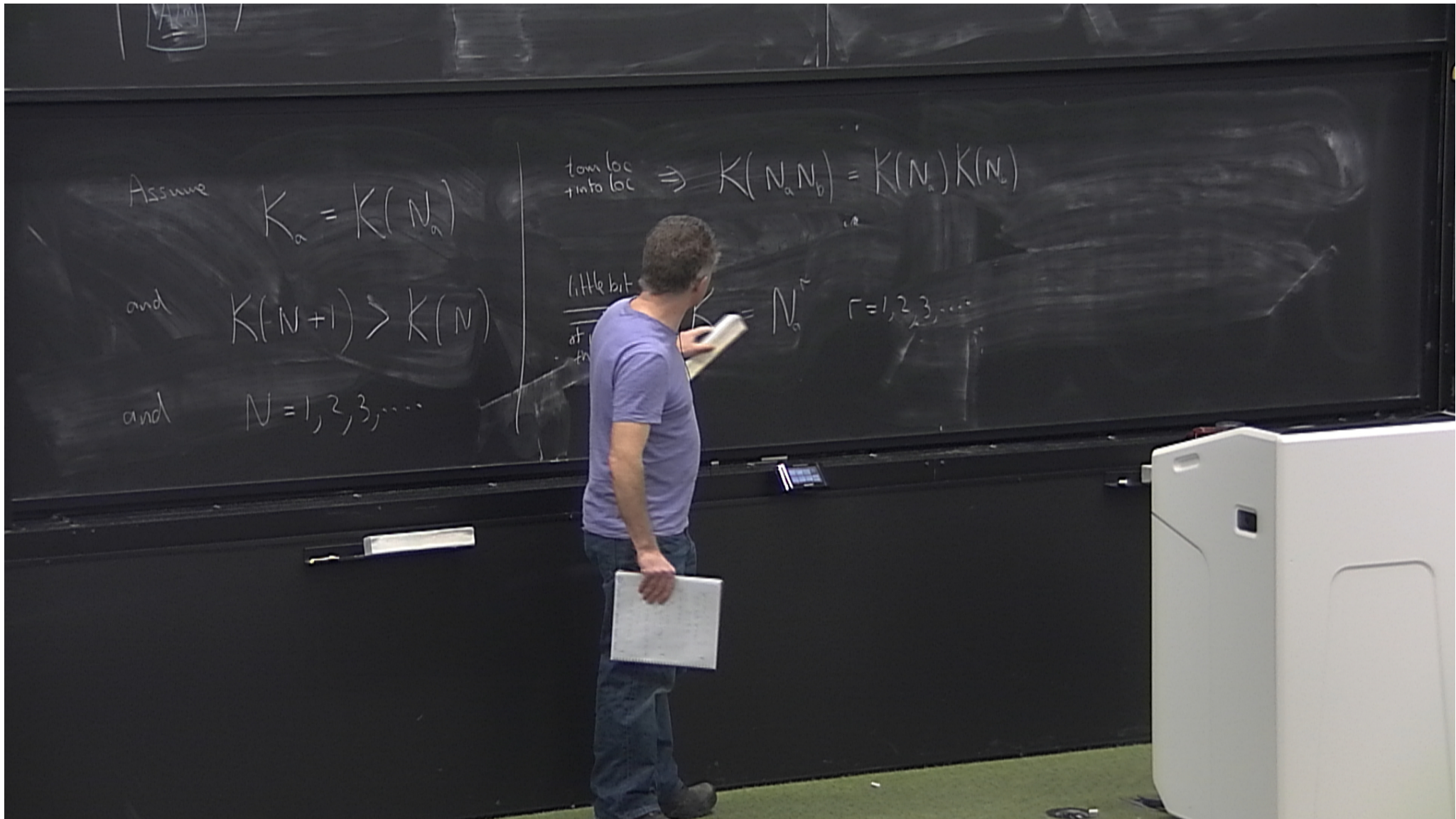
and $K(N+1) > K(N)$

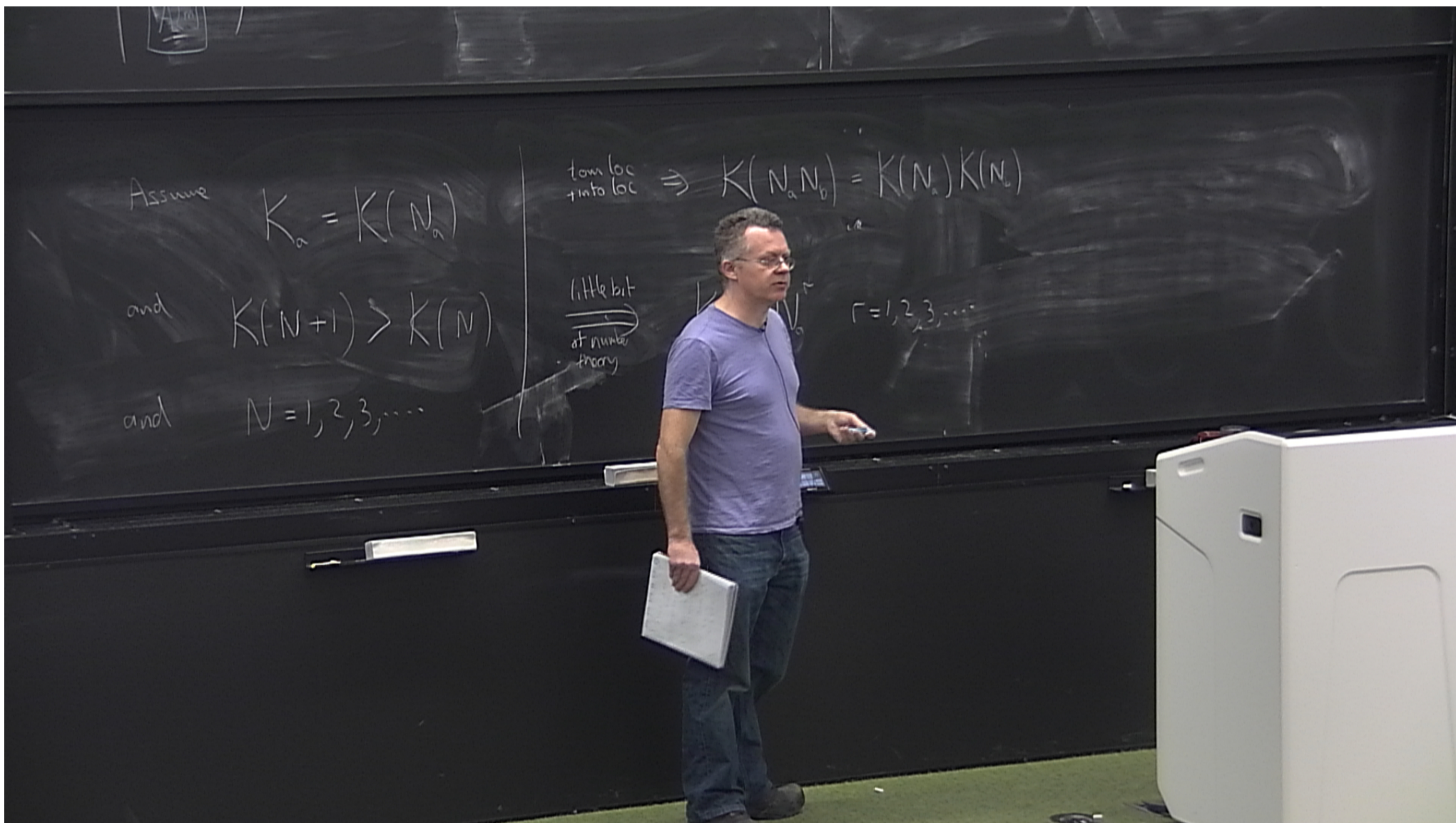
and $N = 1, 2, 3, \dots$

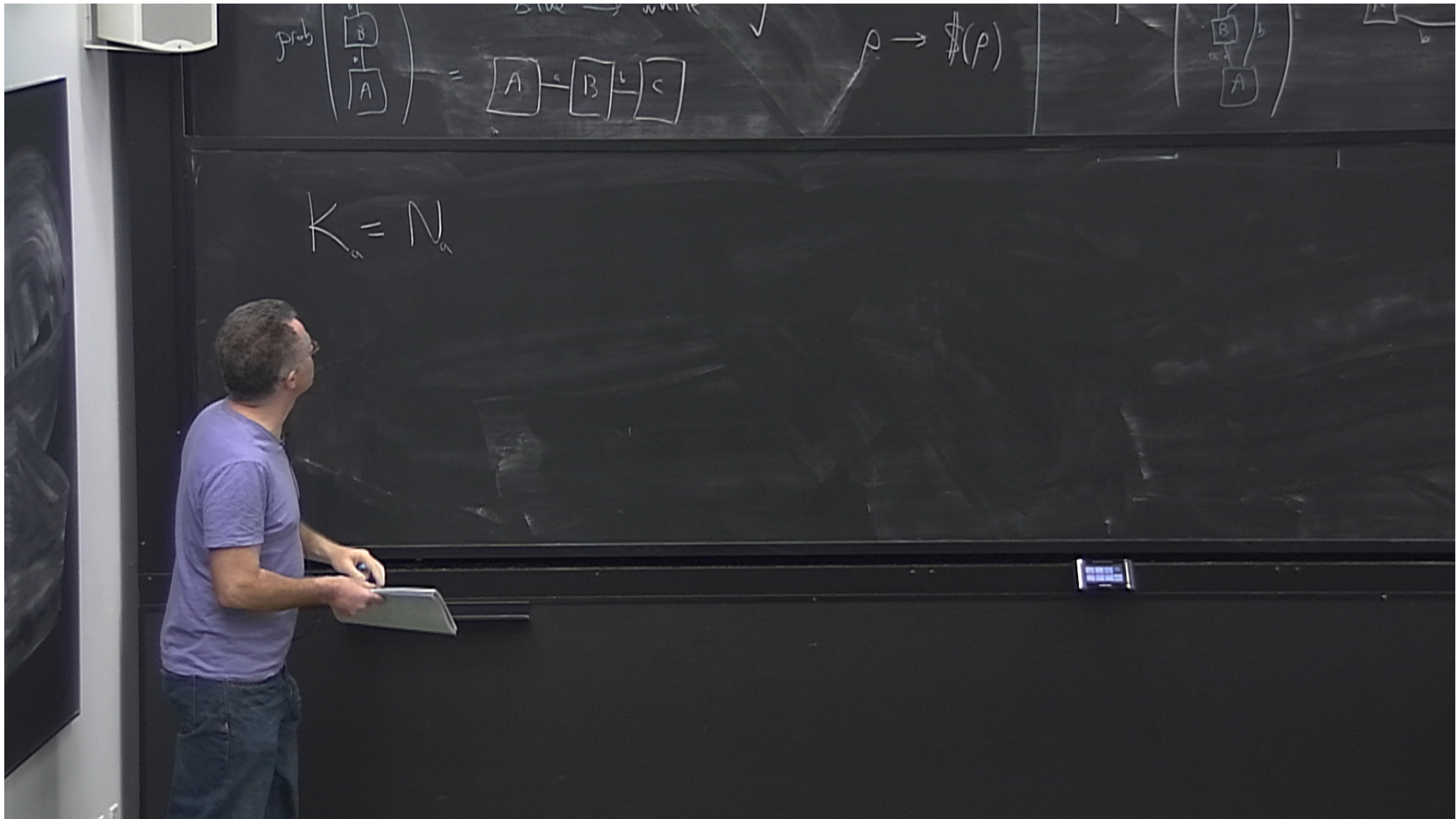
low loc
+ into loc $\Rightarrow K(N_a N_b) = K(N_a) K(N_b)$

little bit
at number
theory

K









$$K_s = N_s \quad (r=1) \quad \text{classical prob theory}$$

$\text{prob} \left(\begin{array}{|c|} \hline B \\ \hline A \\ \hline \end{array} \right) = \begin{array}{|c|c|c|} \hline A & B & C \\ \hline \end{array}$
 $\rho \rightarrow \mathcal{I}(\rho)$

$K_s = N_n \quad (r=1) \quad \text{classical prob theory}$

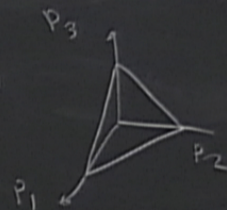




$$K_s = N_s$$

$$(r=1)$$

classical prob theory

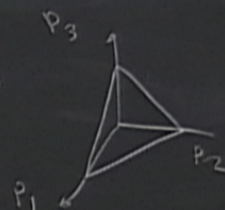


$\text{prob} \left(\begin{array}{c} \boxed{B} \\ \vdots \\ \boxed{A} \end{array} \right) = \boxed{A} \xleftarrow{c} \boxed{B} \xleftarrow{b} \boxed{C}$

$$K_s = N_s$$

$$(r=1)$$

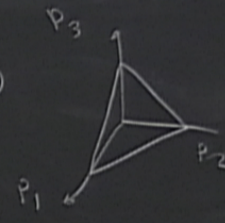
classical prob theory





$$K_a = N_a \quad (r=1) \quad \text{classical prob theory}$$

$$K_a = N_b^2 \quad (r=2) \quad \text{quantum theory.}$$



$$\text{prob} \left(\begin{array}{|c|} \hline B \\ \hline A \\ \hline \end{array} \right) = \boxed{A} \xrightarrow{c} \boxed{B} \xrightarrow{b} \boxed{C}$$

$$\rho \rightarrow \mathcal{I}(\rho)$$

$$\left(\begin{array}{|c|} \hline B \\ \hline A \\ \hline \end{array} \right) \begin{array}{l} b \\ a \end{array}$$

$$K_s = N_a$$

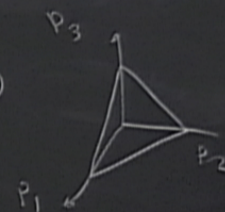
$$(r=1)$$

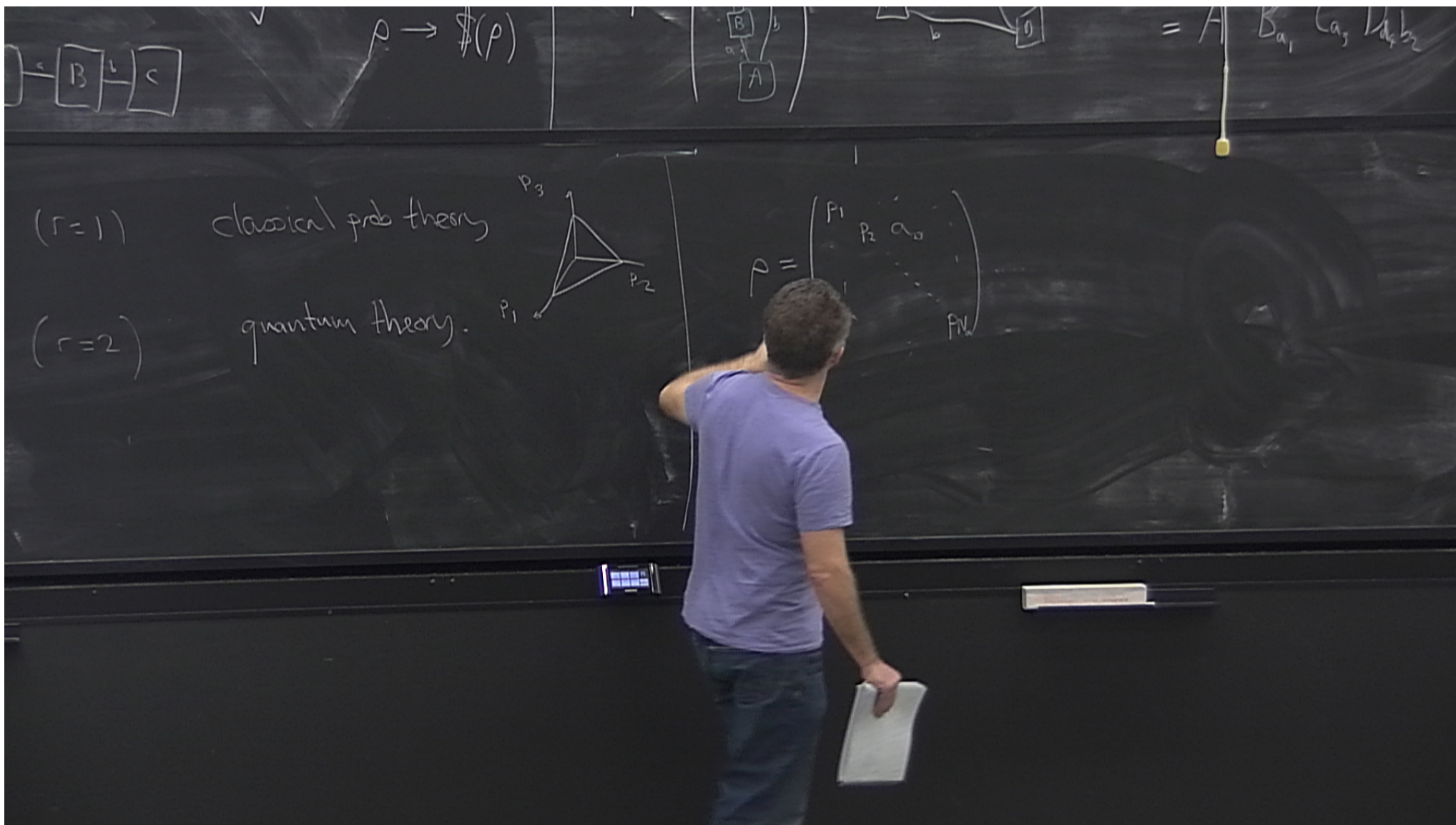
classical prob theory

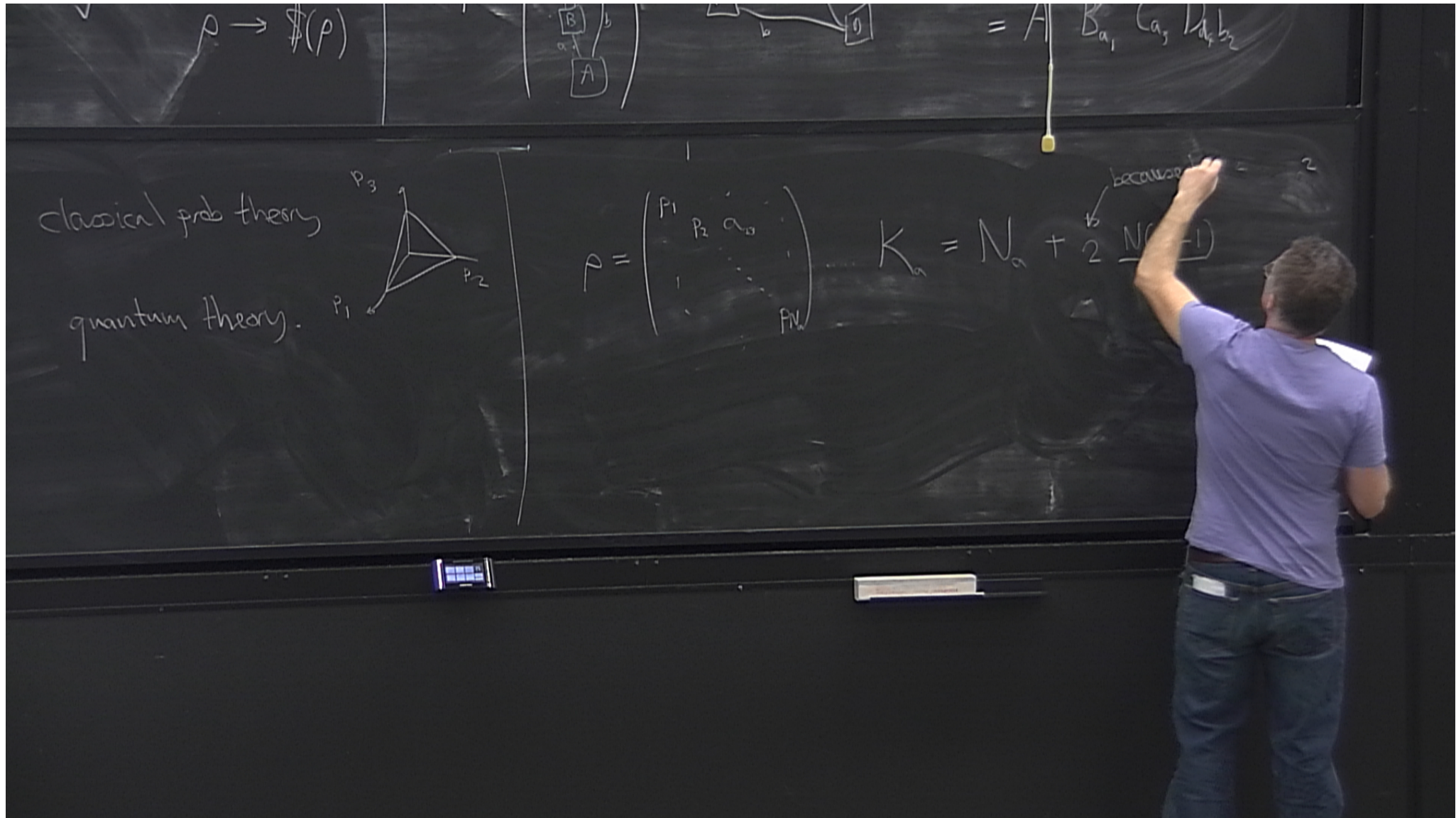
$$K_a = N_b^2$$

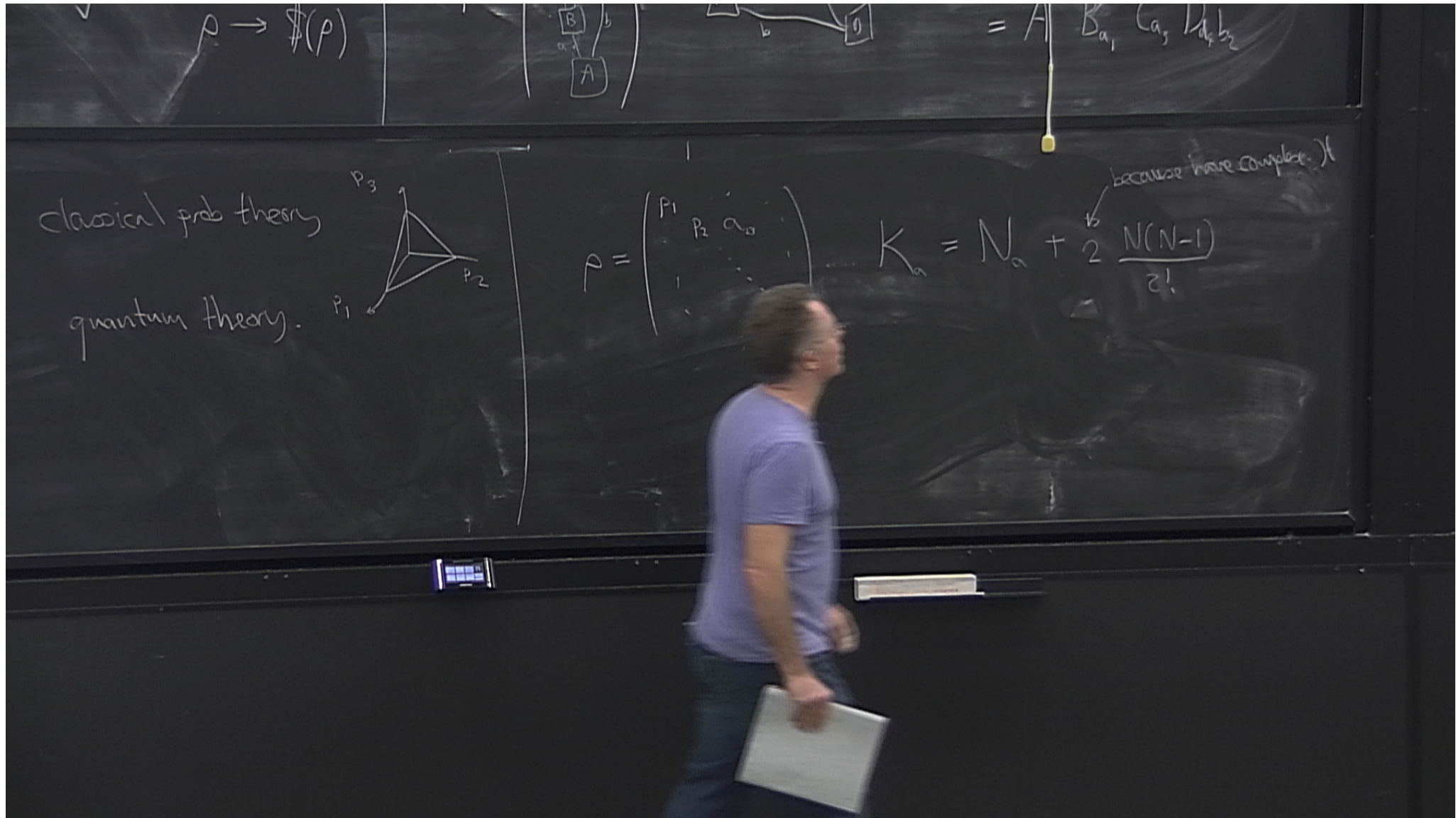
$$(r=2)$$

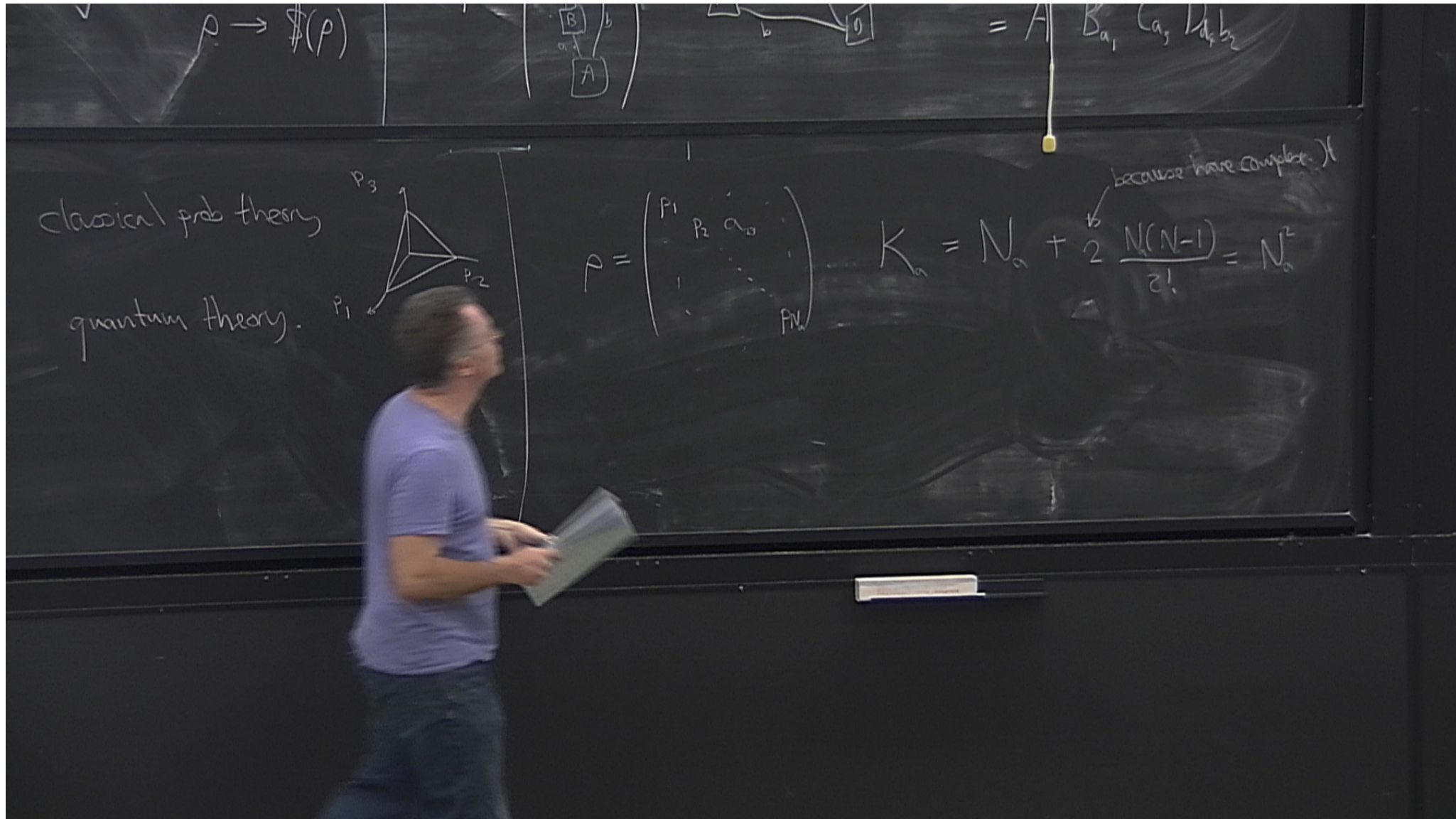
quantum theory.

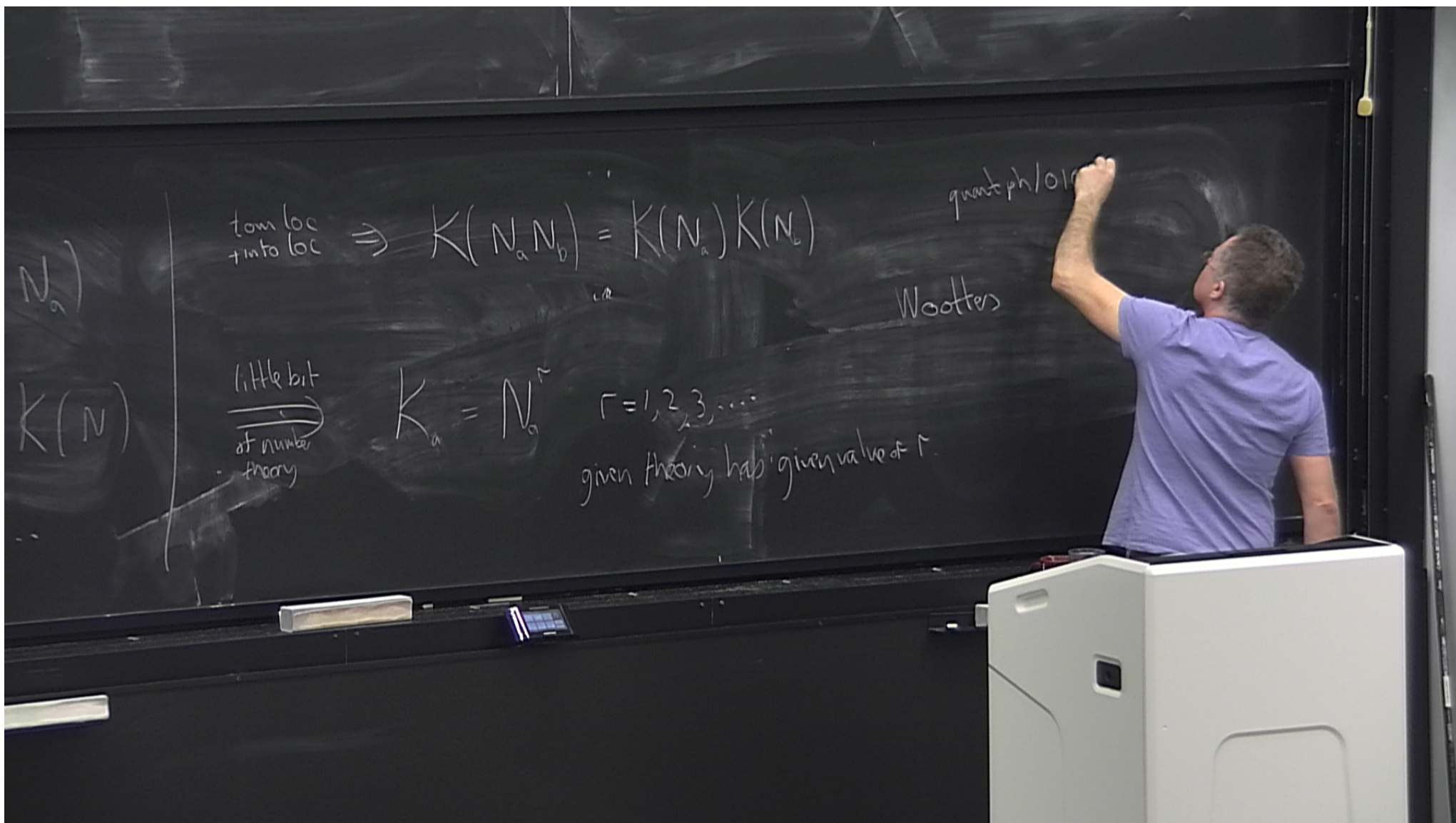


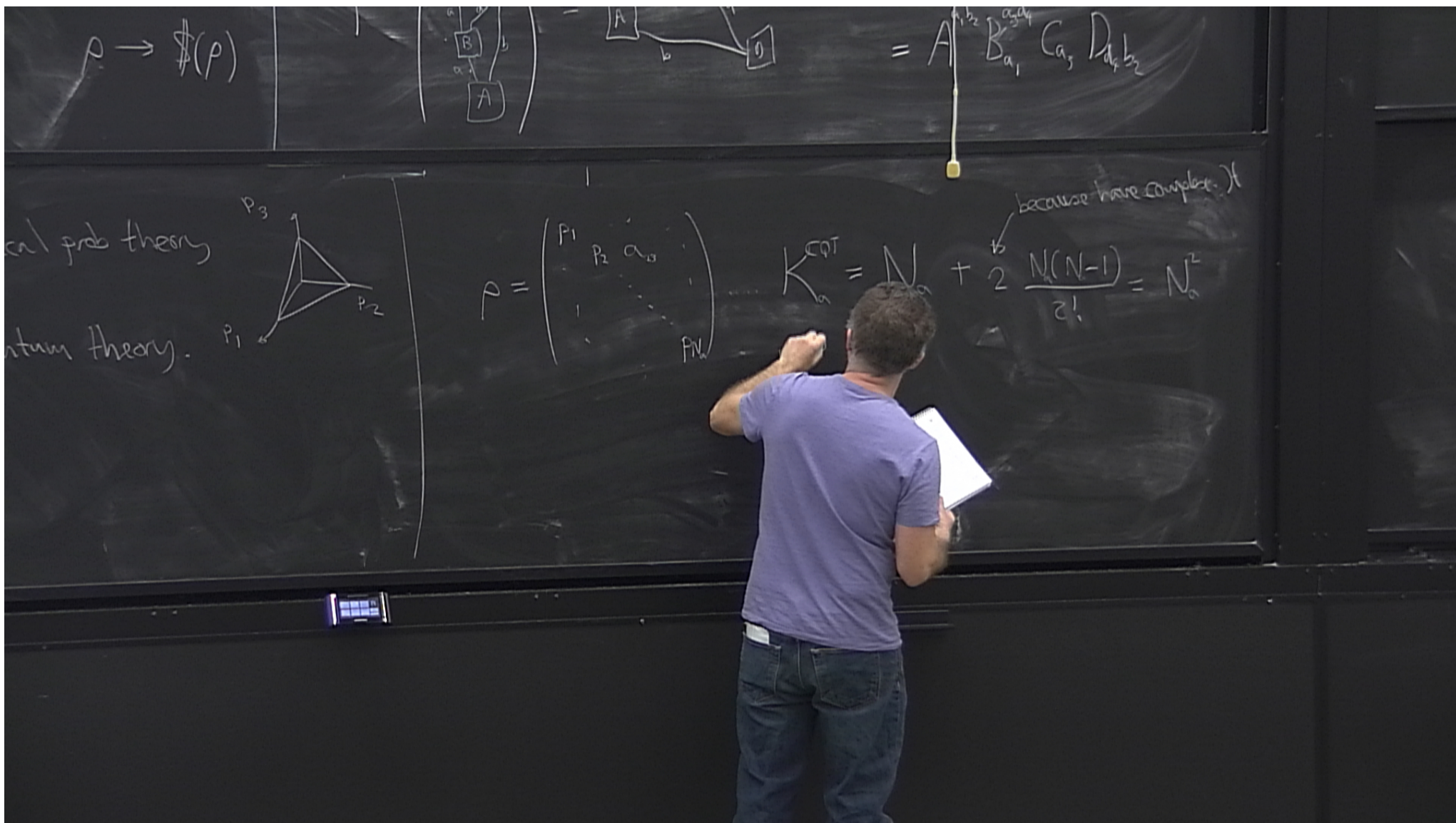


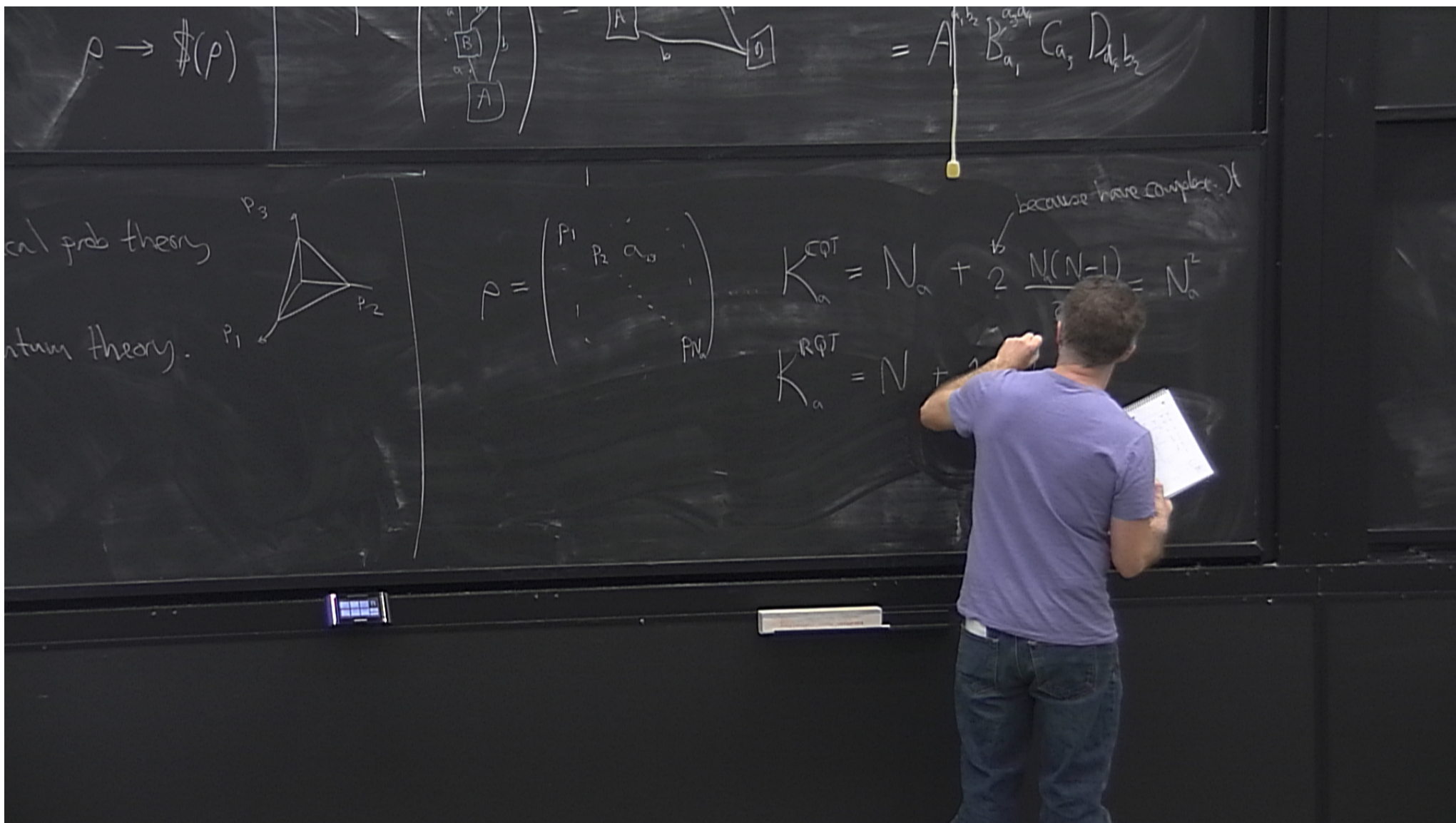


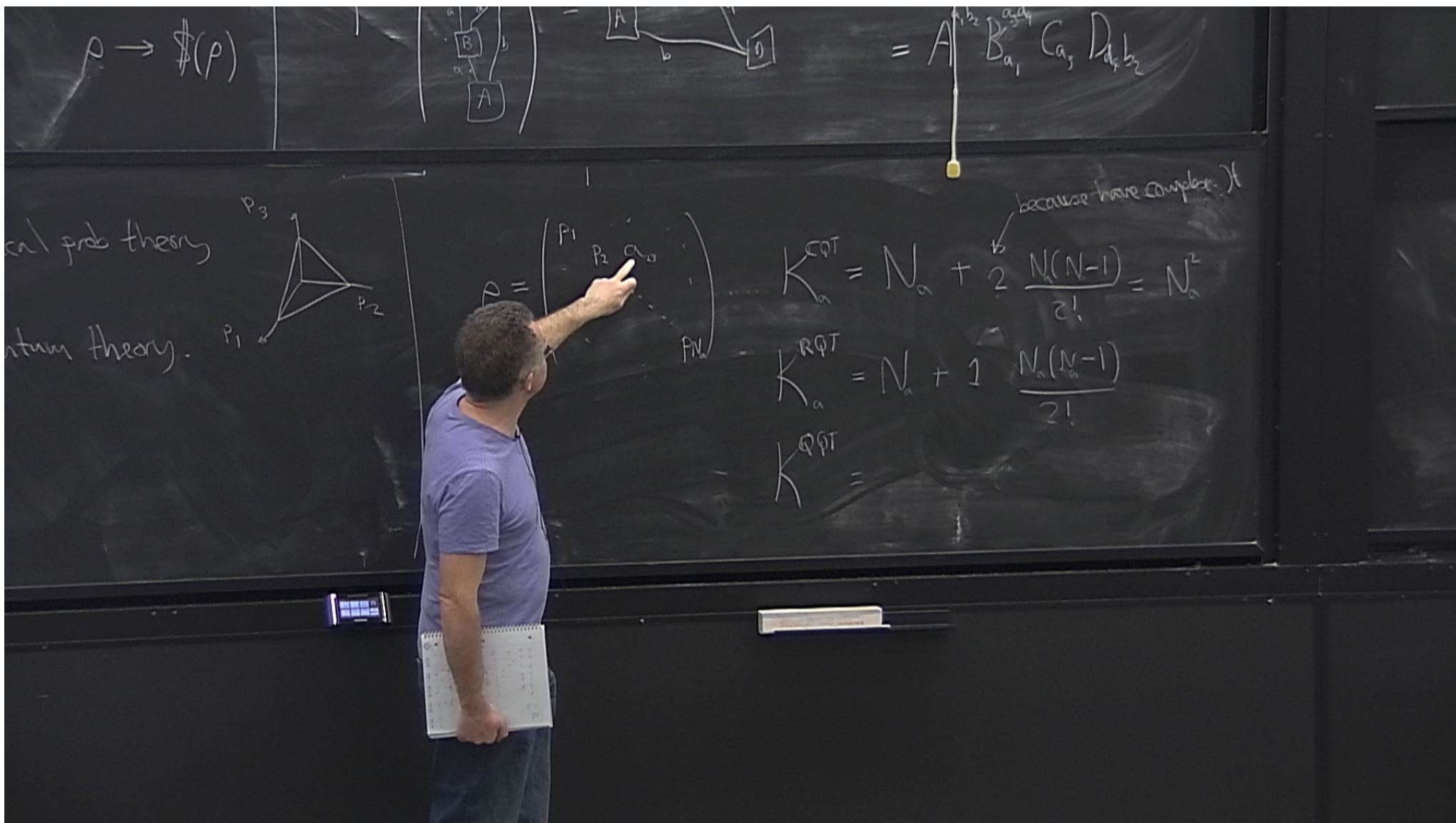


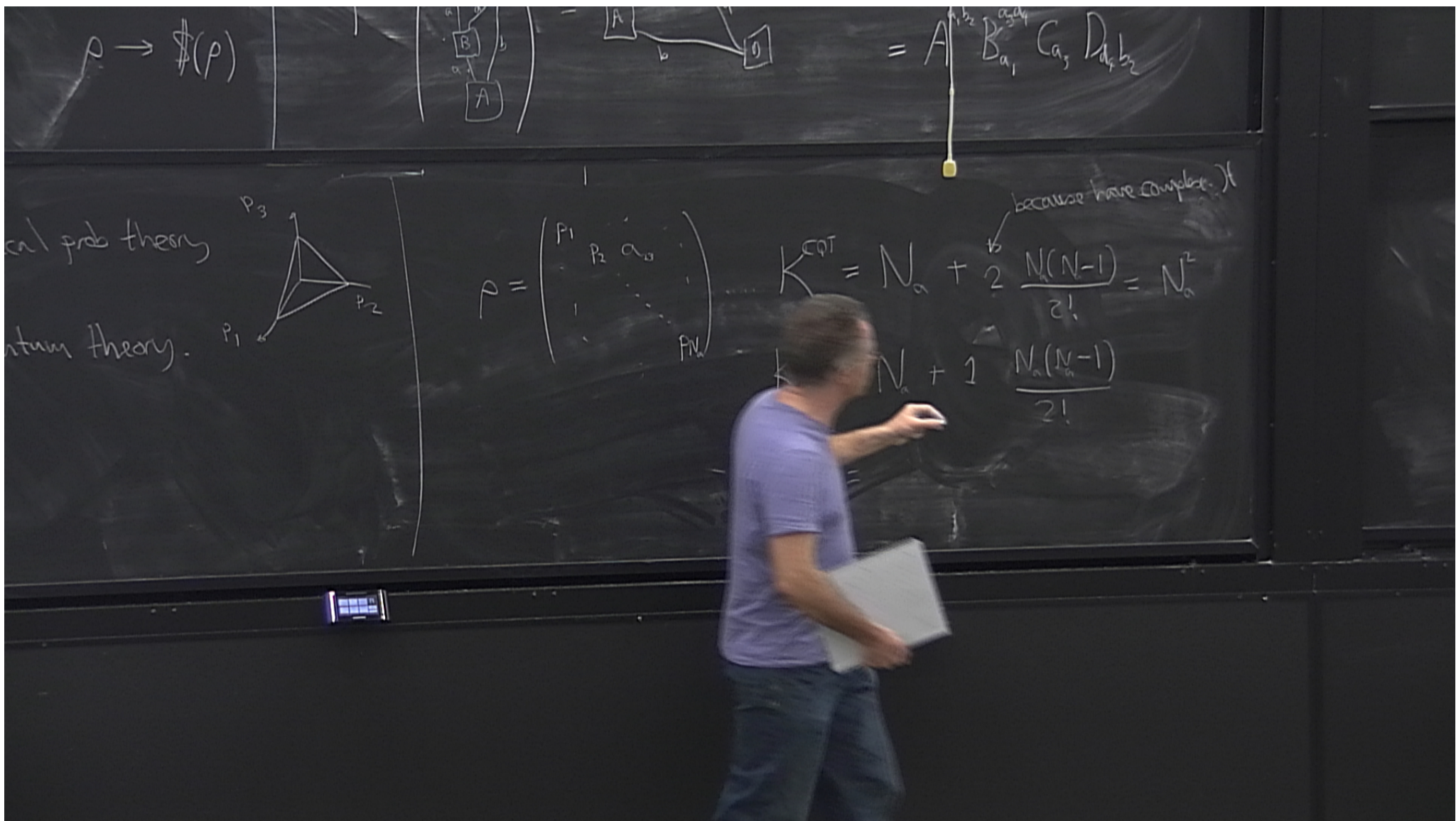


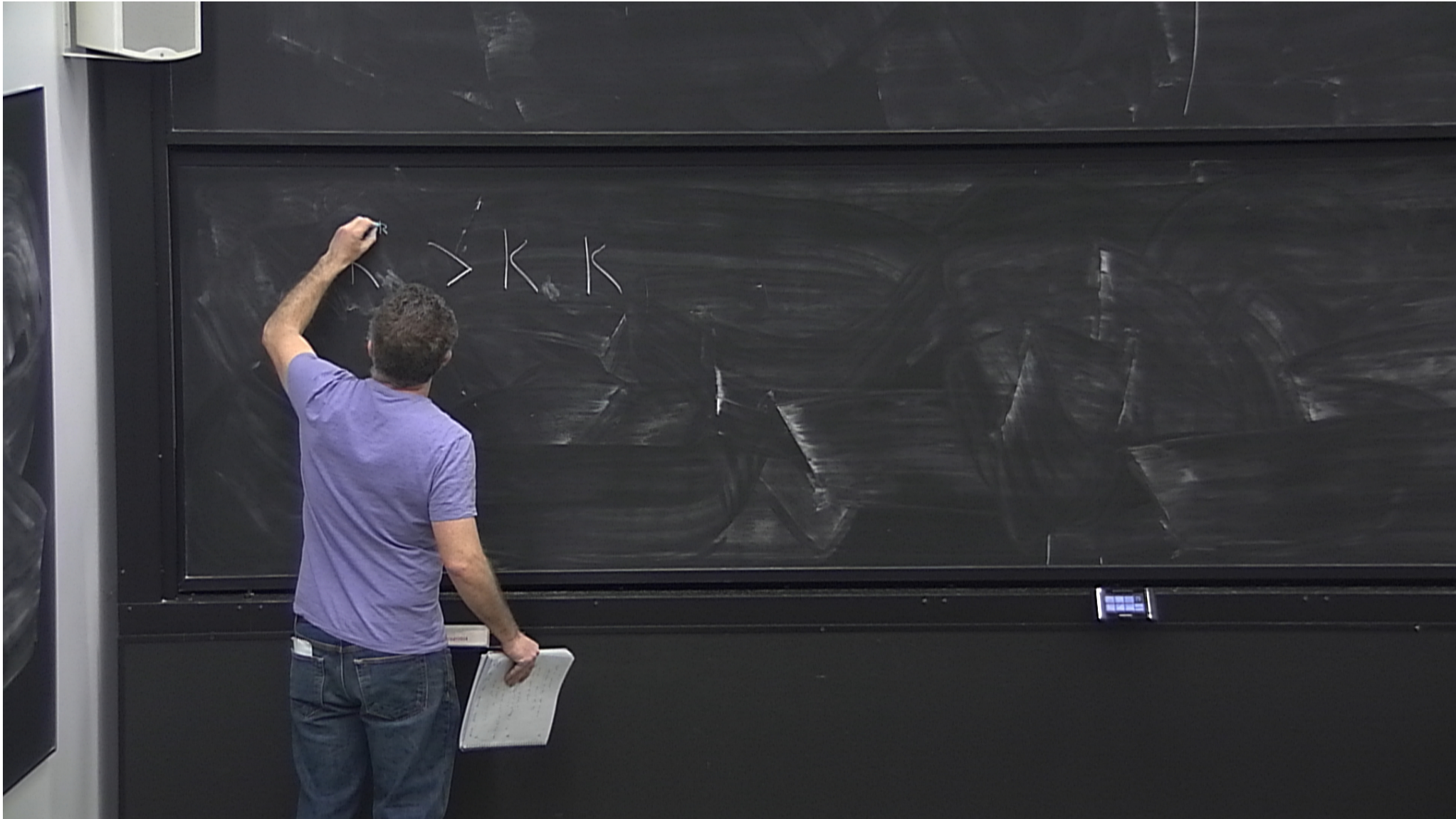


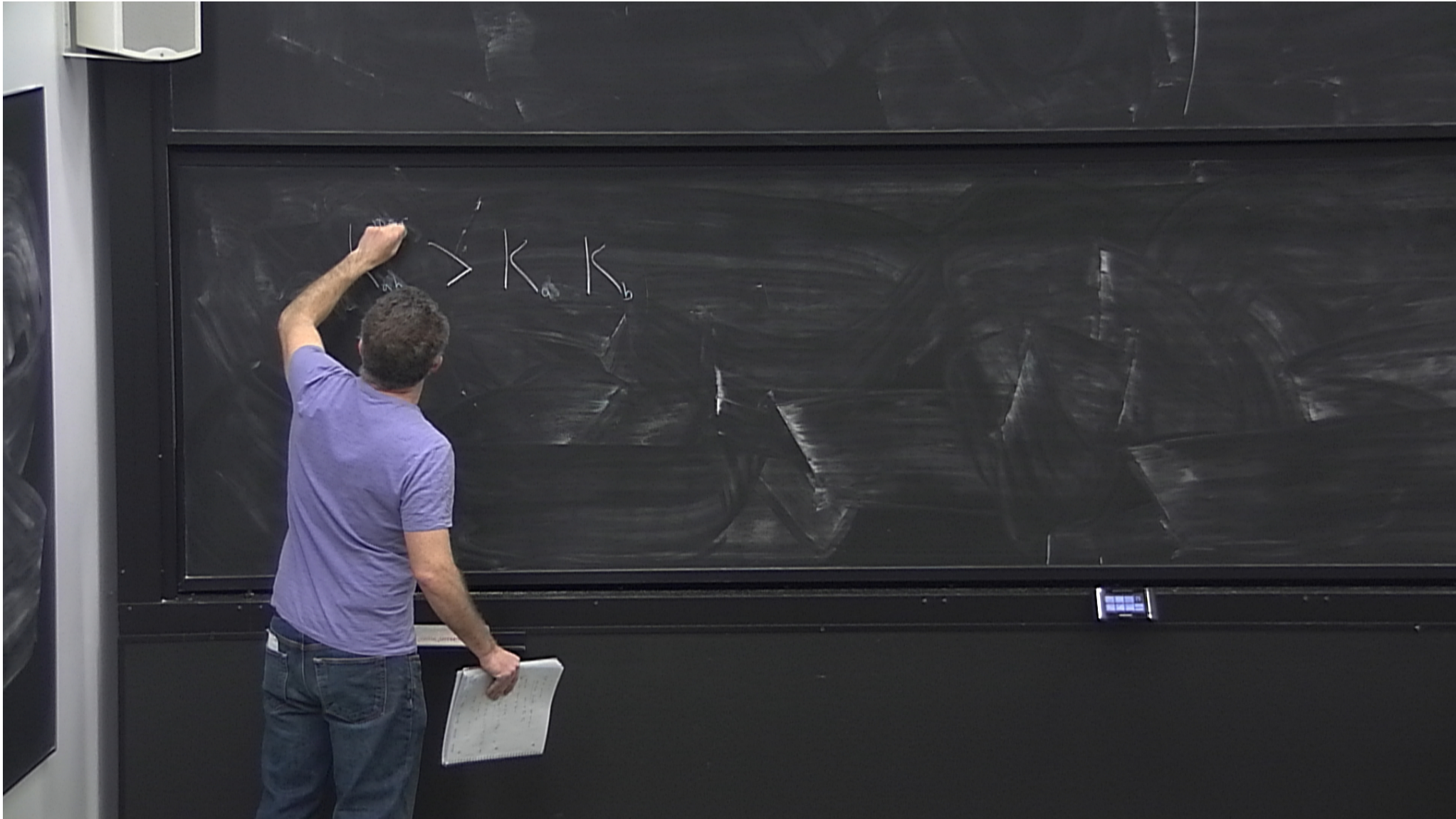


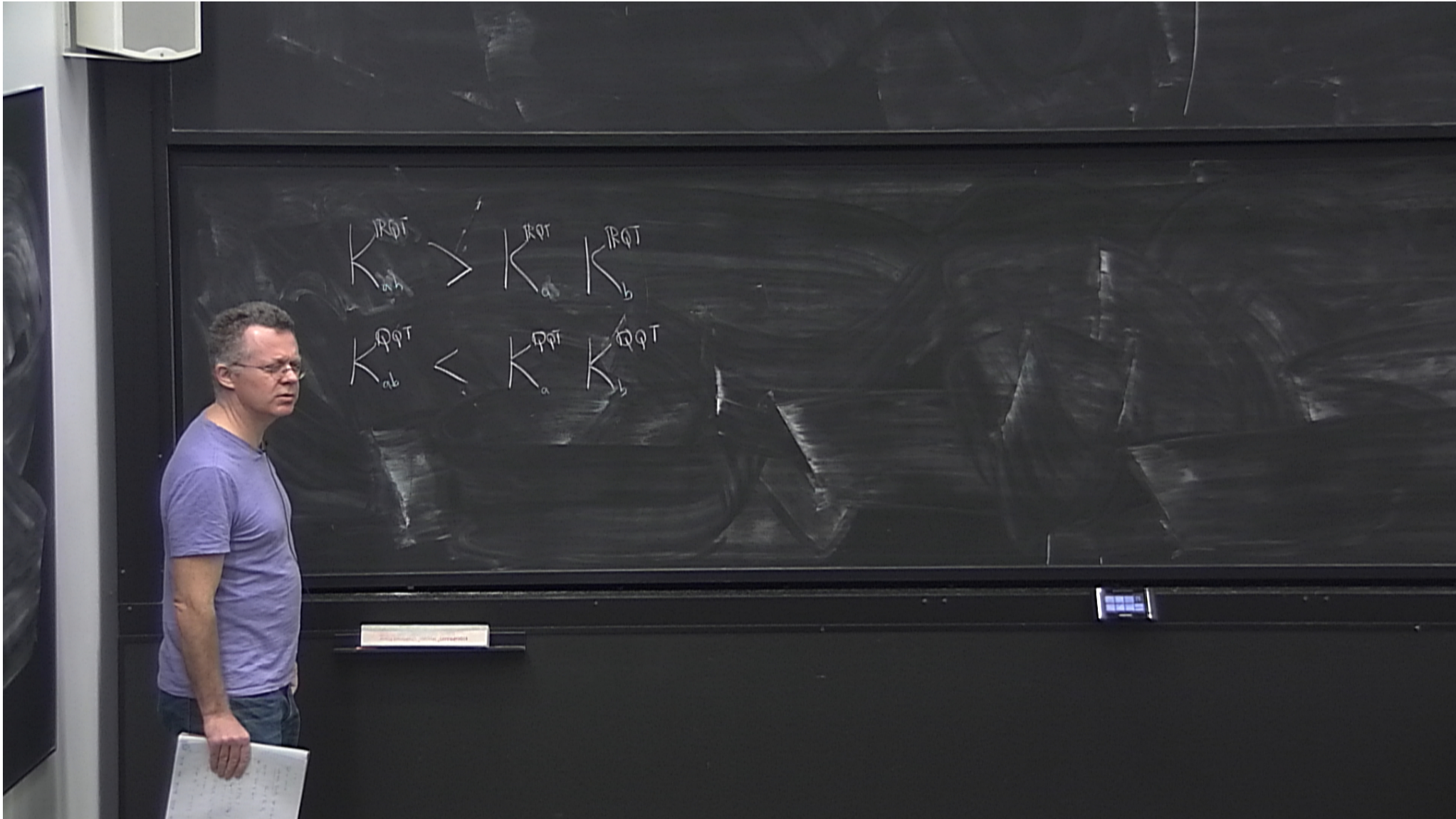


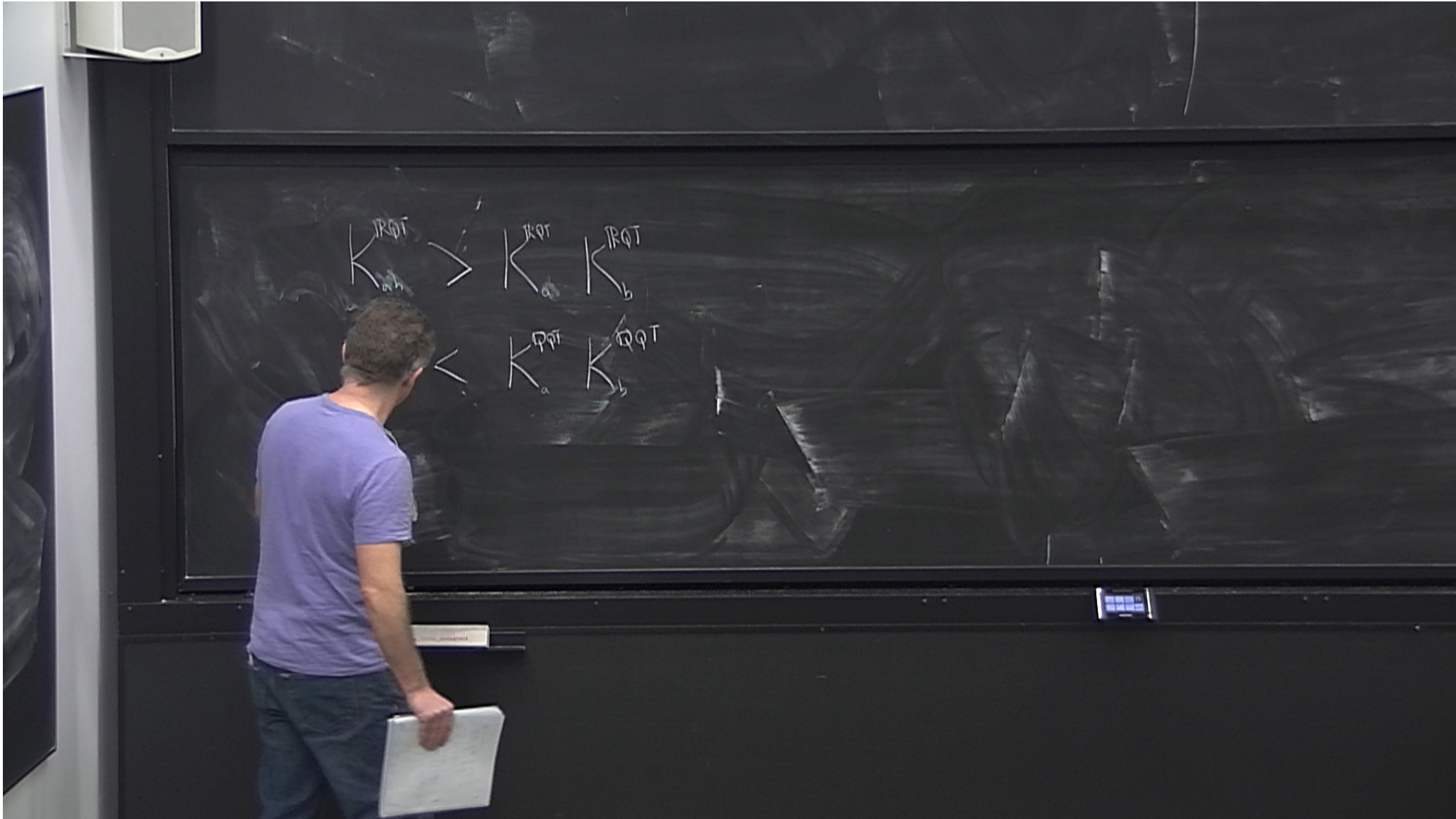


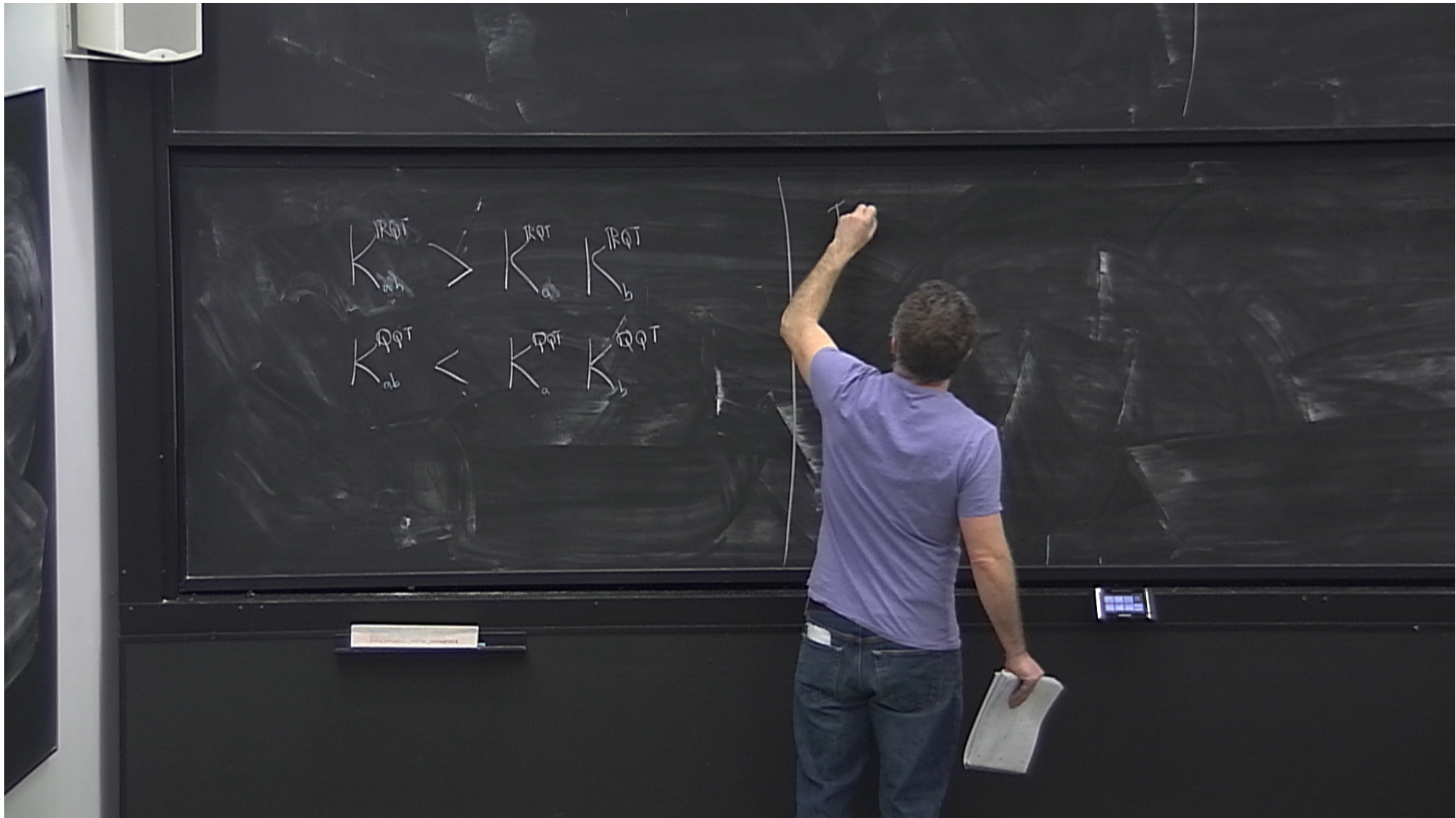












$$K_{ab}^{RQT} > K_a^{RQT} K_b^{RQT}$$

$$K_{ab}^{QQT} < K_a^{QQT} K_b^{QQT}$$

Two "qubits" $N_a = 2$ $N_{aa} = 4$

N	K_{RQT}	K_{CQT}	K_{QQT}
2			

$$\begin{array}{ccc}
 K_{ab}^{RQT} & > & K_a^{RQT} K_b^{RQT} \\
 K_{ab}^{QQT} & < & K_a^{QQT} K_b^{QQT}
 \end{array}$$

violates condition 1

Two "qubits" $N_a = 2$ $N_{aa} = 4$

N	K_{RQT}	K_{CQT}	K_{QQT}
2			

$$K_{ab}^{RQT} > K_a^{RQT} K_b^{RQT}$$

$$K_{ab}^{QQT} < K_a^{QQT} K_b^{QQT}$$

violates Assumption 1

Two "qubits" $N_a = 2$ $N_{aa} = 4$

N	K_{RQT}	K_{CQT}	K_{QQT}
2	3	4	6
4	$10 > 3^2$	$16 = 4^2$	$28 < 6^2$

Assumption 1

4

$$10 > 3^2$$

$$16 = 4^2$$

$$28 < 6^2$$

Reasonable postulates for QT

motivation

Ad hoc

"explanatory"

K

Assumption 1

4

$$10 > 3^2$$

$$16 = 4^2$$

$$28 < 6$$

Reasonable postulates for QT

motivation

Ad hoc

"explanatory"

Kopler's laws

Newtons laws.

Lorentz transformations

Einstein's S

Assumption 1

4

$10 > 3^2$

$16 = 4^2$

$28 < 6$

Reasonable postulates for QT

motivation

Ad hoc

"explanatory"

Kepler's laws

Newton's laws

Lorentz transformations

Einstein's SR postulates

QT (in usual
axiomatic form)
[Hilbert, ...]

?

Assumption 1

$$4$$

$$10 > 3^2$$

$$16 = 4^2$$

$$28 < 6$$

Reasonable postulates for QT

motivation

Ad hoc

"explanatory"

Kopler's laws

Newtons laws.

Lorentz transformations

Einstein's SR postulates

QT (in usual
axiomatic form)
[Hilbert space, ...]

?

Assumption 1

4

$10 > 3^2$

$16 = 4^2$

$28 < 6$

Reasonable postulates for QT

motivation

Ad hoc (data fitting) "explanatory"

Kopler's laws

Newtons laws.

Lorentz transformations

Einstein's SR postulates

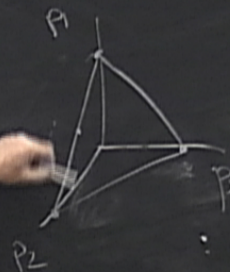
QT (in usual
axiomatic form)
[Hilbert space, ...]

?

LH quantph/0101012

$$4 \quad | \quad 10 > 3^2 \quad | \quad 16 = 4^2 \quad | \quad 28 < 6^2$$

into a continuous reversible transformation between pure states.



violates Assumption 1

4

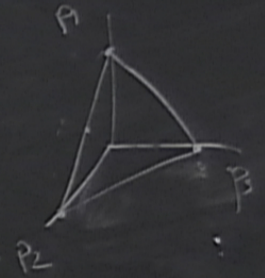
$10 > 3^2$

$16 = 4^2$

$28 < 6^2$

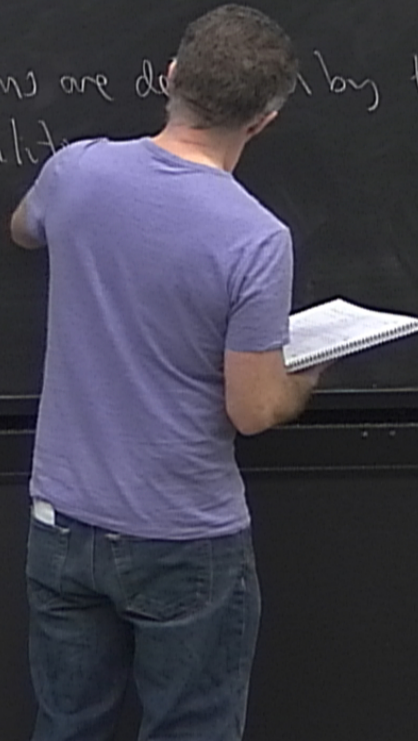
Continuity

There exists a continuous reversible transformation between any pair of pure states.
(rules out CProbT)



Simplicity

Systems are defined by the smallest number of probabilities.



violates Assumption 1

4

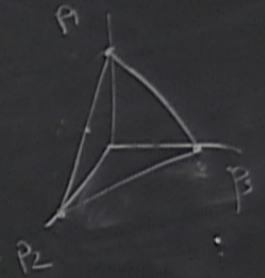
$$10 > 3^2$$

$$16 = 4^2$$

$$28 < 6^2$$

Continuity

There exists a continuous reversible transformation between any pair of pure states.
(rules out CProbT)



Simplicity

Systems are described by the smallest number of probabilities consistent with the postulates.
(take smallest value)

$$K = N$$

$$10 > 3^2 \quad | \quad 16 = 4^2 \quad | \quad 28 < 6^2$$

reversible transformation between
(rules out CProbT)

the smallest number of
the other postulates.

(up of r)

$$K = N^2$$



$\hat{P}$
 $\hat{S}()$
 $\hat{A}$

Dakic Brukner,
Masanes Mueller
Chiribella, D'Ariano,
Perinotti
LH

Assume

and

KF

and

N

$$10 > 3^2 \quad | \quad 16 = 4^2 \quad | \quad 28 < 6^2$$

reversible transformation between
(rules out CProbT)

the smallest number of
the other postulates.

(up of r)

$$K = N^2$$



$\hat{P}$
 $\hat{S}()$
 $\hat{A}$

Dakic Brukner
Masanes Mueller
Chiribella, D'Ariano,
Perinotti
LH

Assume

K
K
N

