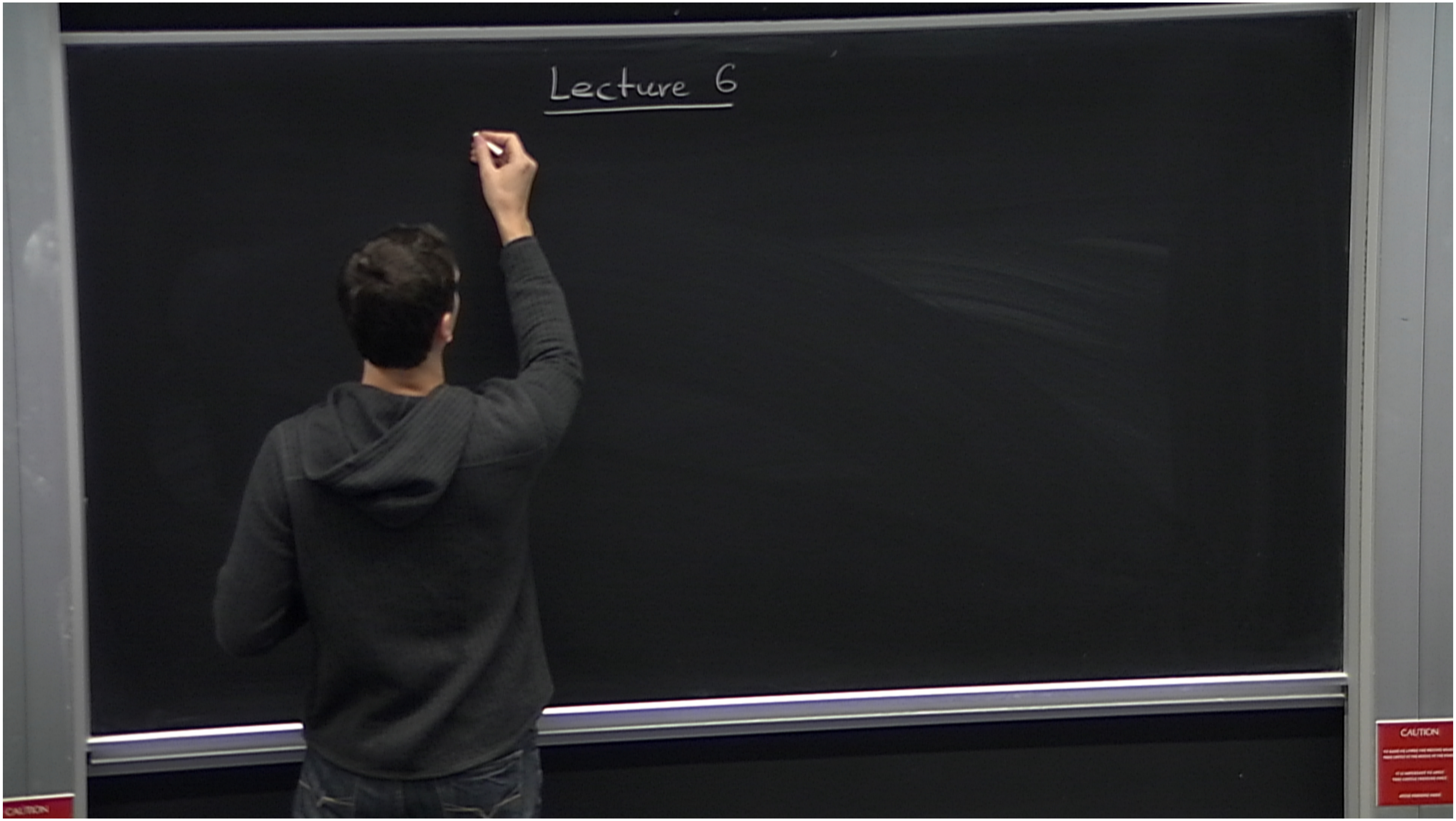
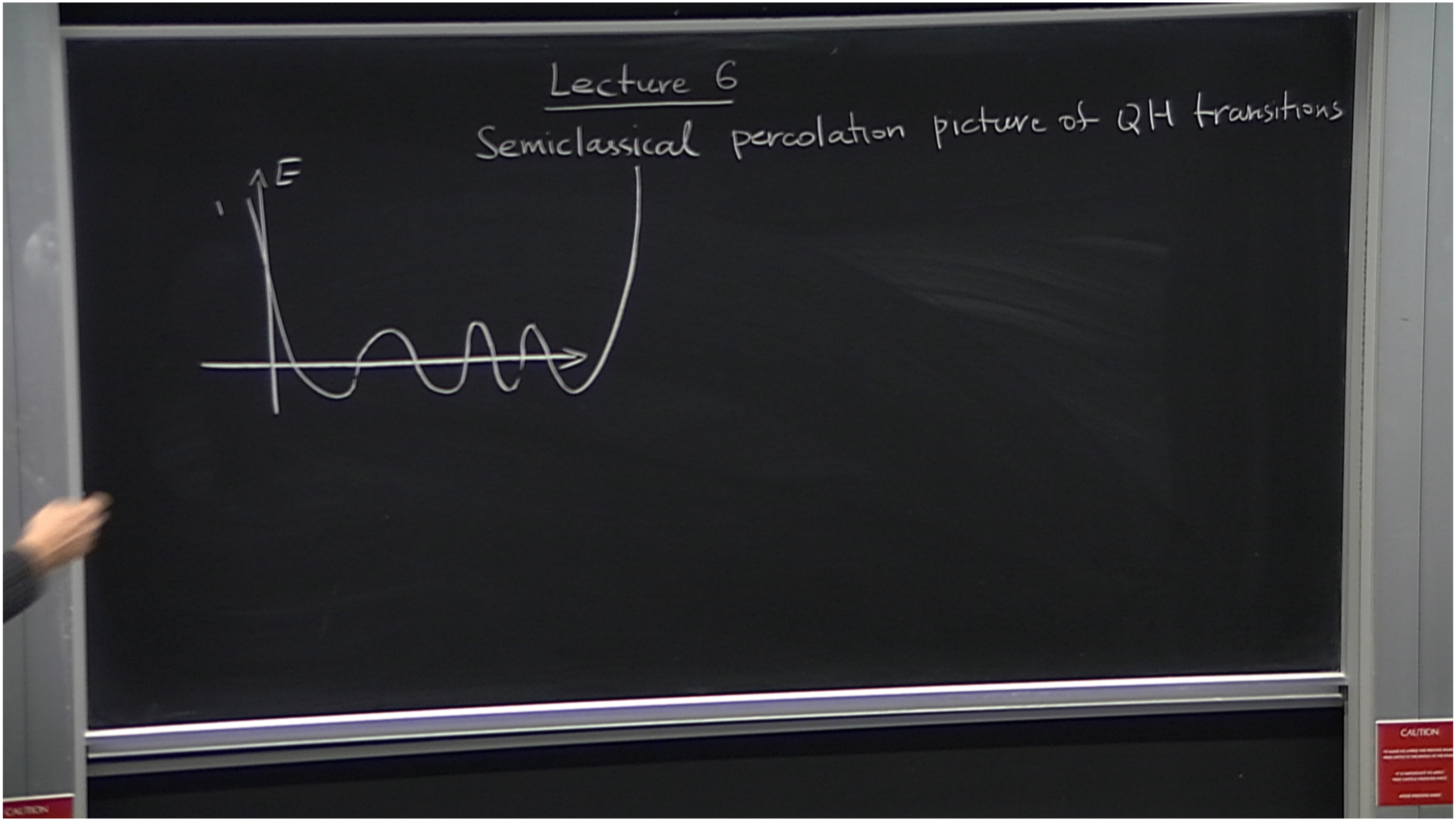
Title: Explorations in Condensed Matter - Lecture 7

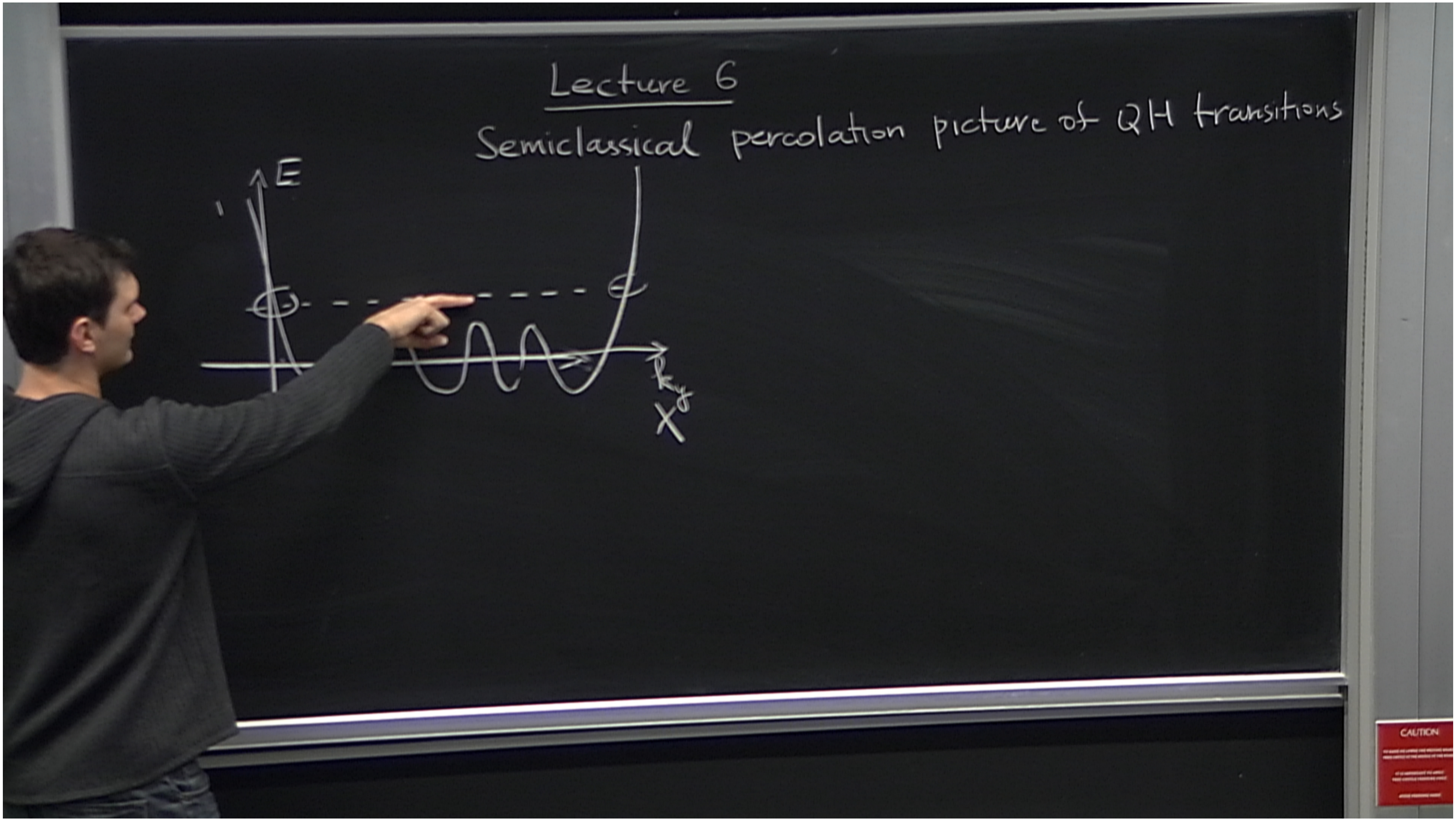
Date: Apr 11, 2012 10:15 AM

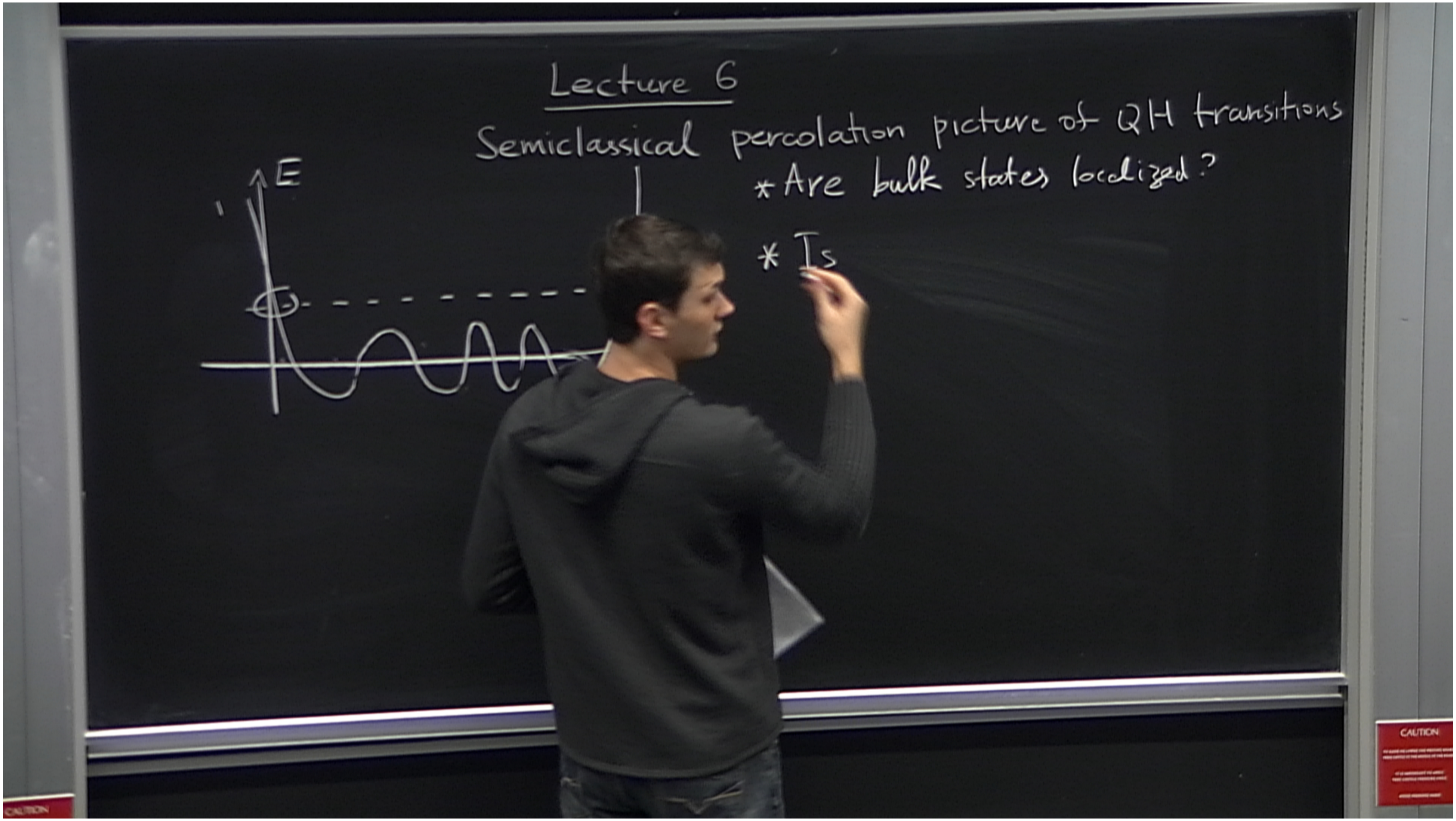
URL: http://www.pirsa.org/12040090

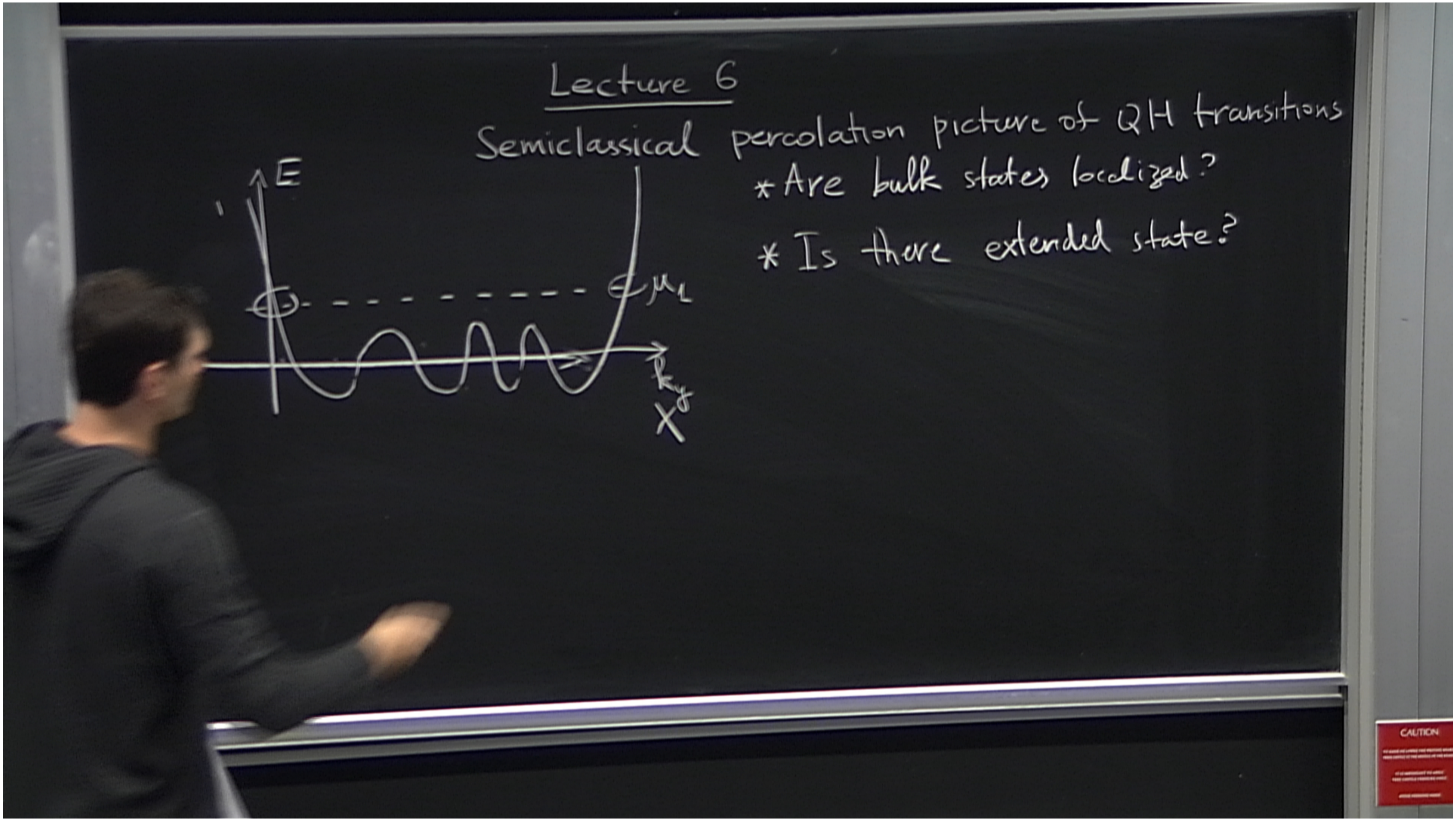
Abstract:

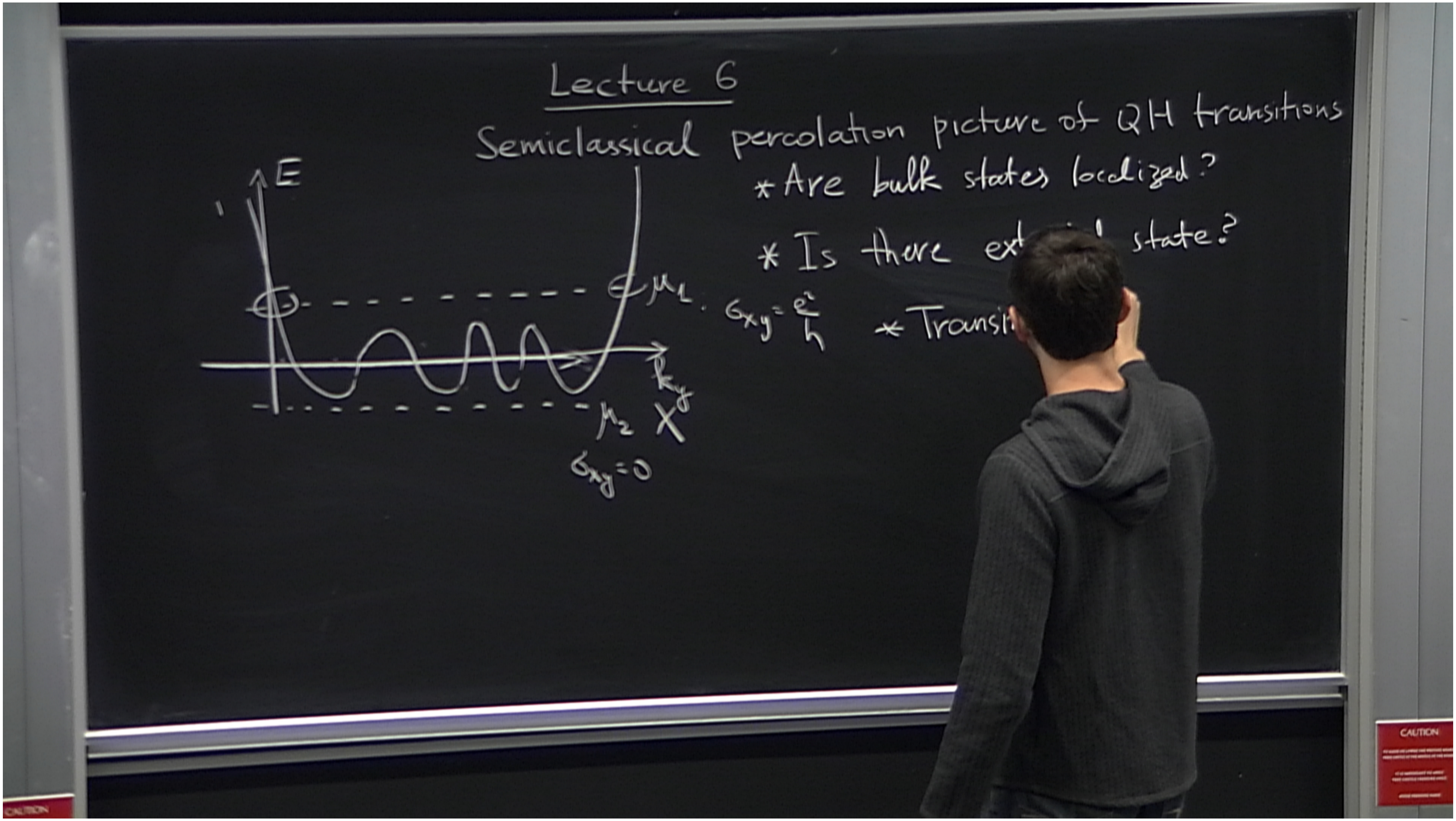

Lecture 6
CAUTION

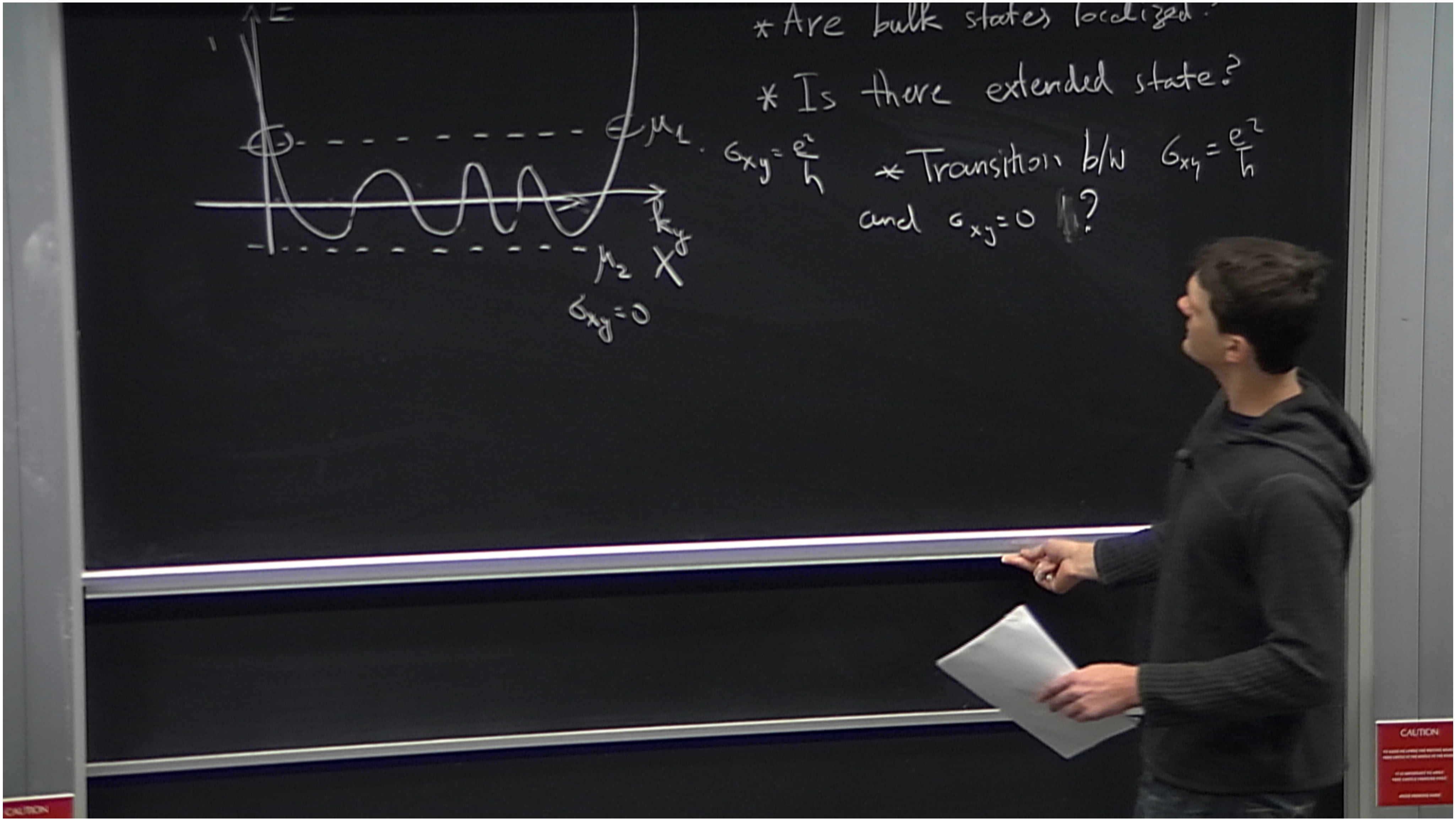

Lecture 6
Semiclassical percolation picture of QH transitions
E

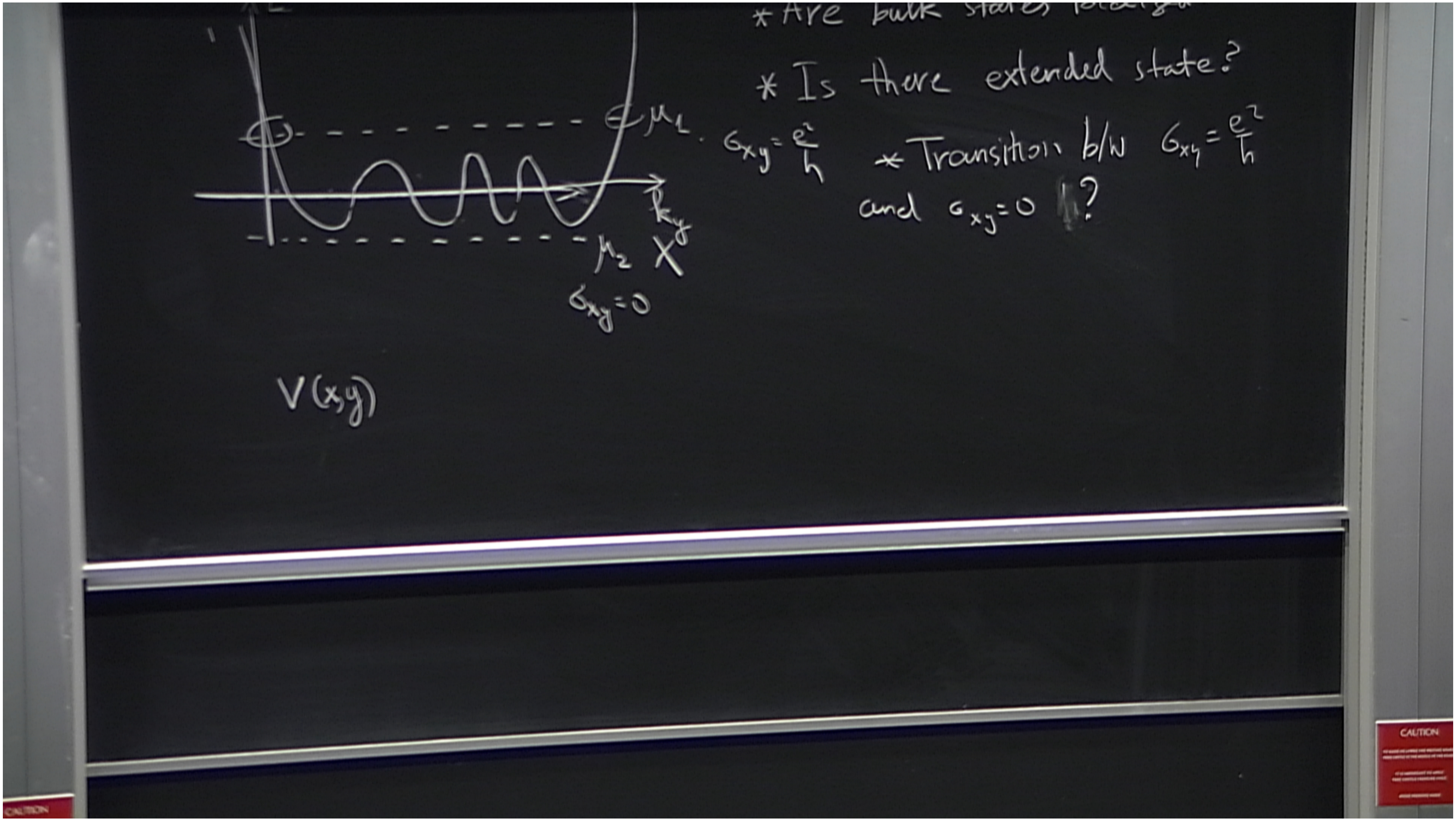

Lecture 6
Semiclassical percolation picture of QH transitions
E
ky
X
CAUTION

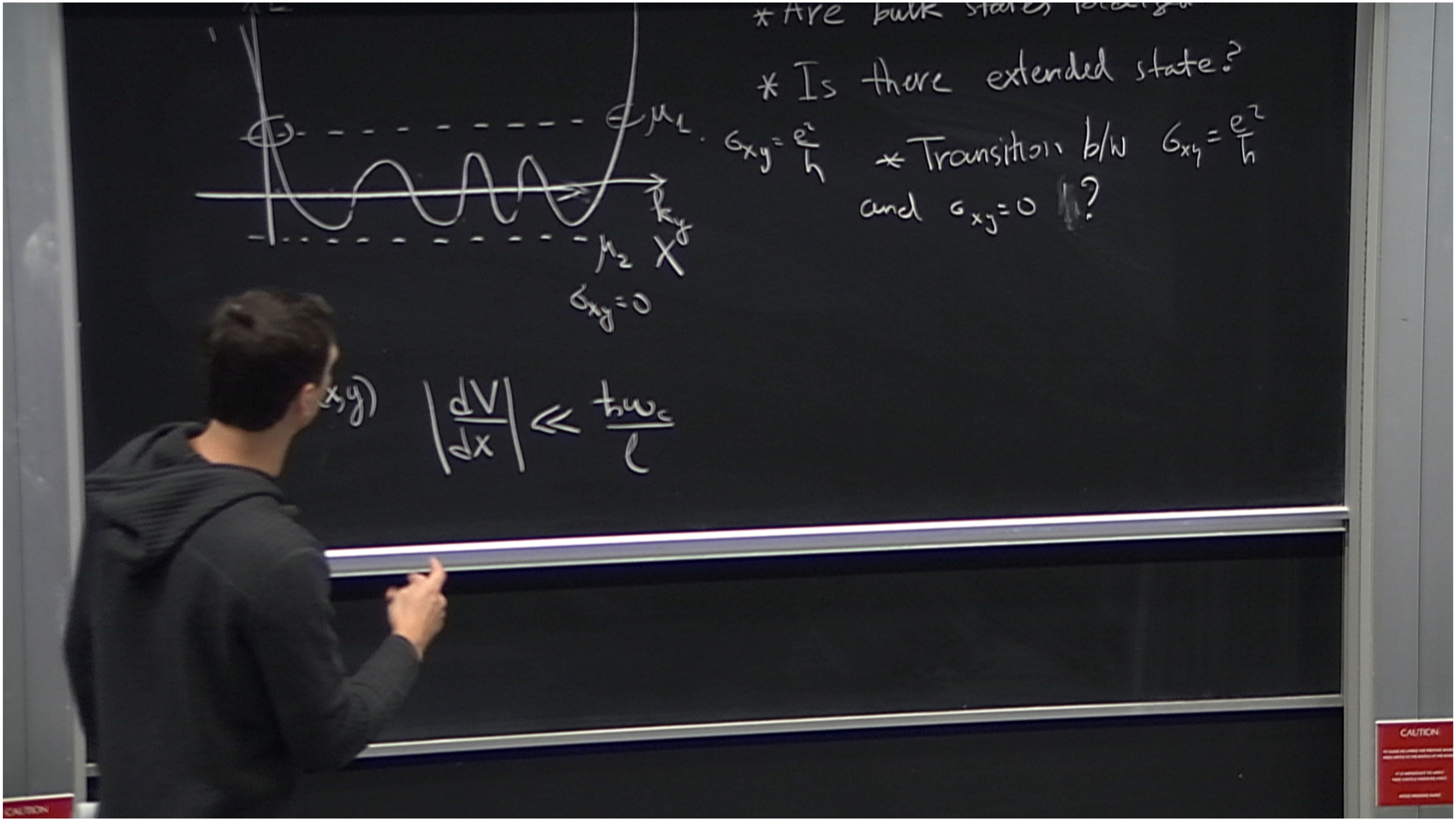

Lecture 6
Semiclassical percolation picture of QH transitions
* Are bulk states localized?
* Is
E
CAUTION

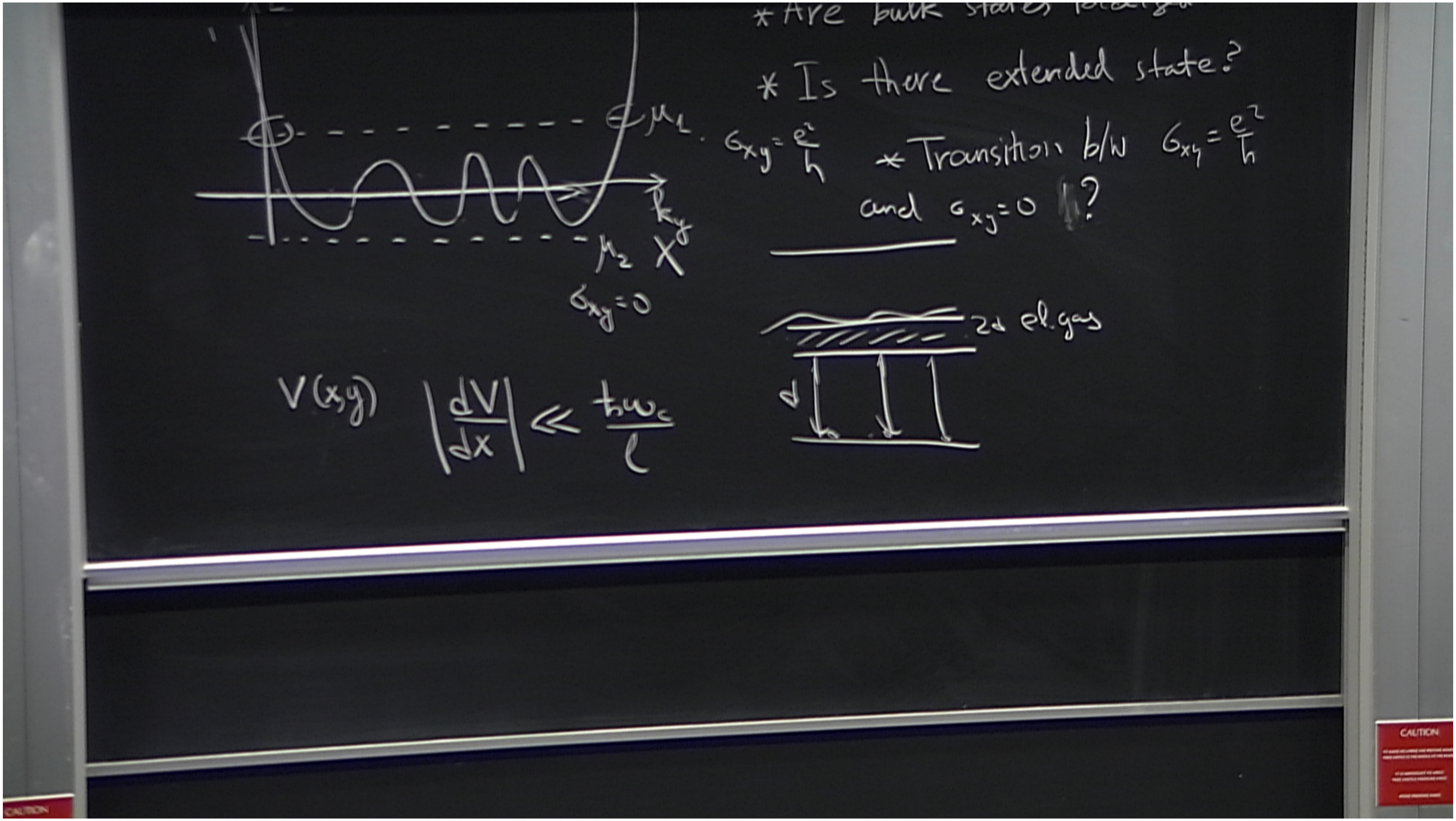

Lecture 6
Semiclassical percolation picture of QH transitions
* Are bulk states loclized?
* Is there extended state?
E
μ1
ky
X

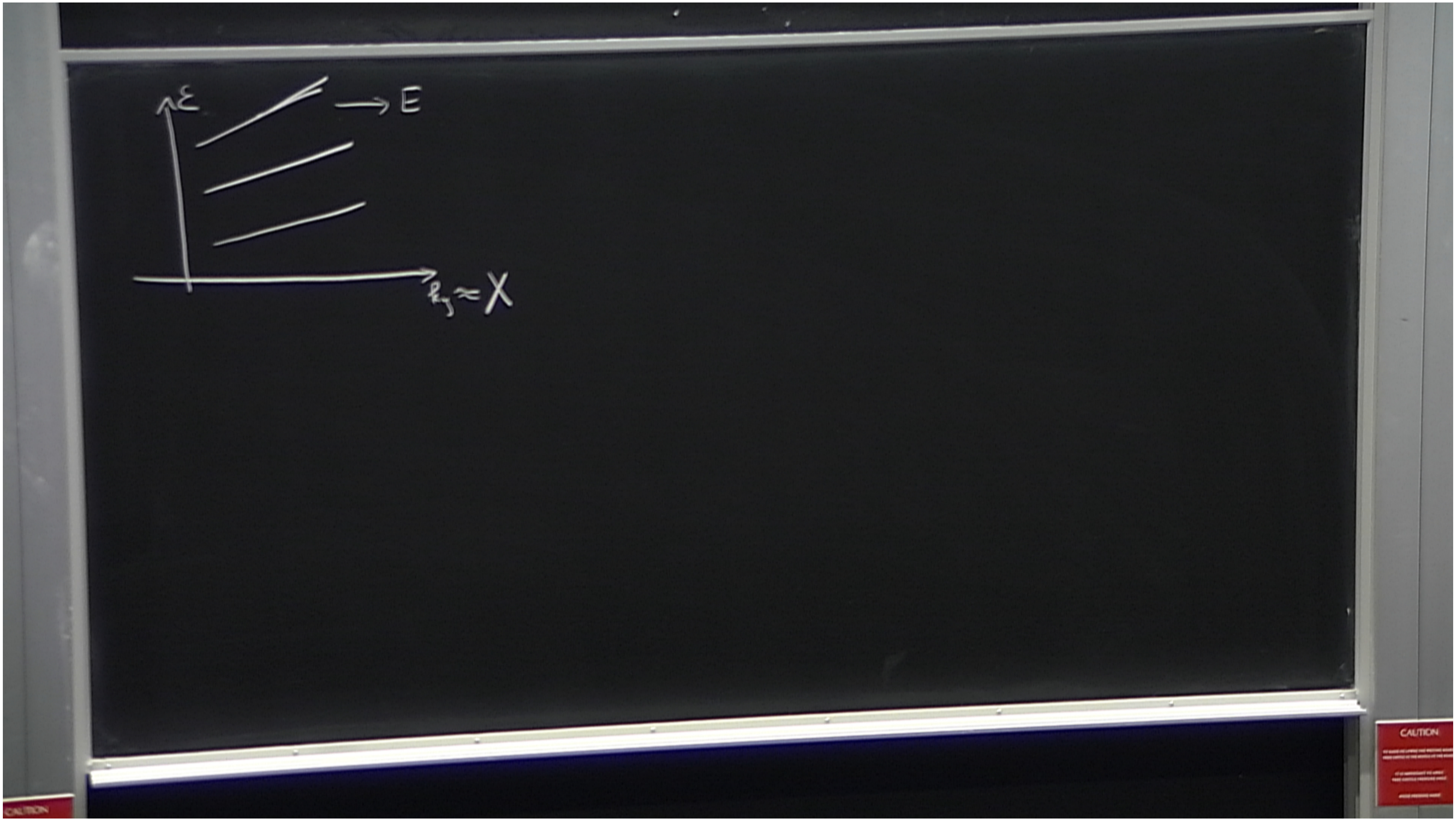

Lecture 6
Semiclassical percolation picture of QH transitions
* Are bulk states localized?
* Is there ext
state?
E
μ1
σxy = e²/h
* Transi
ky
X
μ2
σxy = 0

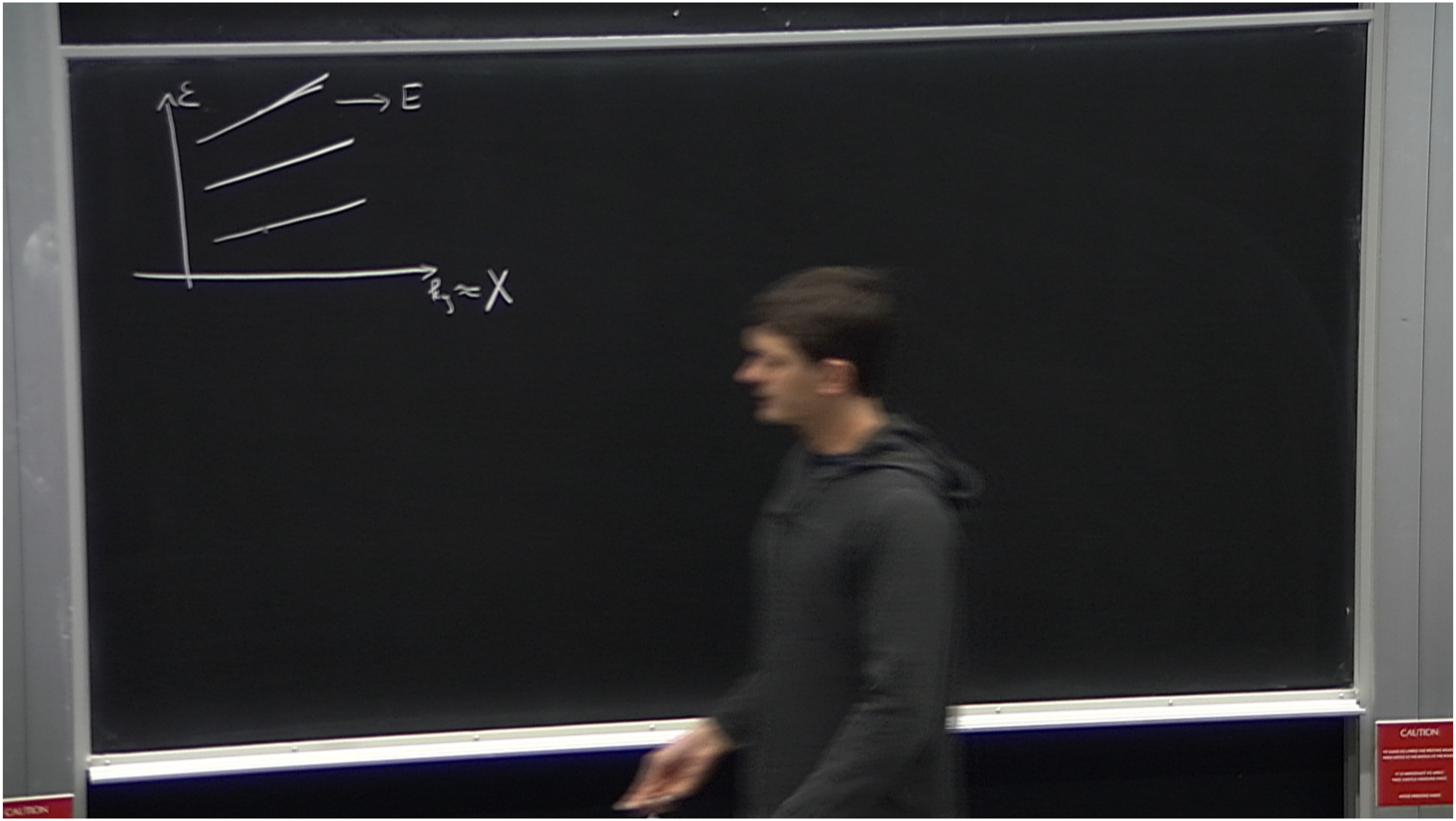

* Are bulk states localized?
* Is there extended state?
* Transition b/w σxy = e²/h
and σxy = 0 ?
E
μ1
μ2
ky
σxy = e²/h
σxy = 0
CAUTION

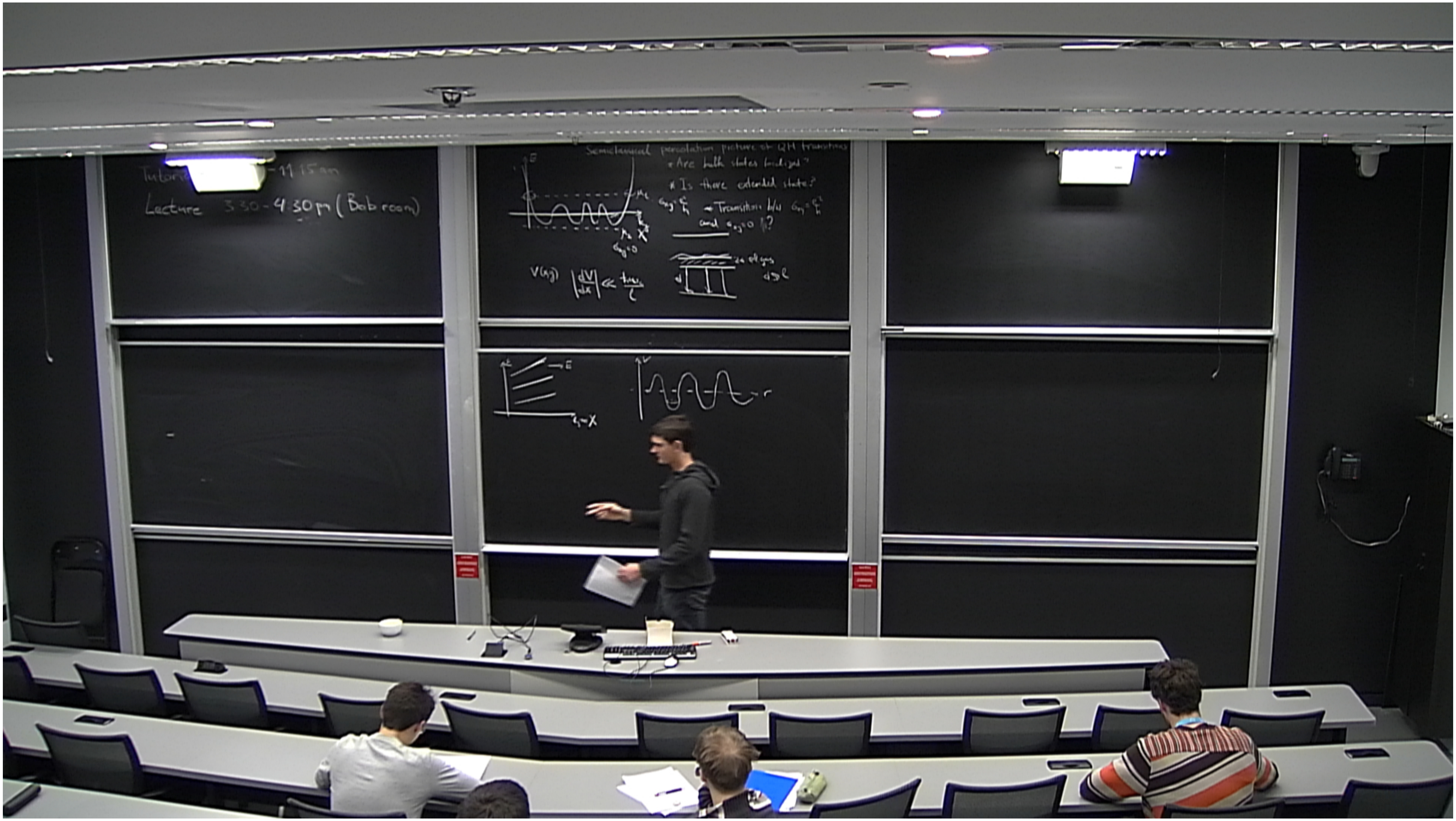

* Are bulk
* Is there extended state?
μ_1
$\sigma_{xy} = \frac{e^2}{h}$
* Transition b/w $\sigma_{xy} = \frac{e^2}{h}$
and $\sigma_{xy} = 0$?
k_y
μ_2
X
$\sigma_{xy} = 0$
V(x,y)

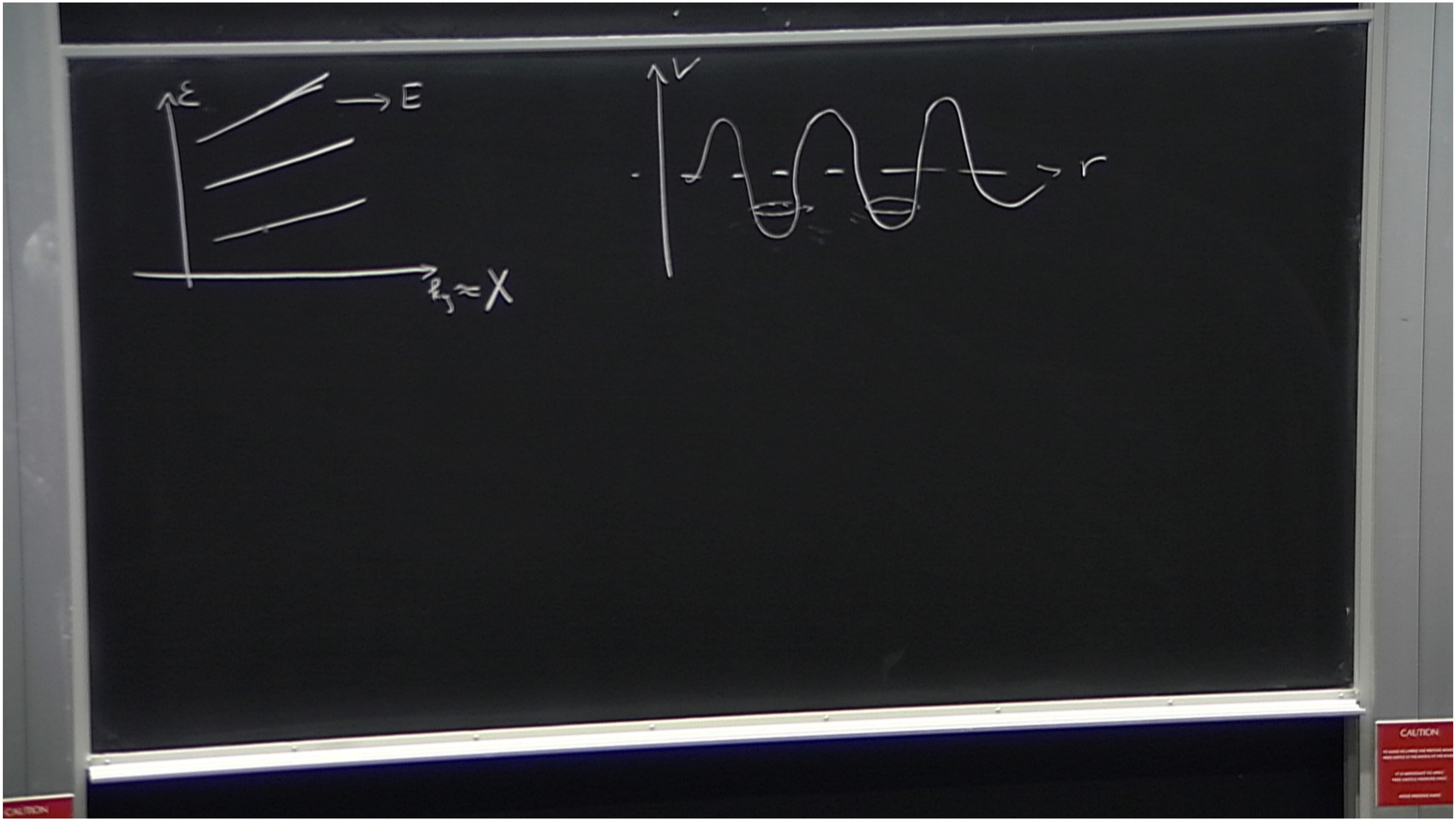

* Is there extended state?
μ1
σxy = e²/h
* Transition b/w σxy = e²/h
and σxy = 0 ?
ky
μ2
σxy = 0
|dV/dx| ≪ ħωc/l


* Are bulk states
* Is there extended state?
μ1
σxy = e²/h
* Transition b/w σxy = e²/h and σxy = 0 ?
ky
X
μ2
σxy = 0
2d el. gas
d
V(x,y)
|dV/dx| ≪ ħωc/l

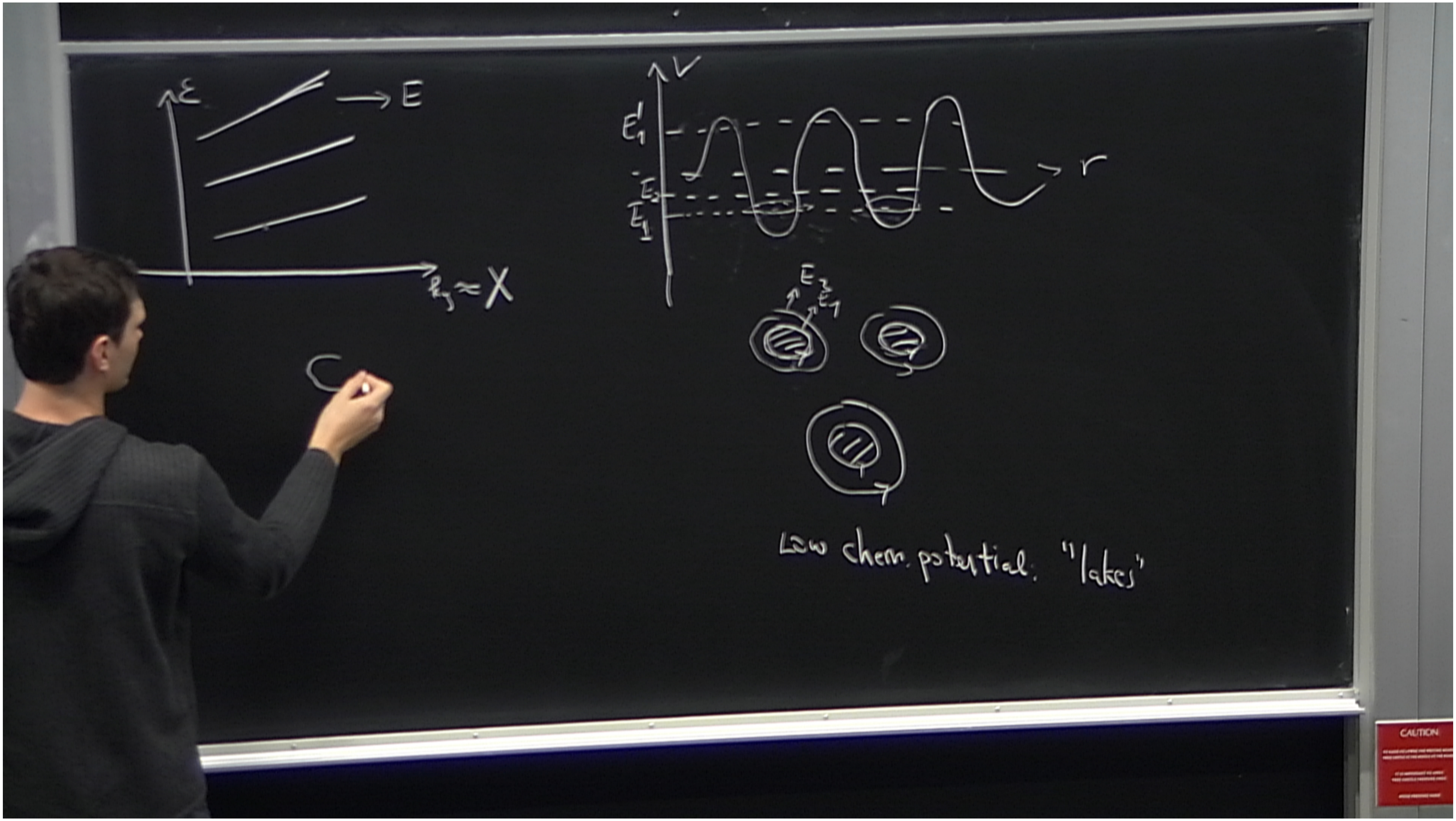

ε
E
$k_y \approx X$

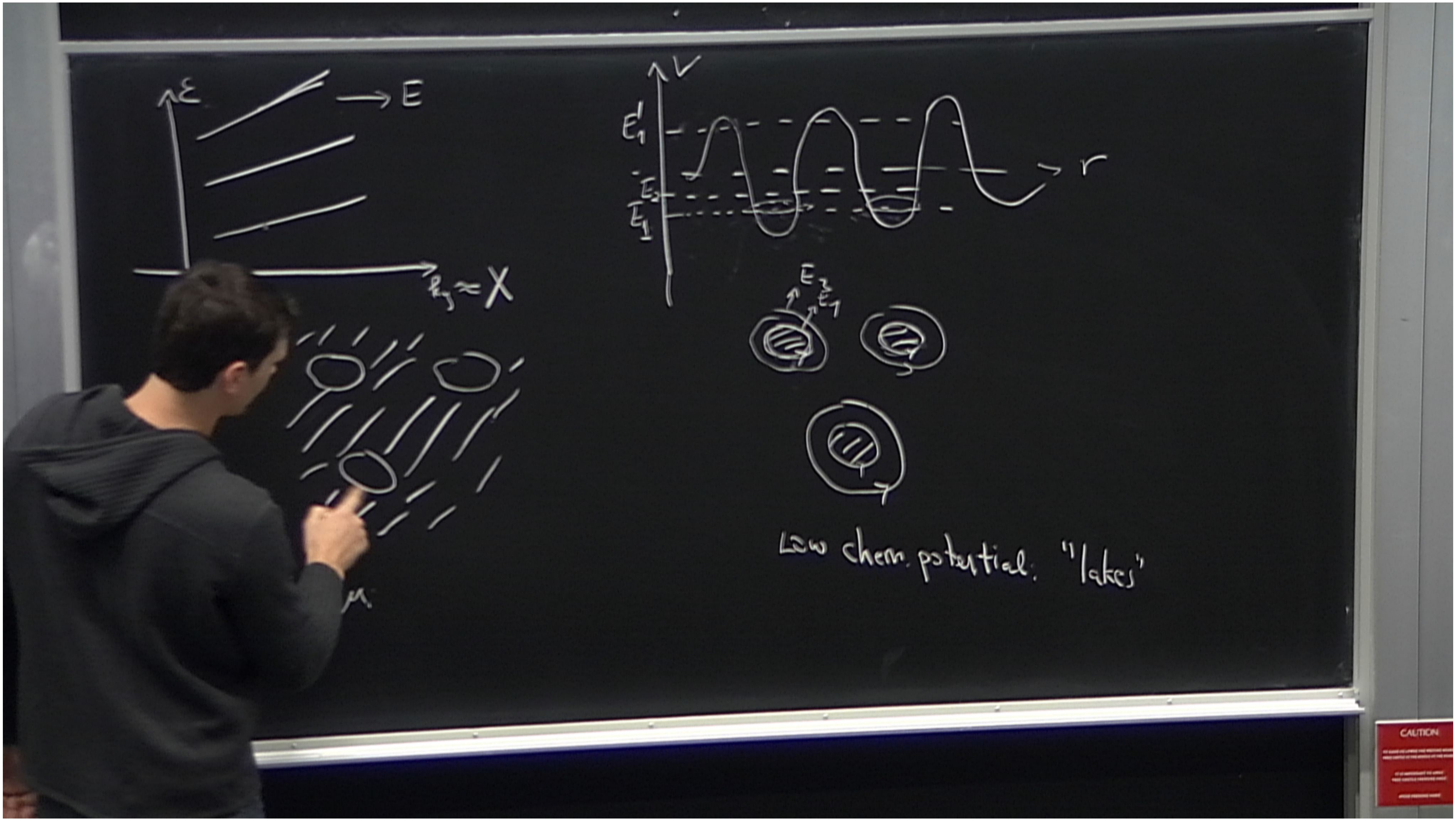

ε
→ E
$k_y \approx X$


Lecture 3:30-4:30pm (Bob room)
* Is there extended state?

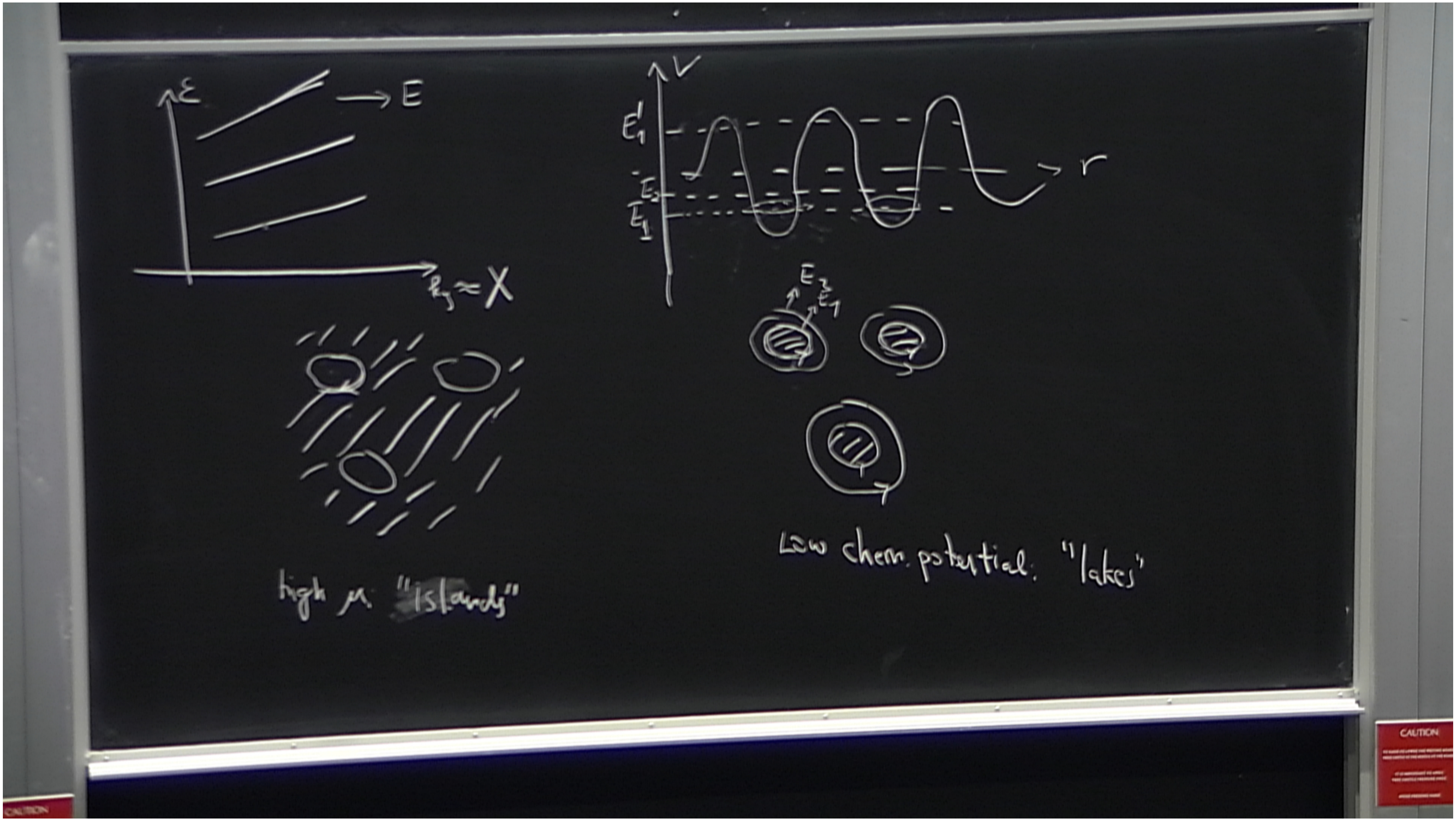


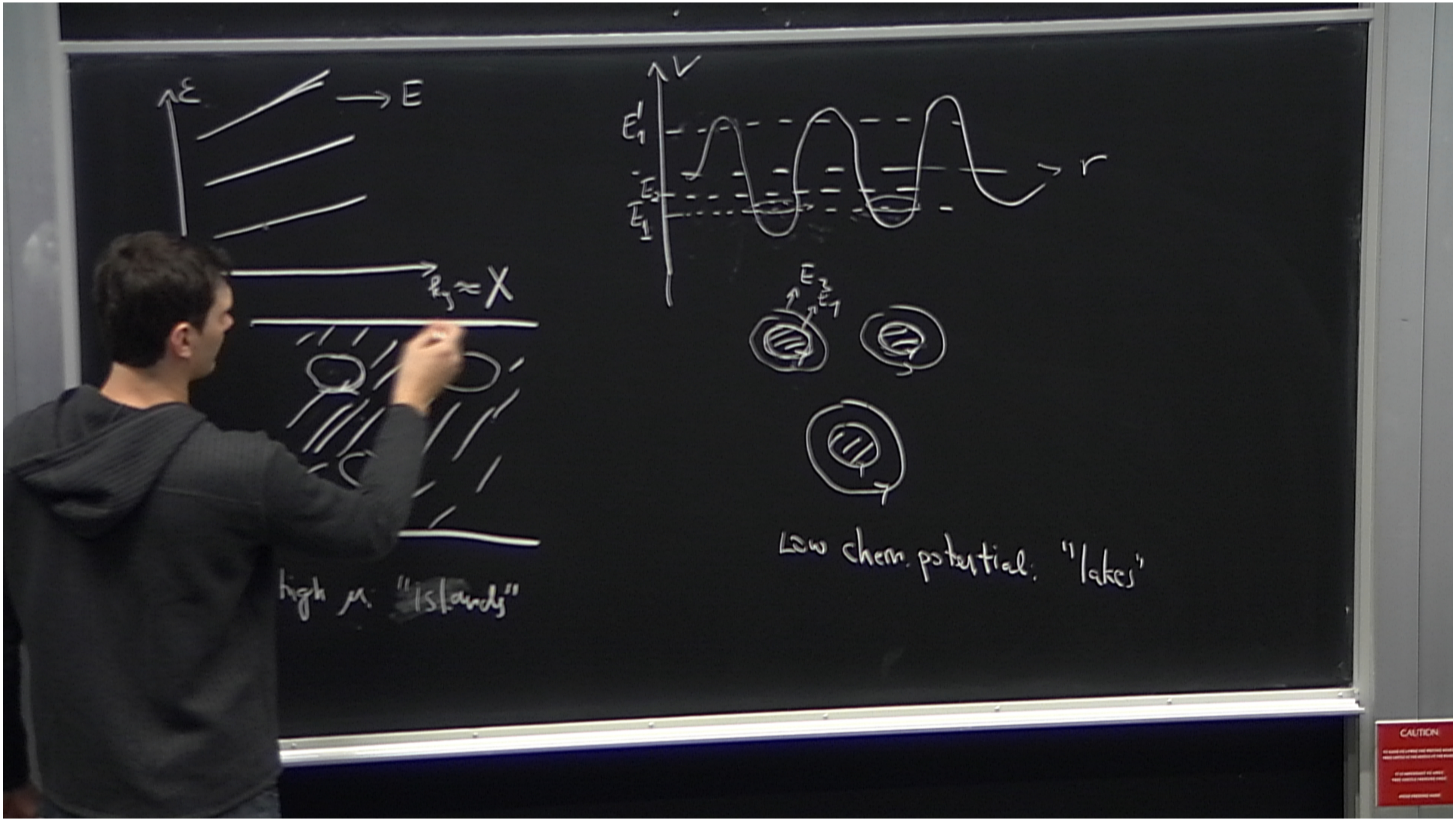
ε
E
$k_y \approx X$
V
r

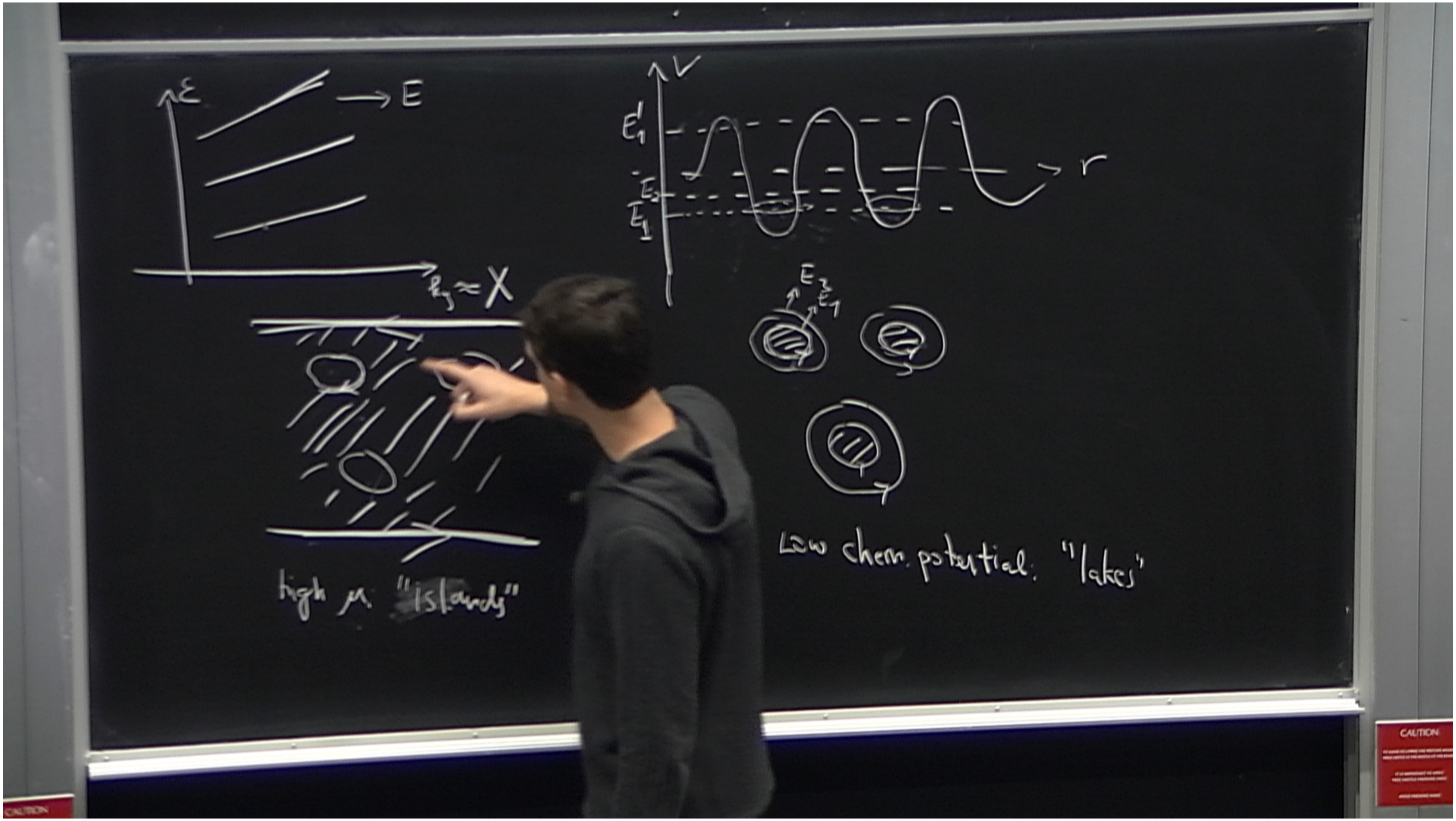

E
E
X
V
r
Low chem. potential: "lakes"



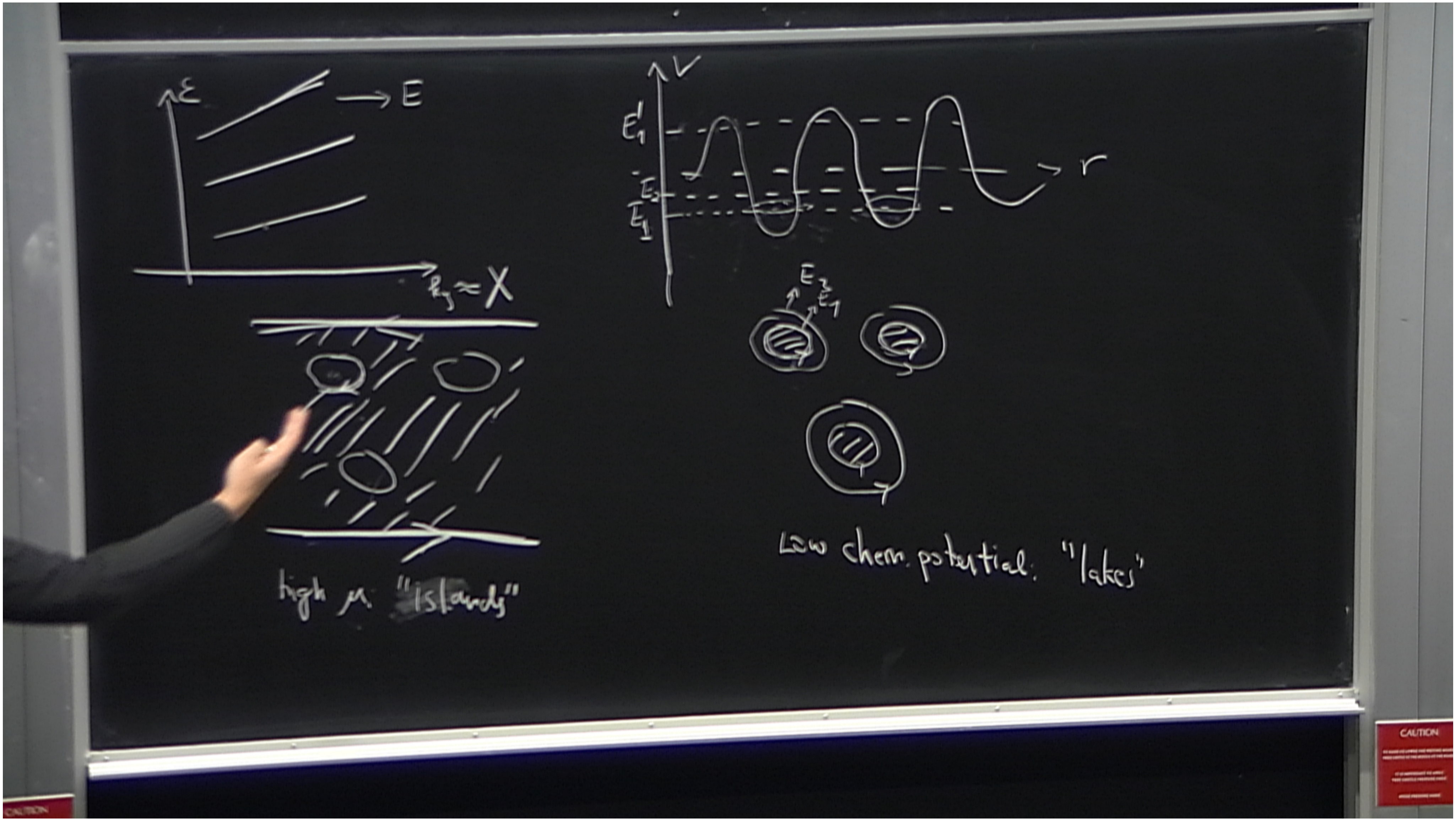
E
$k_y \approx X$
V
r
Low chem. potential: "lakes"


high μ: "Islands"
Low chem. potential: "lakes"

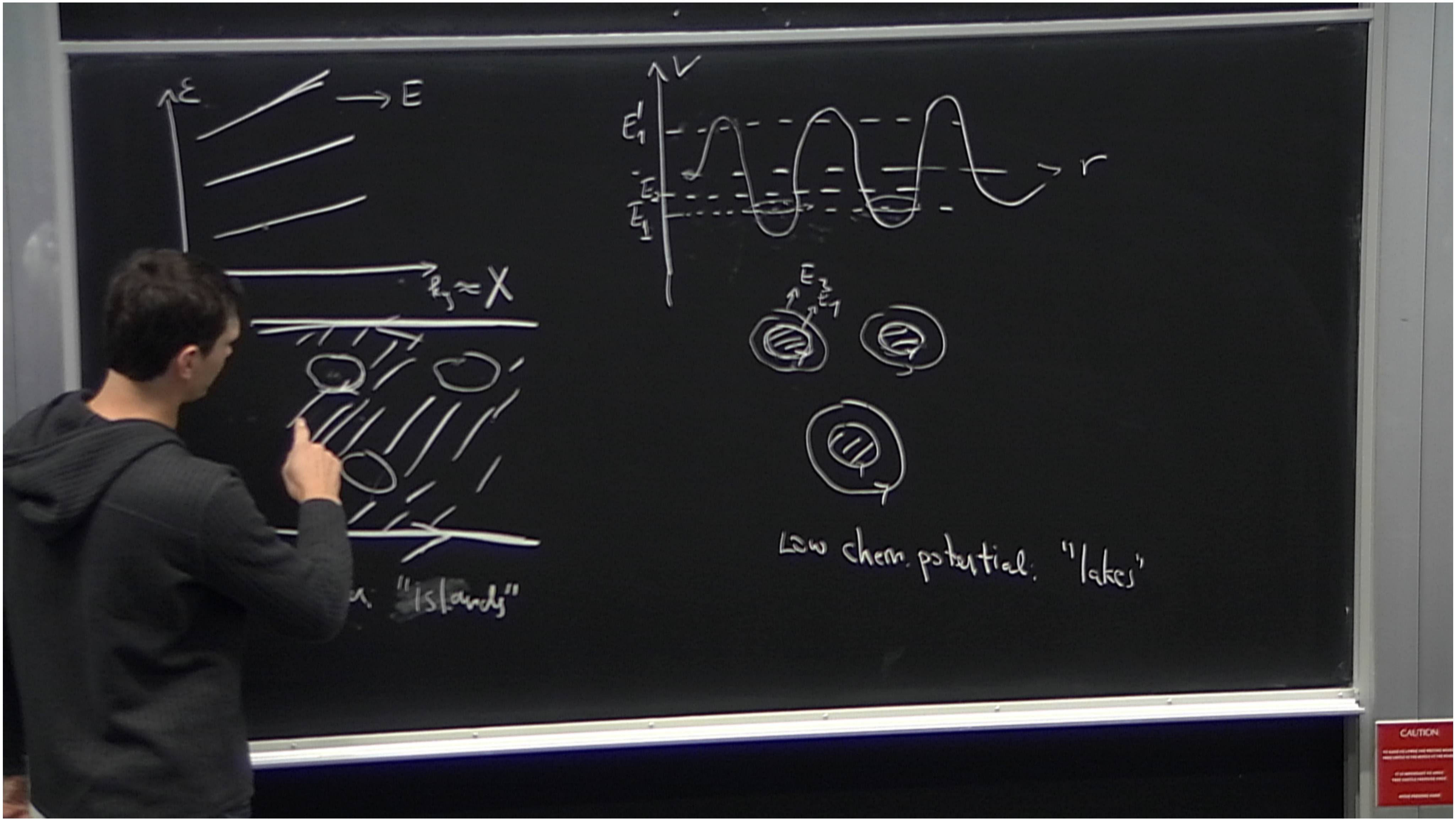

E
r
Low chem. potential: "lakes"
high μ: "islands"



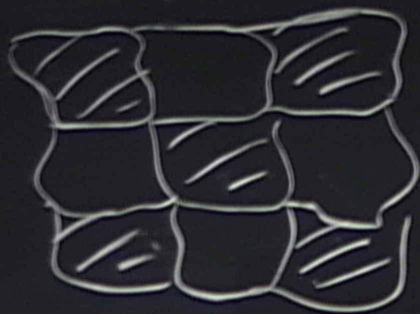
→ E
Low chem. potential: "lakes"
high μ: "islands"



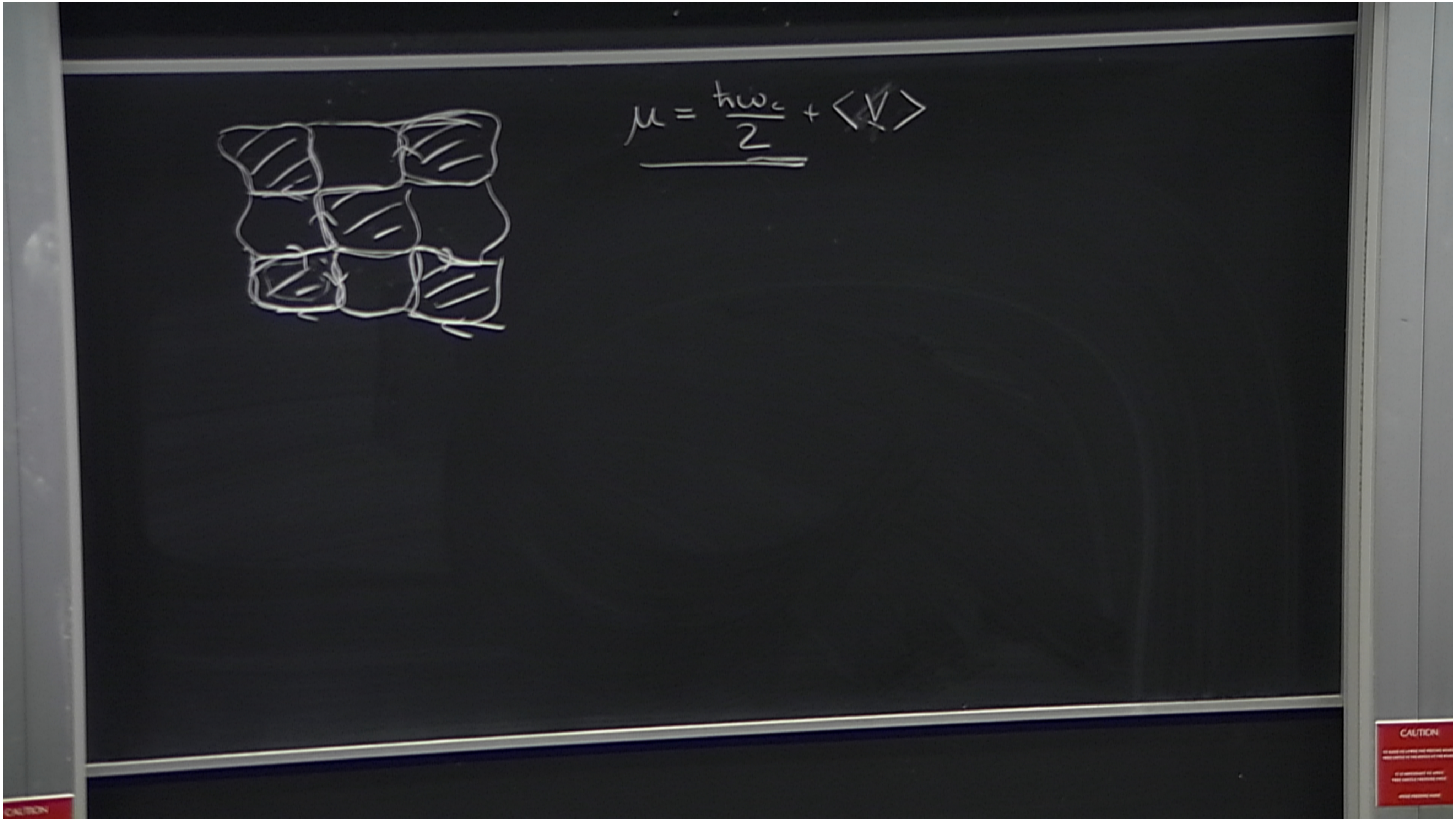
E
high μ: "islands"
r
Low chem. potential: "lakes"

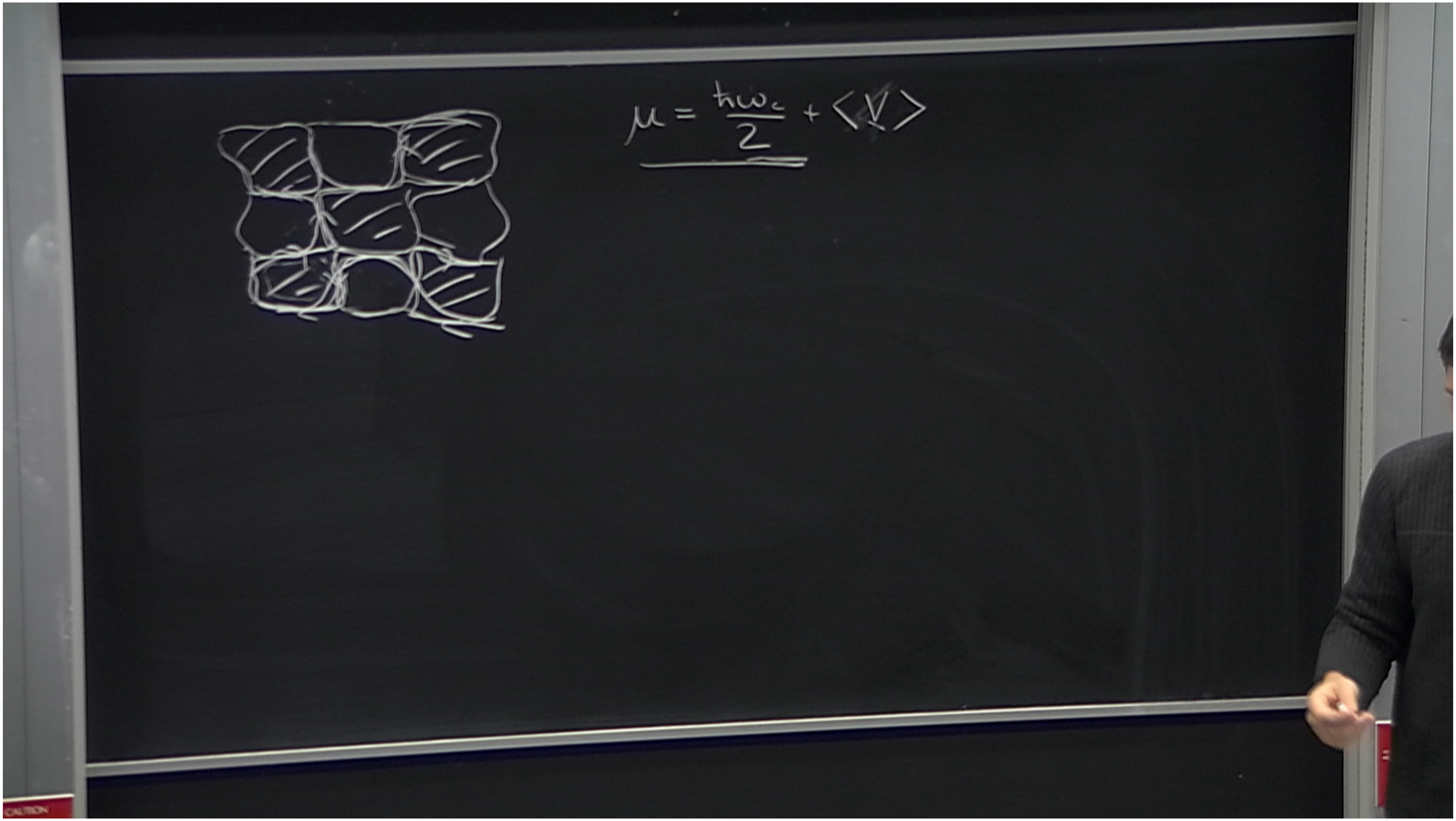


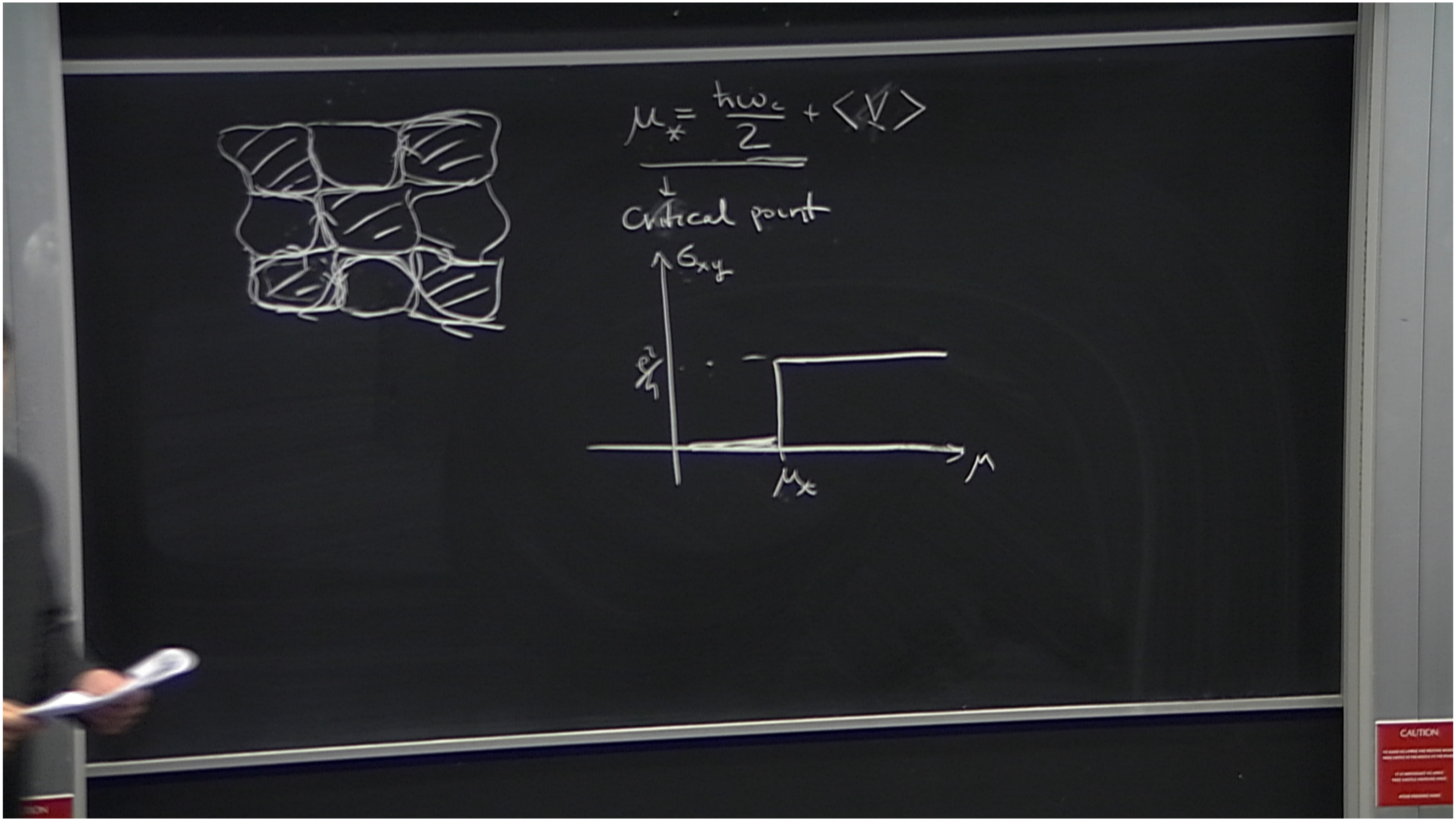
E
V
r
Low chem. potential: "lakes"
"Islands"



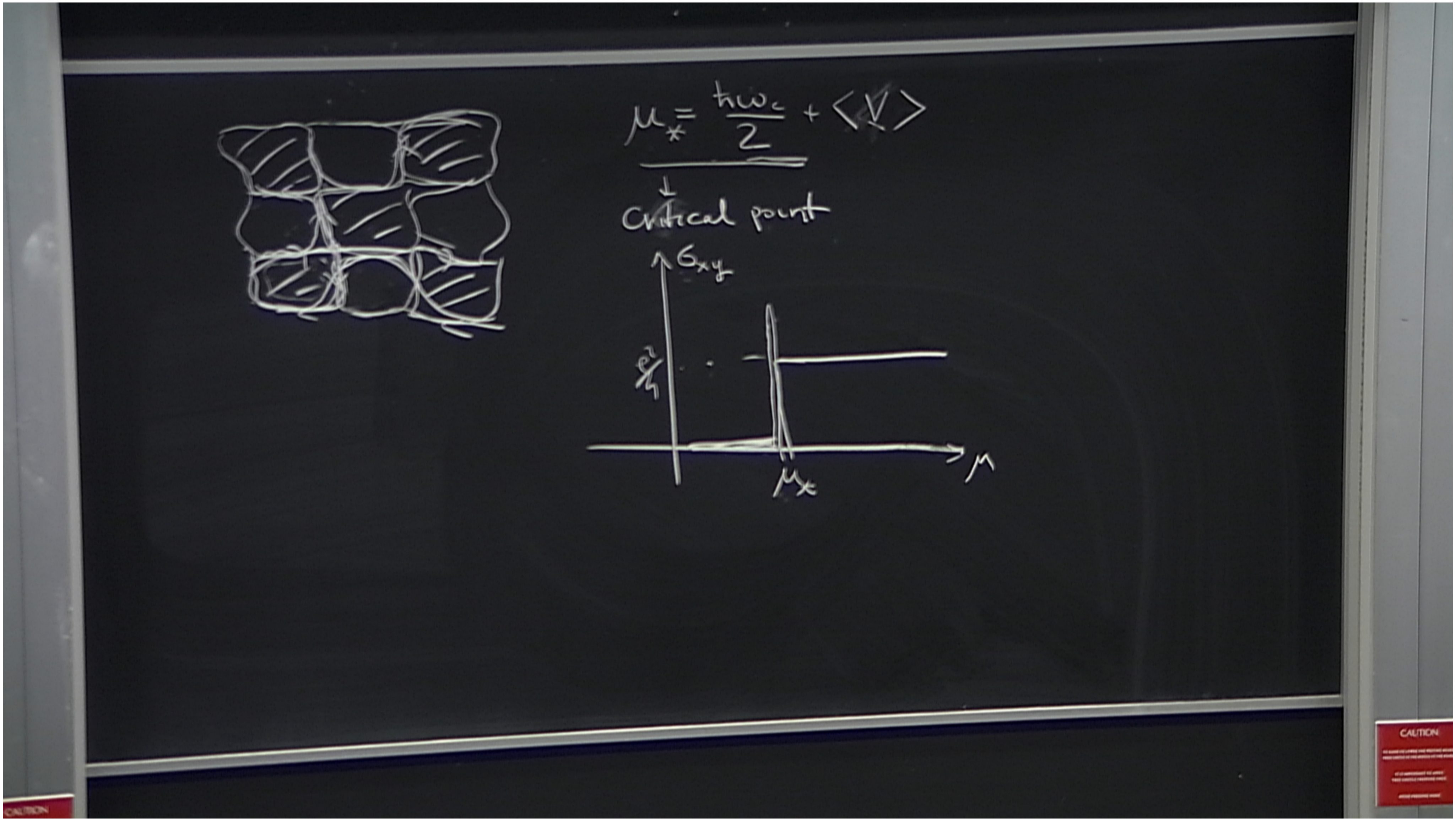
$$\mu = \frac{\hbar\omega_c}{2} + \langle V \rangle$$

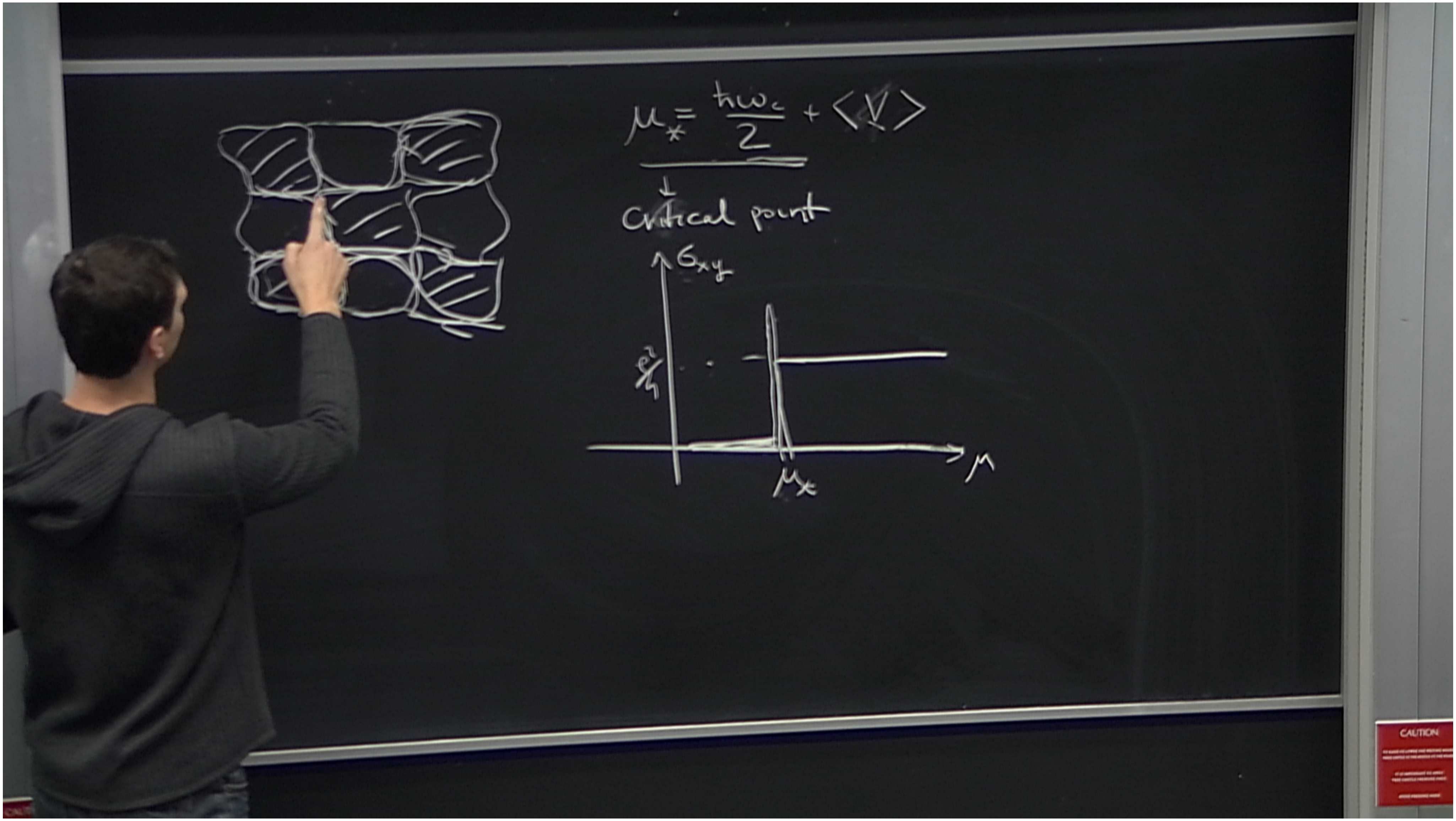

$\mu = \frac{\hbar\omega_c}{2} + \langle V \rangle$


$\mu = \frac{\hbar\omega_c}{2} + \langle V \rangle$

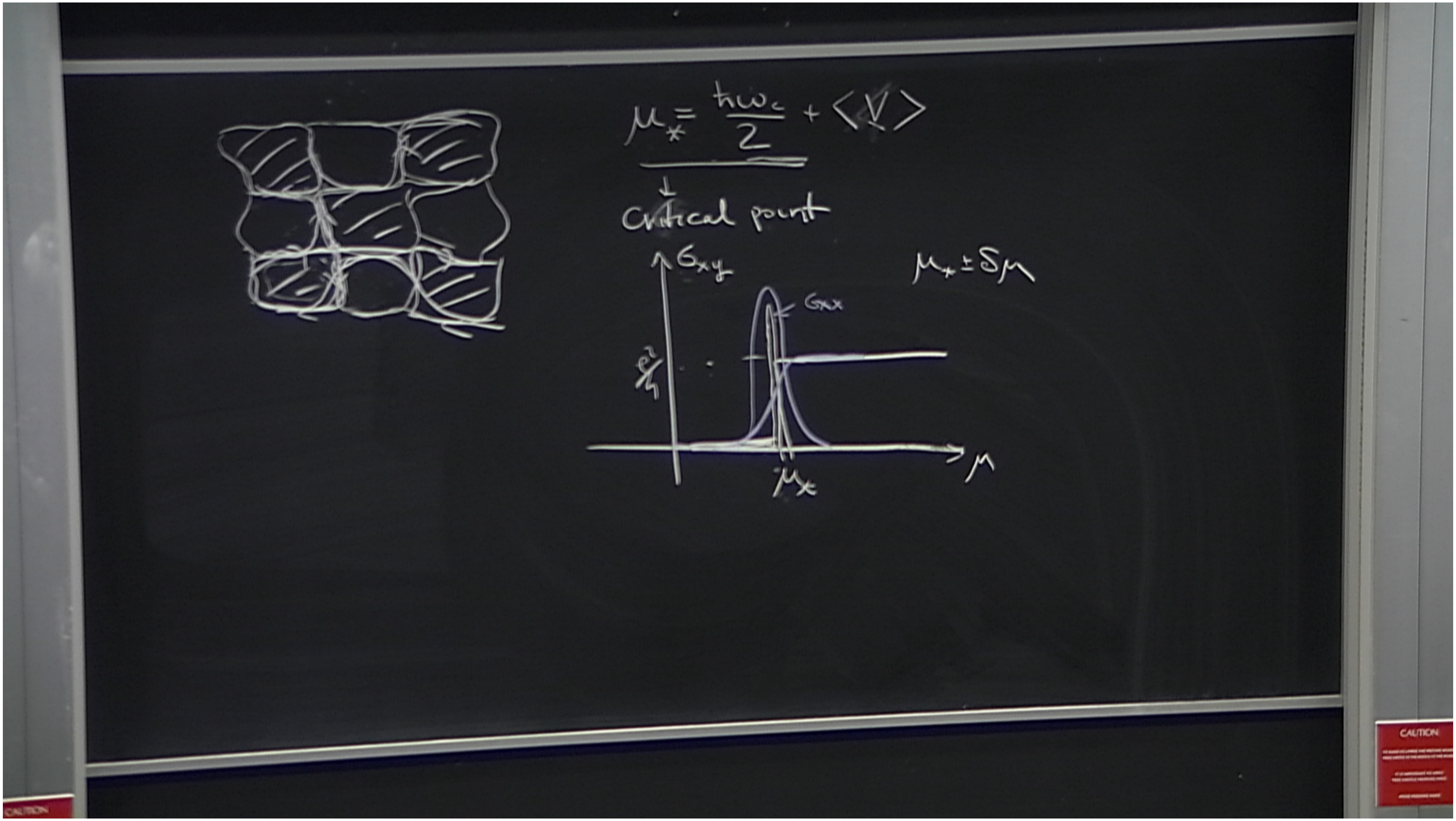


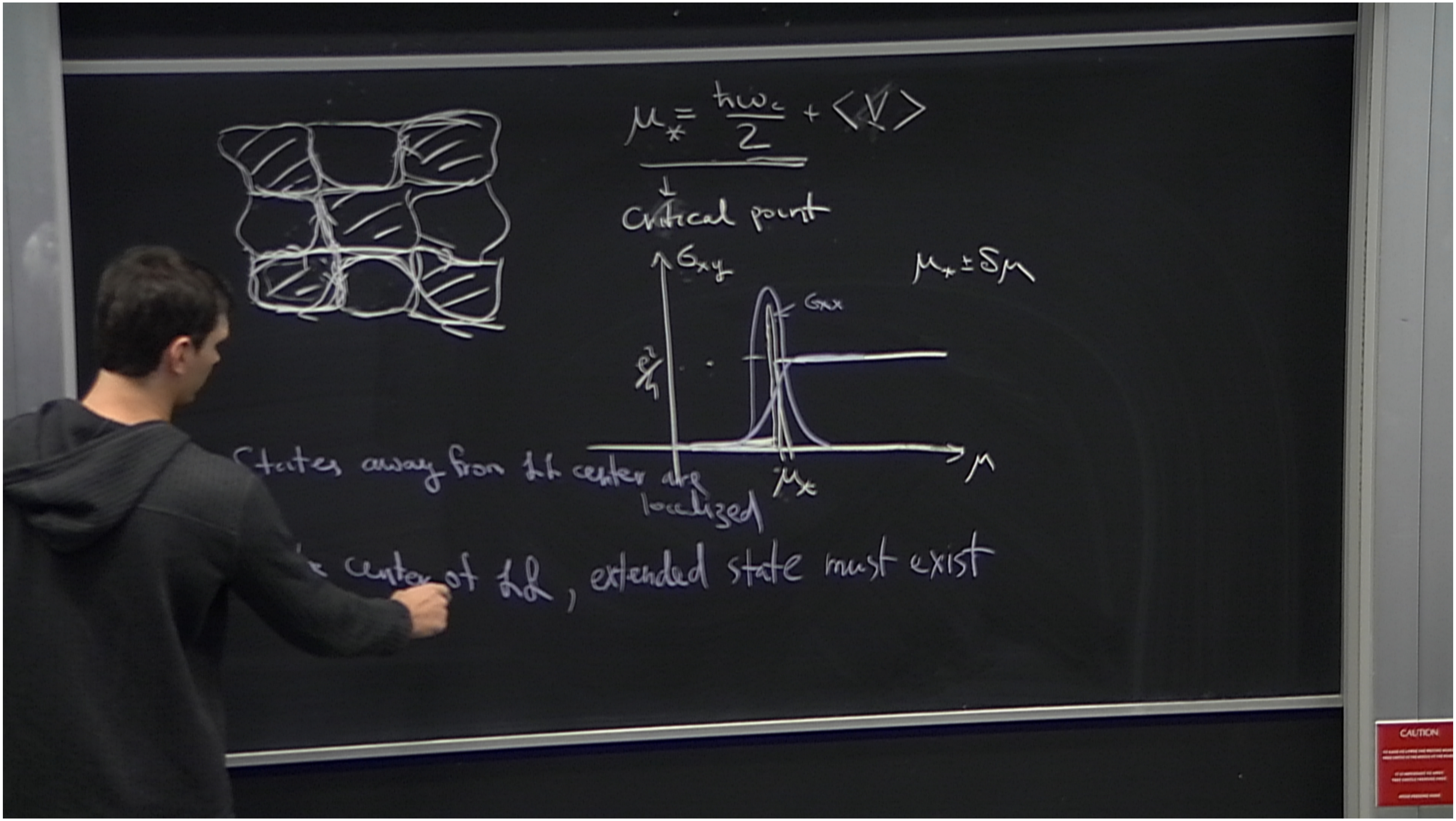
μ* = ħω_c/2 + ⟨V⟩
critical point
σ_xy
e²/h
μ*
μ


$\mu_* = \frac{\hbar\omega_c}{2} + \langle V \rangle$
critical point
σ_{xy}
$\frac{e^2}{h}$
μ_*
μ
CAUTION

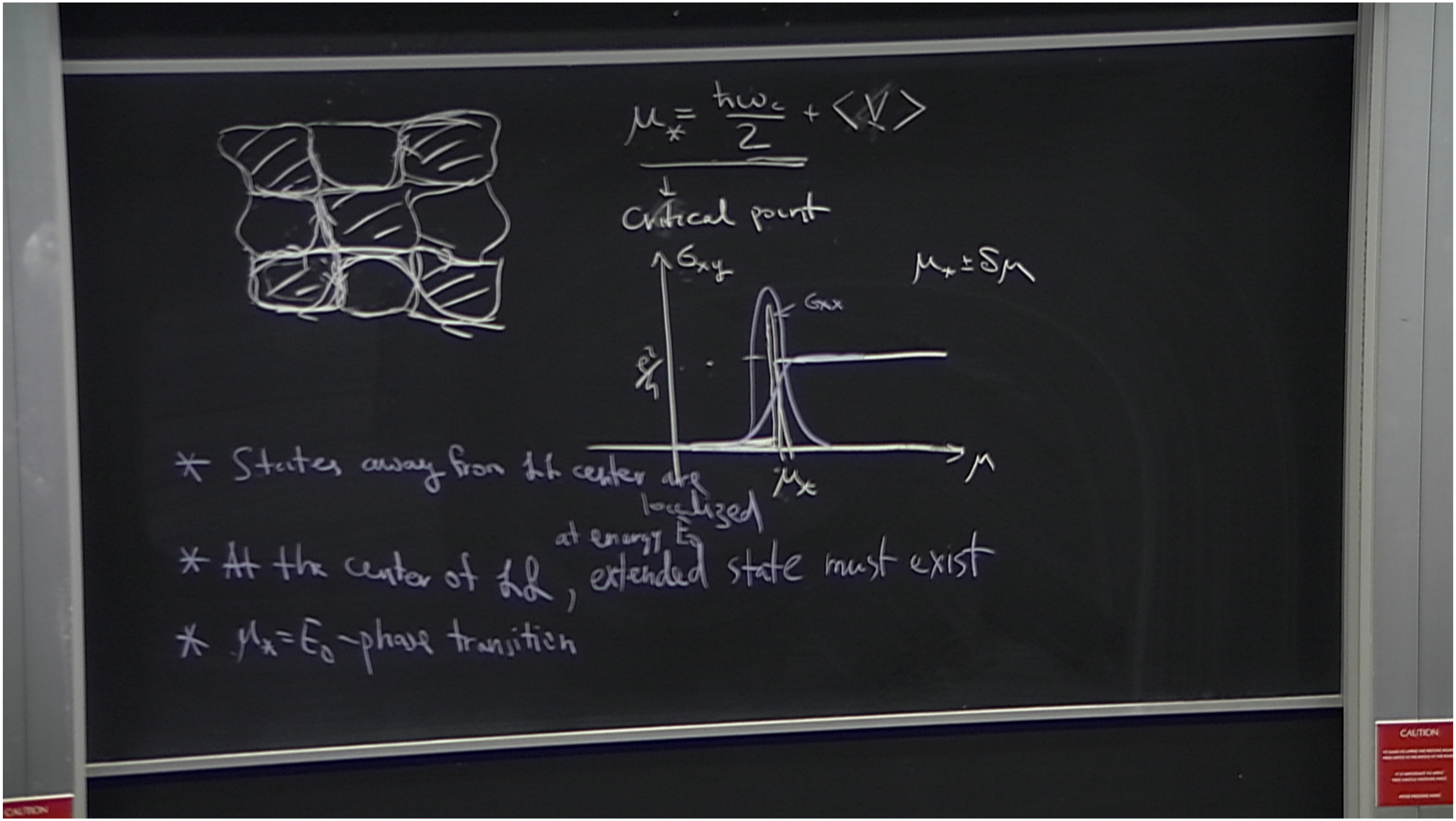


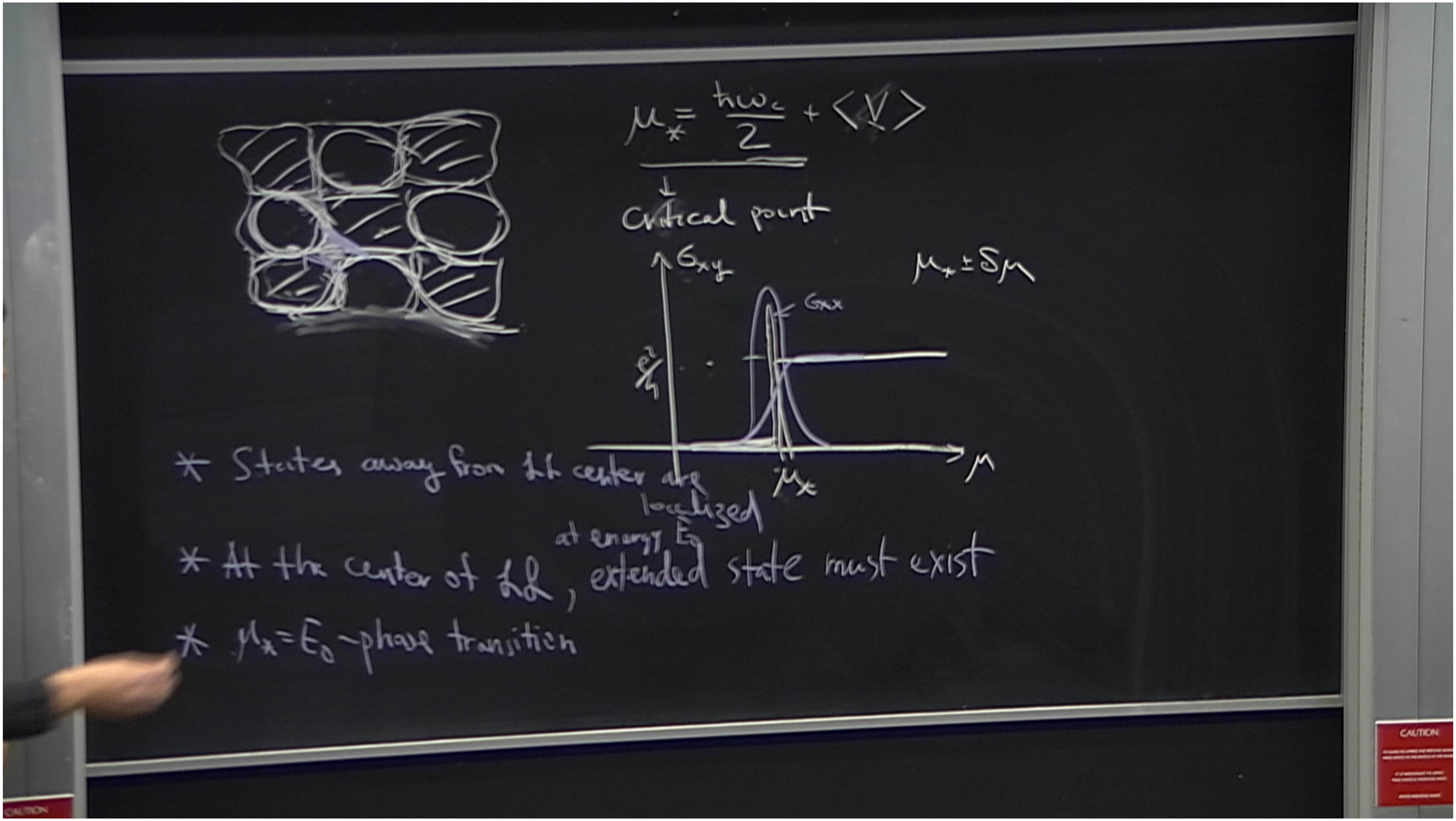
$\mu_* = \frac{\hbar\omega_c}{2} + \langle V \rangle$
critical point
σ_{xy}
$\frac{e^2}{h}$
μ_*
μ
CAUTION

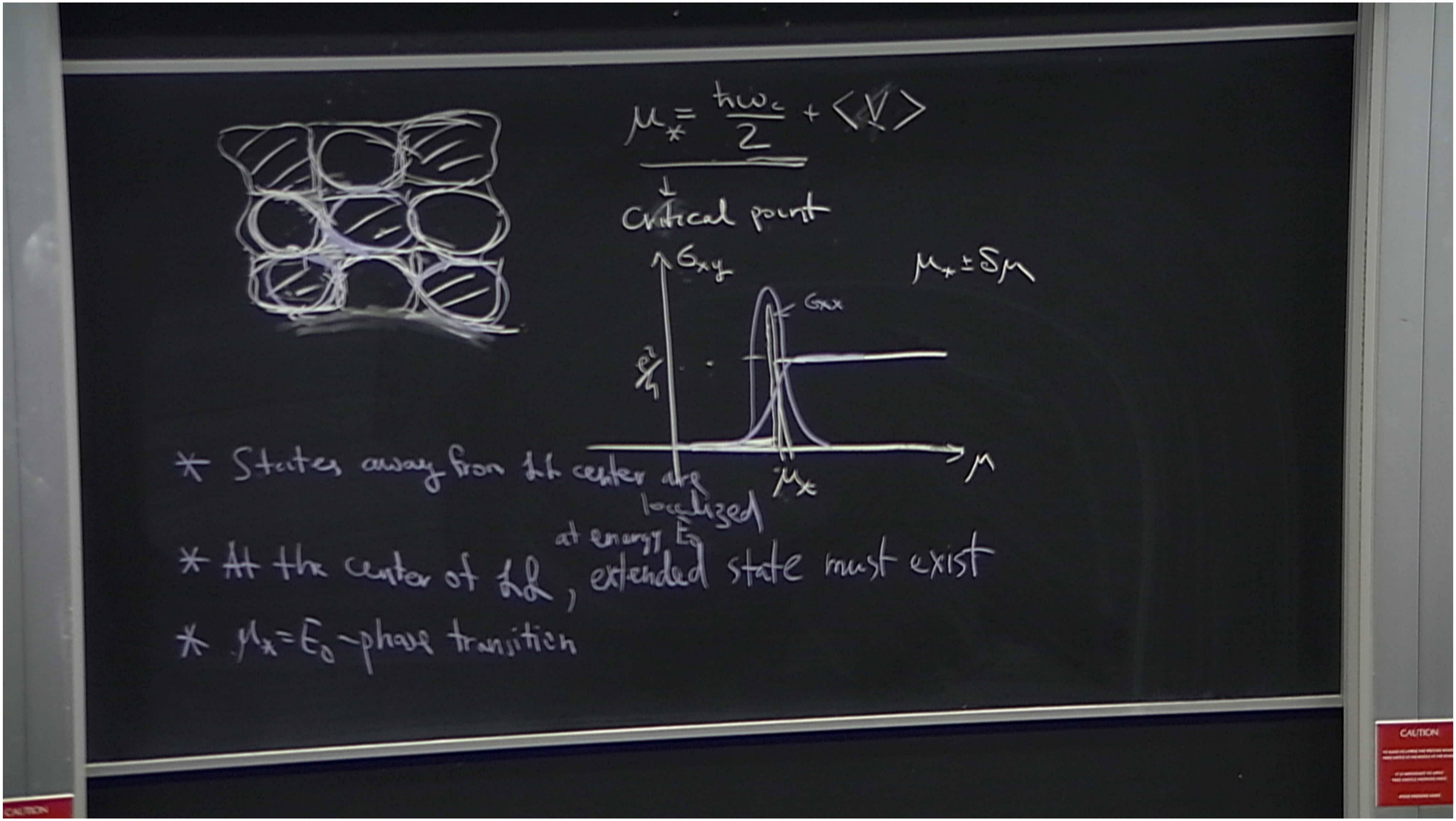

$\mu_* = \frac{\hbar\omega_c}{2} + \langle V \rangle$
critical point
σ_{xy}
$\mu_* \pm \delta\mu$
σ_{xx}
$\frac{e^2}{h}$
μ_*
μ
CAUTION

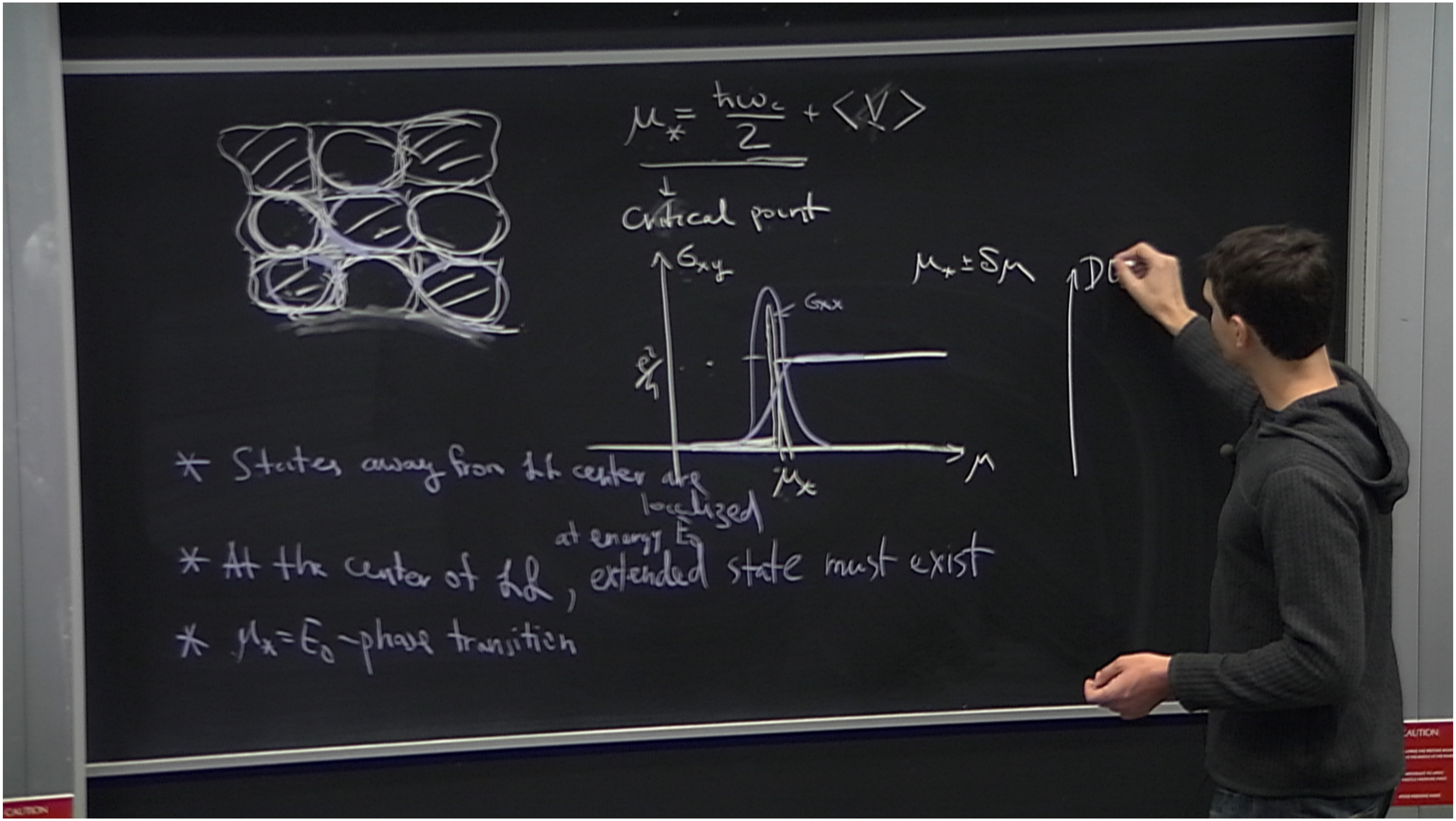


μ* = ħω_c/2 + ⟨V⟩
critical point
σxy
μ* ± δμ
σxx
e²/h
μ
μ*
States away from LL center are localized
center of LL, extended state must exist

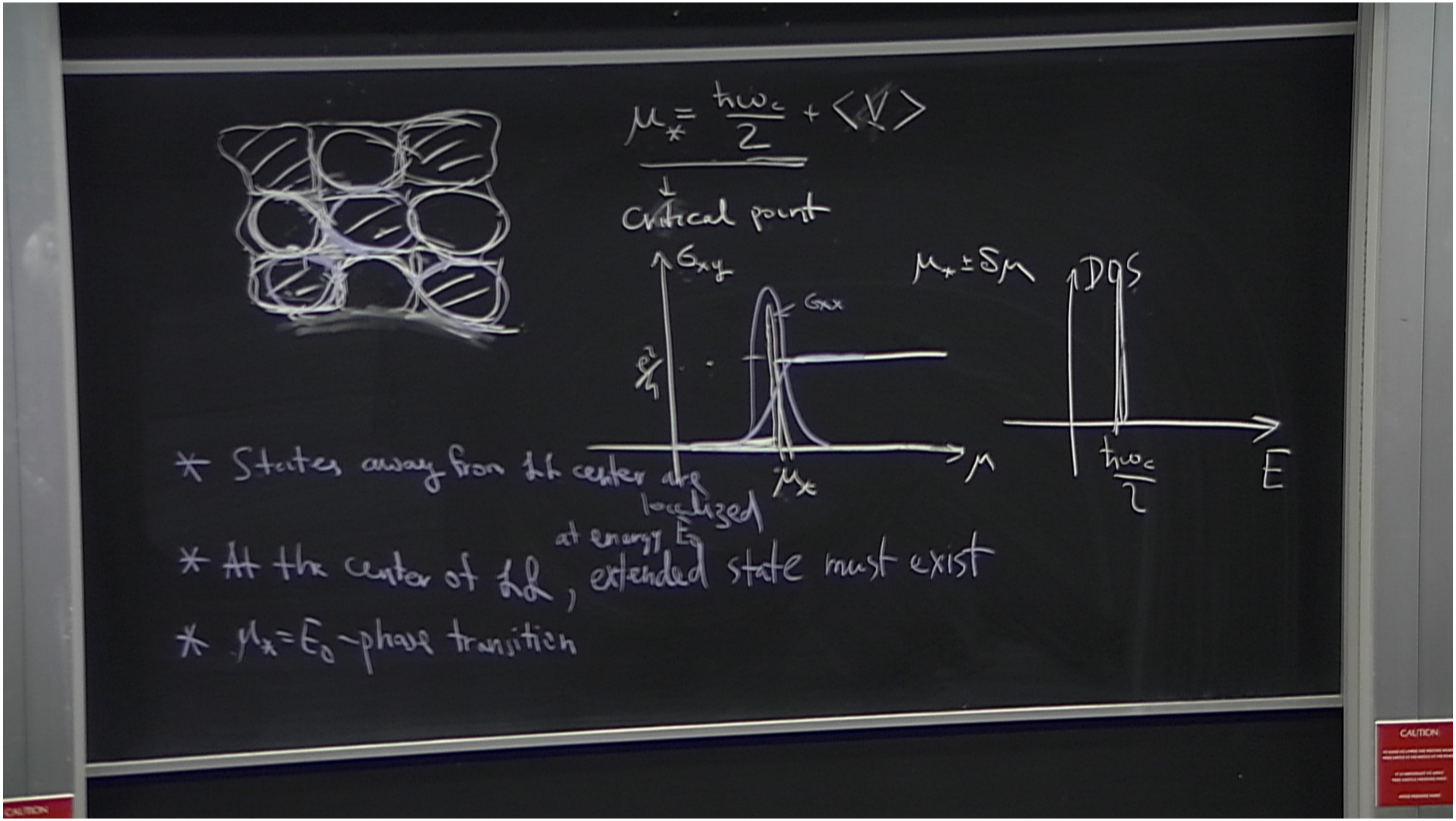

μ* = ħω_c/2 + ⟨V⟩
critical point
μ* ± δμ
σxy
σxx
e²/h
μ*
μ
* States away from LL center are localized
* At the center of LL, extended state must exist at energy E0
* μ* = E0 − phase transition
CAUTION

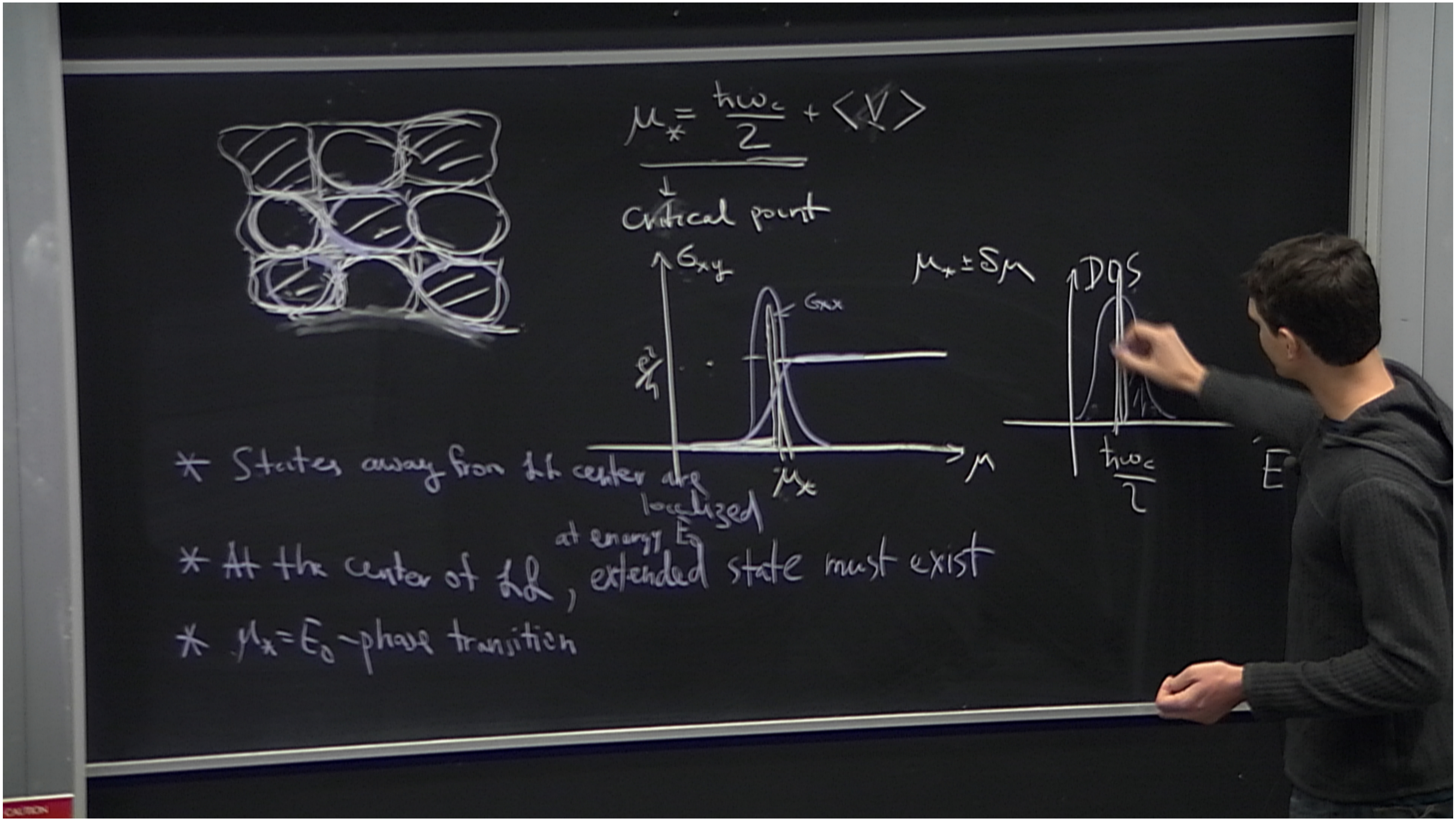

μ* = ħω_c/2 + ⟨V⟩
critical point
σxy
σxx
μ* ± δμ
e²/h
μ*
μ
* States away from LL center are localized
* At the center of LL, extended state must exist at energy E0
* μ* = E0 — phase transition


$\mu_* = \frac{\hbar\omega_c}{2} + \langle V \rangle$
critical point
σ_{xy}
σ_{xx}
$\frac{e^2}{h}$
μ_*
μ
$\mu_* \pm \delta\mu$
* States away from LL center are localized
* At the center of LL, extended state must exist at energy E_0
* $\mu_* = E_0$ – phase transition

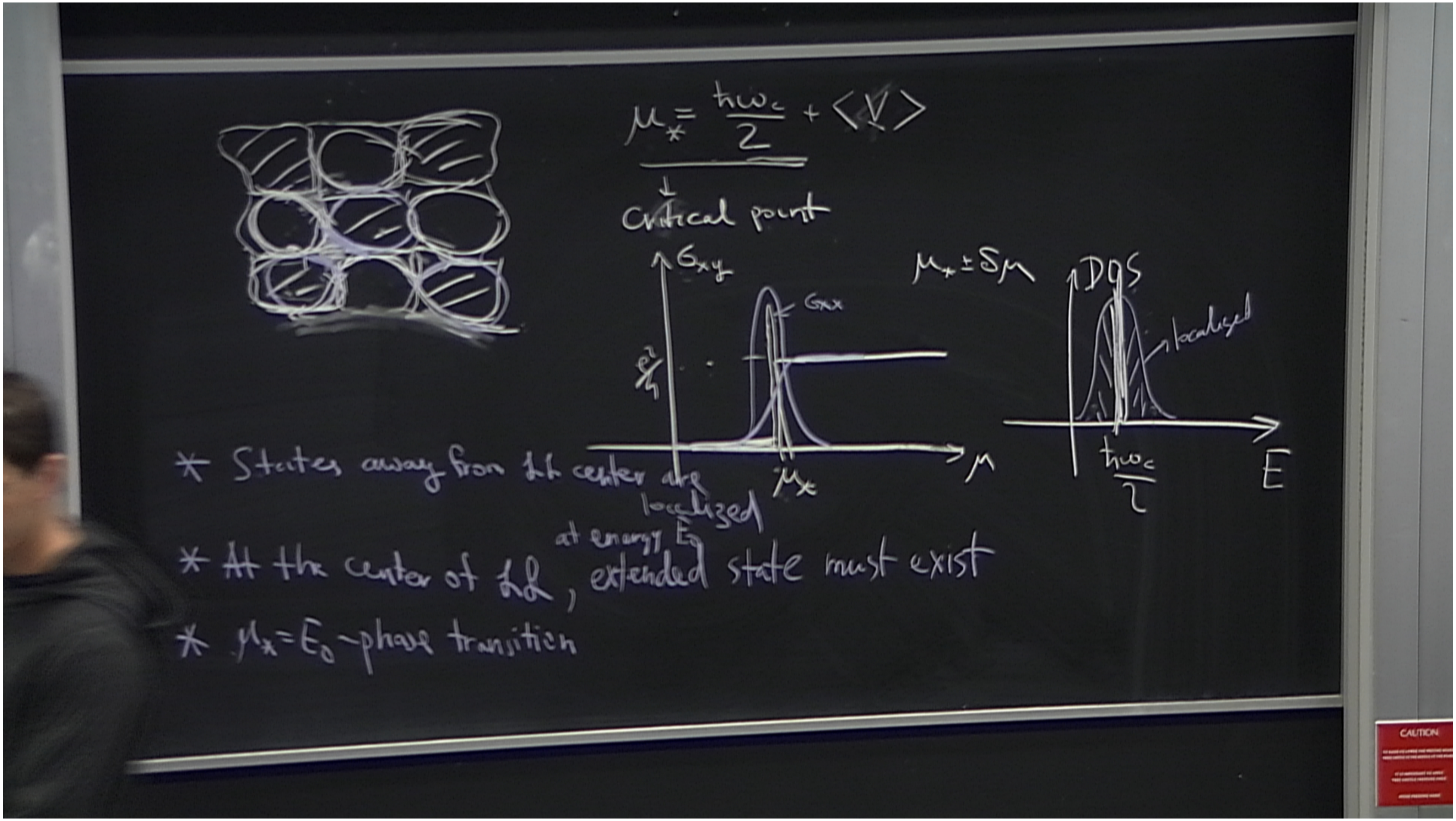


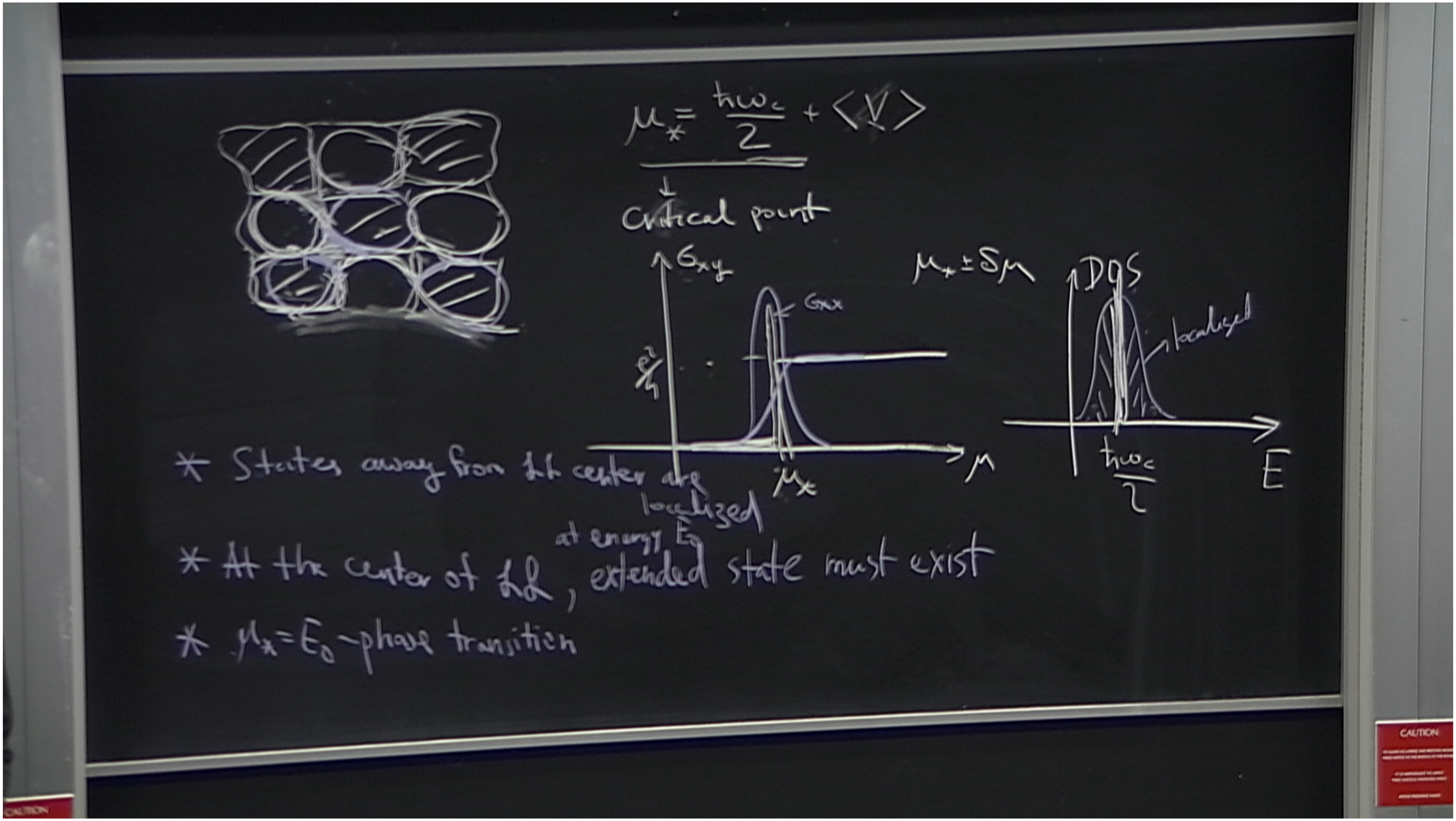
μ* = ħω_c / 2 + ⟨V⟩
Critical point
σxy
σxx
μ* ± δμ
μ
μ*
* States away from LL center are localized
* At the center of LL, extended state must exist
at energy E0
* μ* = E0 – phase transition

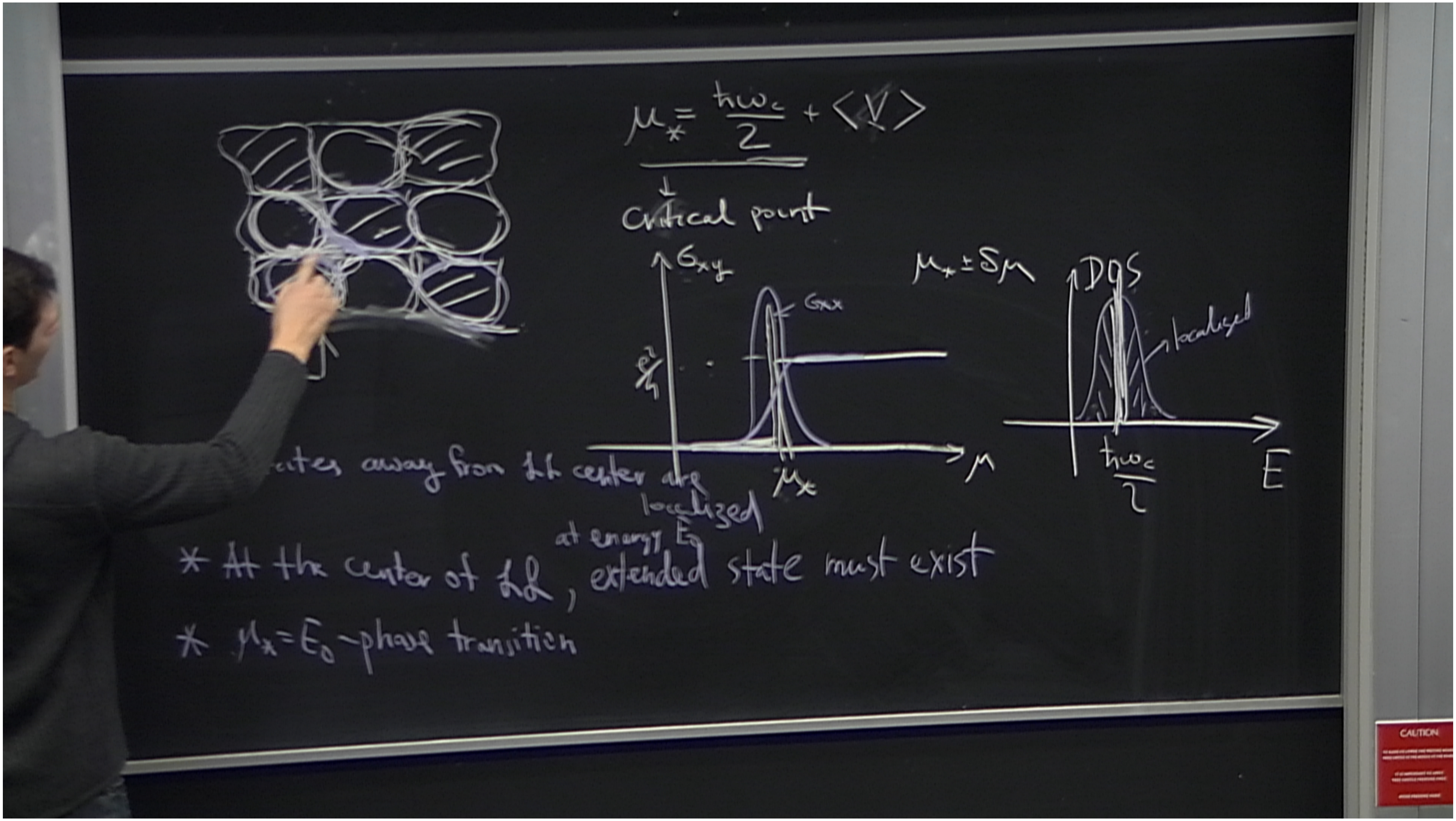

$\mu_* = \frac{\hbar\omega_c}{2} + \langle V \rangle$
critical point
σ_{xy}
σ_{xx}
$\frac{e^2}{h}$
μ
μ_*
$\mu_* \pm \delta\mu$
DOS
$\frac{\hbar\omega_c}{2}$
E
* States away from LL center are localized
* At the center of LL, at energy E_0, extended state must exist
* $\mu_* = E_0$ – phase transition



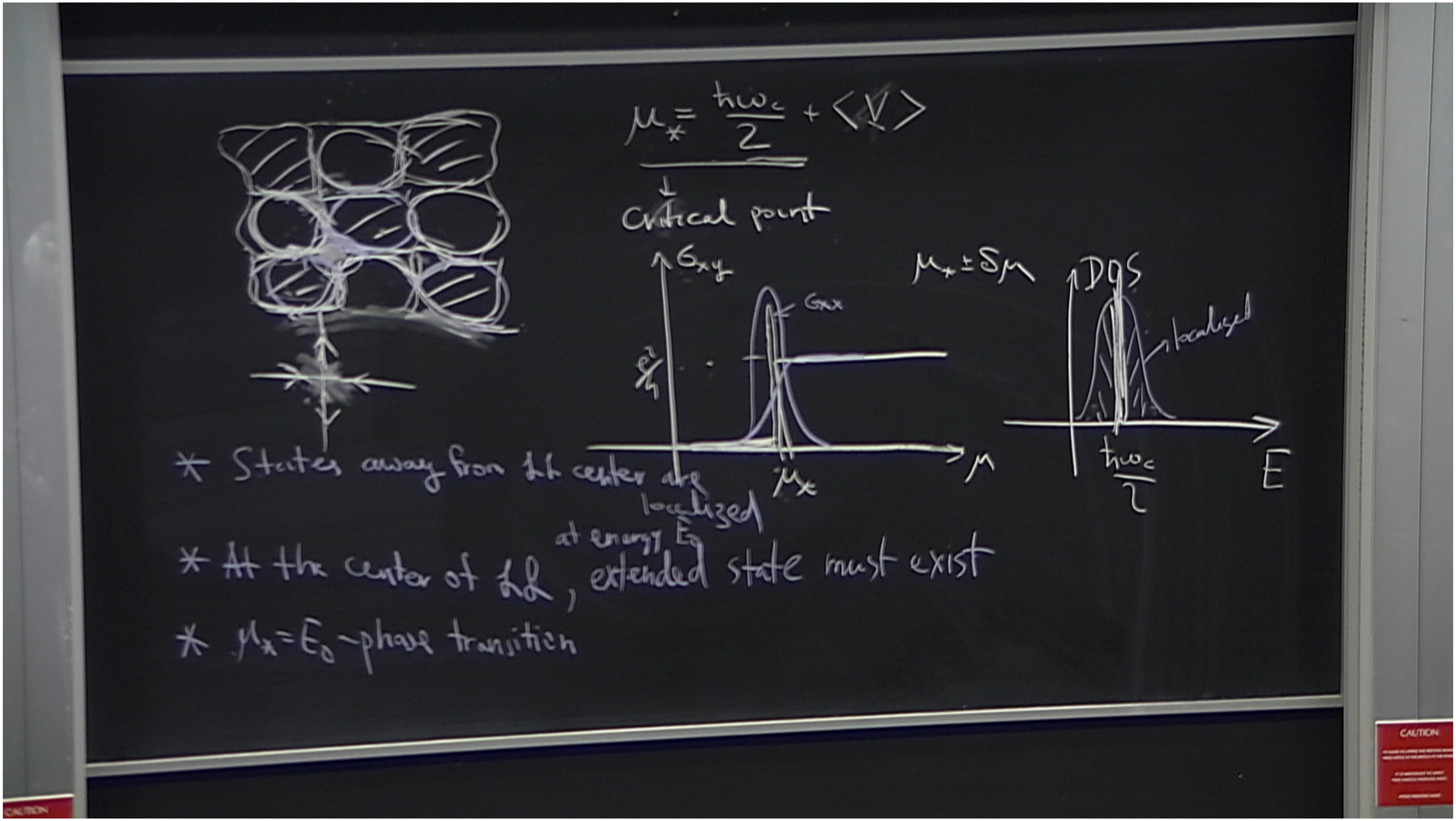
μ* = ħω_c/2 + ⟨V⟩
critical point
σxy
σxx
μ*
μ
μ* ± δμ
DOS
ħω_c/2
E
* States away from LL center are localized
* At the center of LL, extended state must exist at energy E₀
* μ* = E₀ - phase transition

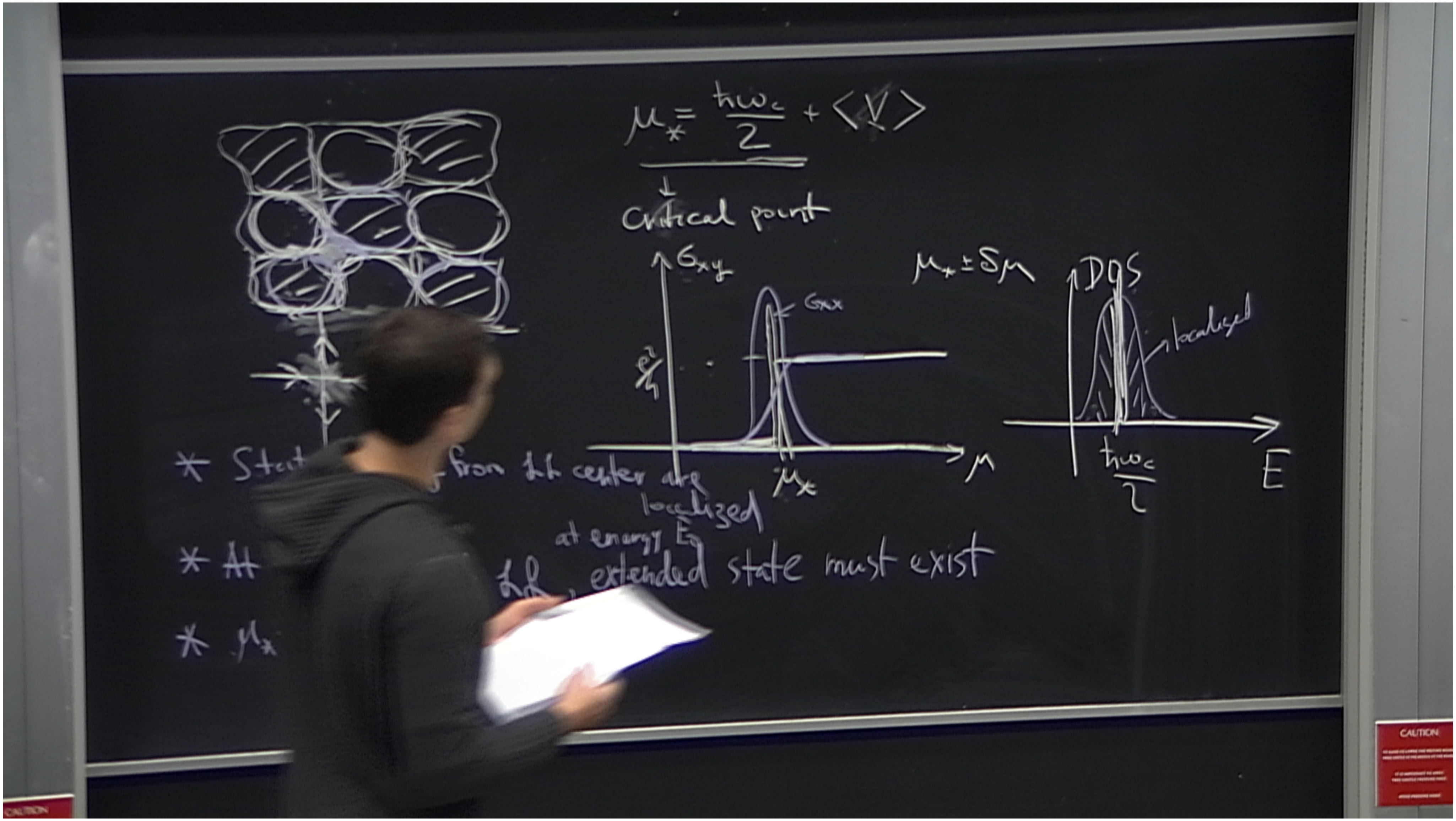

μ* = ħω_c/2 + ⟨V⟩
Critical point
σxy
σxx
e²/h
μ*
μ
μ* ± δμ
DOS
localized
ħω_c/2
E
* States away from LL center are localized
at energy E0
* At the center of LL, extended state must exist
* μ* = E0 - phase transition


$\mu_* = \frac{\hbar\omega_c}{2} + \langle V \rangle$
Critical point
σ_{xy}
σ_{xx}
$\frac{e^2}{h}$
μ
μ_*
$\mu_* \pm \delta\mu$
DOS
localized
$\frac{\hbar\omega_c}{2}$
E
* States away from LL center are localized
* At the center of LL at energy E_0, extended state must exist
* $\mu_* = E_0$ - phase transition

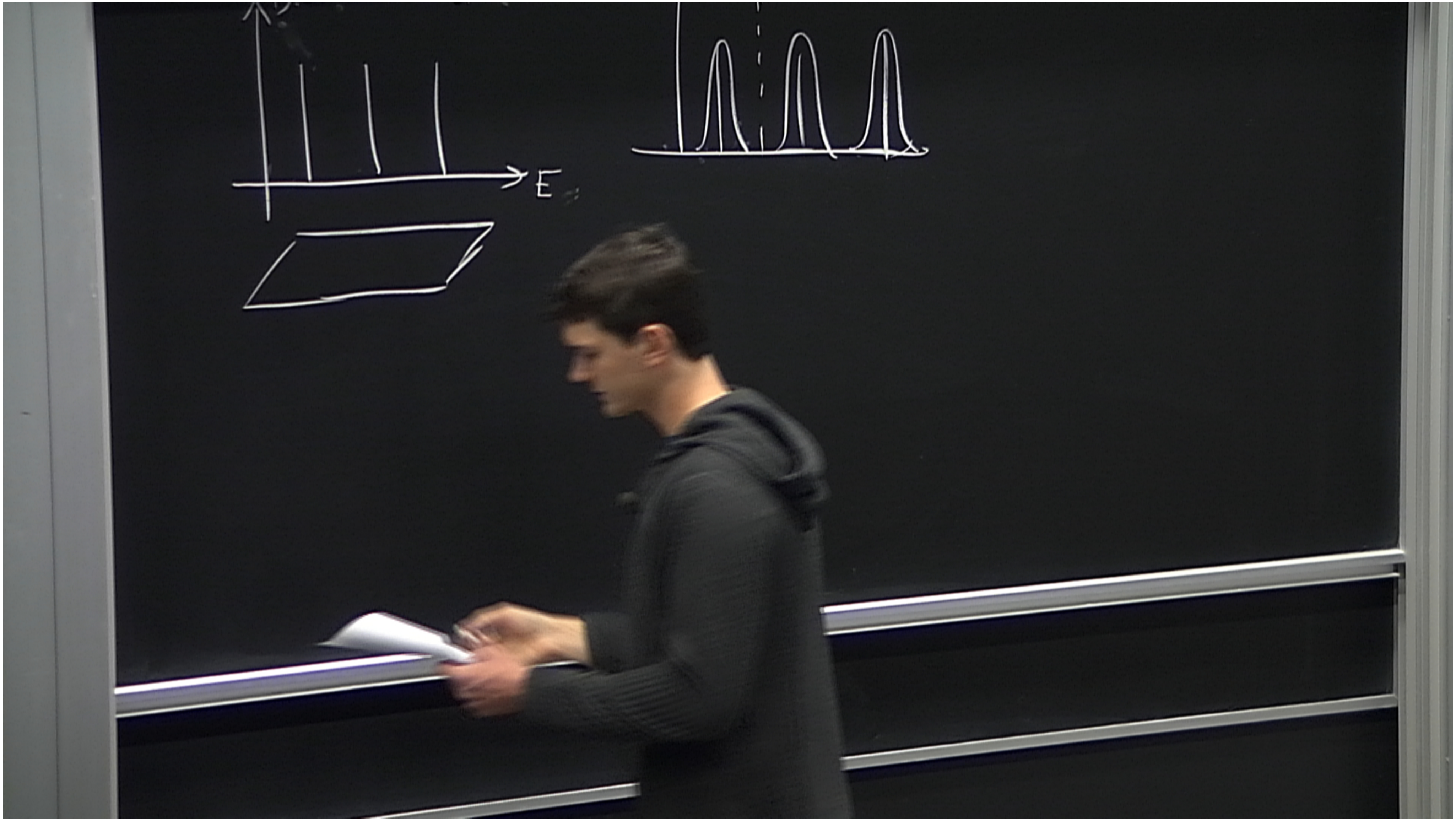


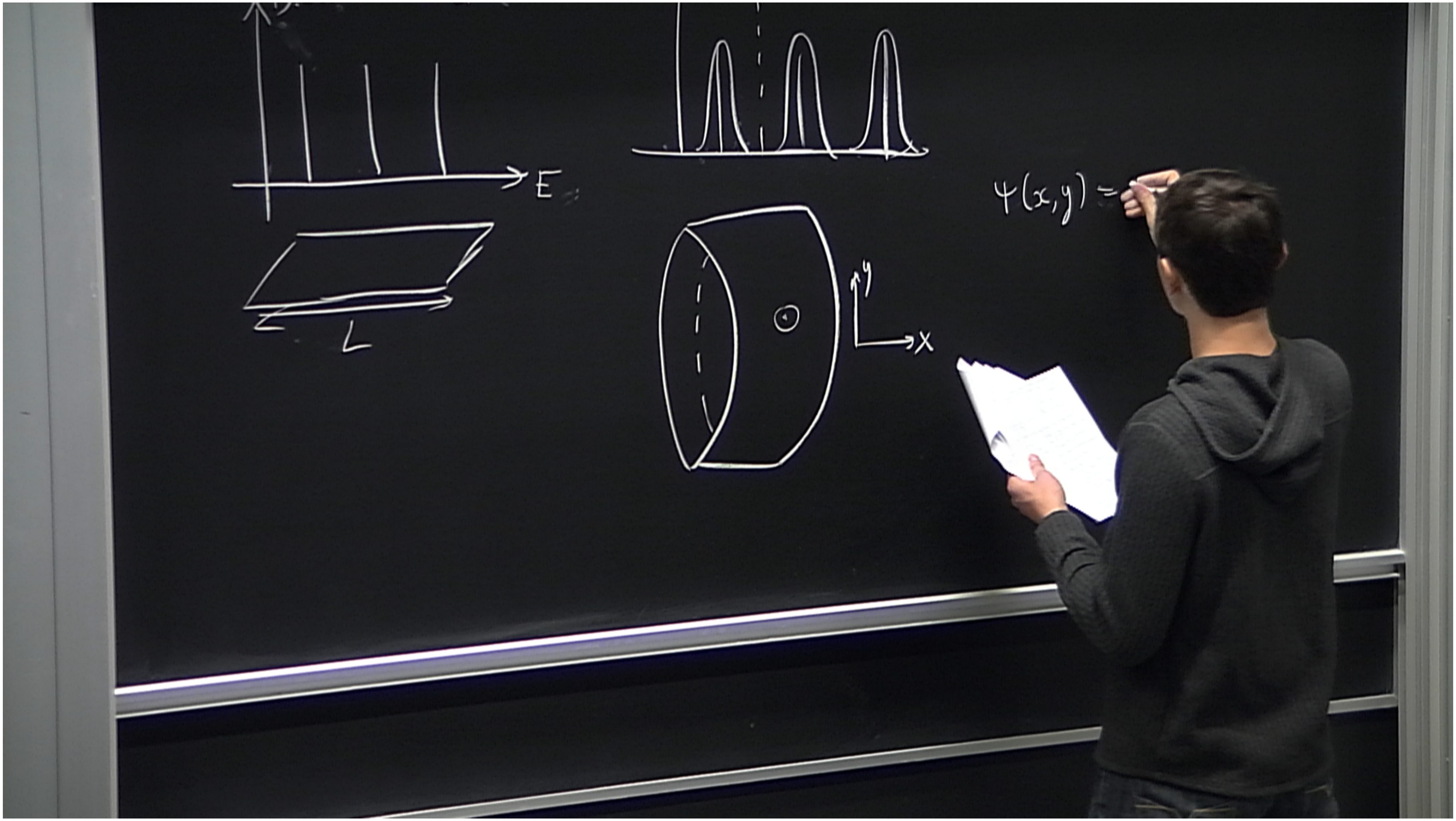
μ* = ħω_c/2 + <V>
critical point
σxy
σxx
μ*
μ
μ* ± δμ
DOS
localized
ħω_c/2
E
...ates away from LL center are localized
* At the center of LL, extended state must exist at energy E0
* μ* = E0 – phase transition


μ* = ħω_c/2 + ⟨V⟩
critical point
σxy
σxx
μ* ± δμ
DOS
localized
μ
μ*
E
ħω_c/2
* States away from LL center are localized
* At the center of LL, at energy E0 extended state must exist
* μ* = E0 - phase transition

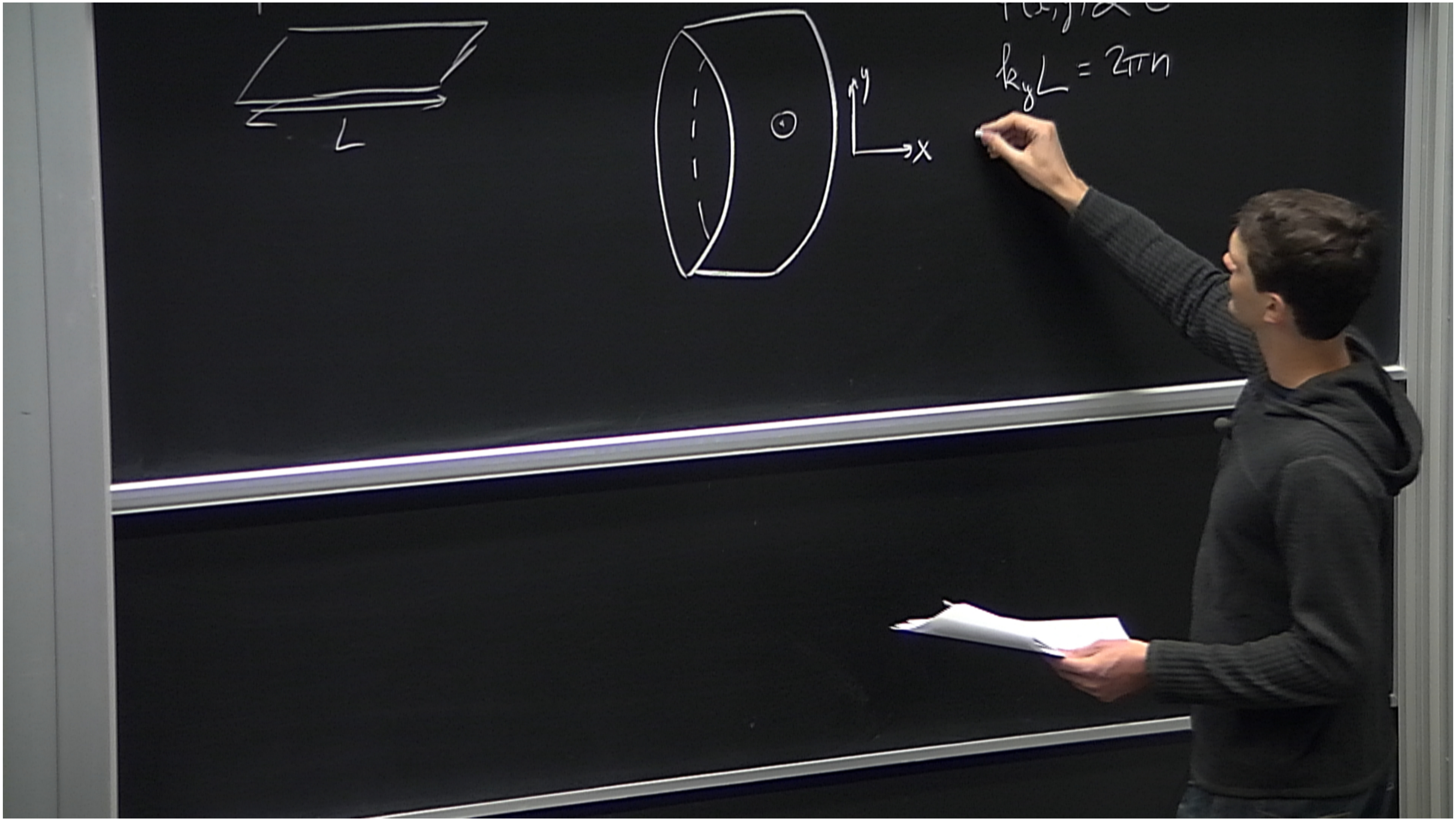


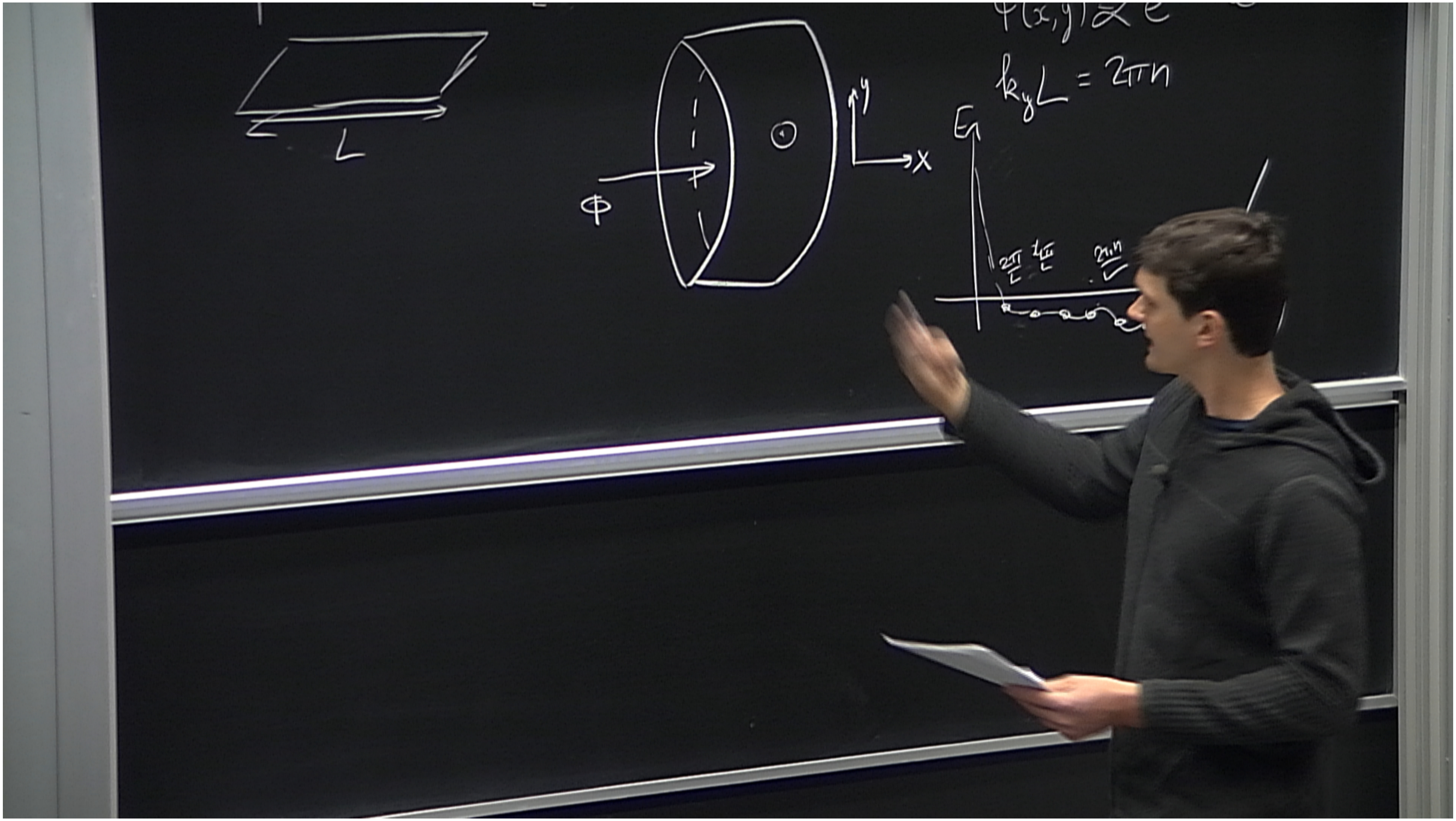
$\mu_* = \frac{\hbar\omega_c}{2} + \langle V \rangle$
critical point
σ_{xy}
σ_{xx}
$\mu_* \pm \delta\mu$
DOS
localized
μ
μ_*
$\frac{\hbar\omega_c}{2}$
E
from the center are localized
at energy
extended state must exist

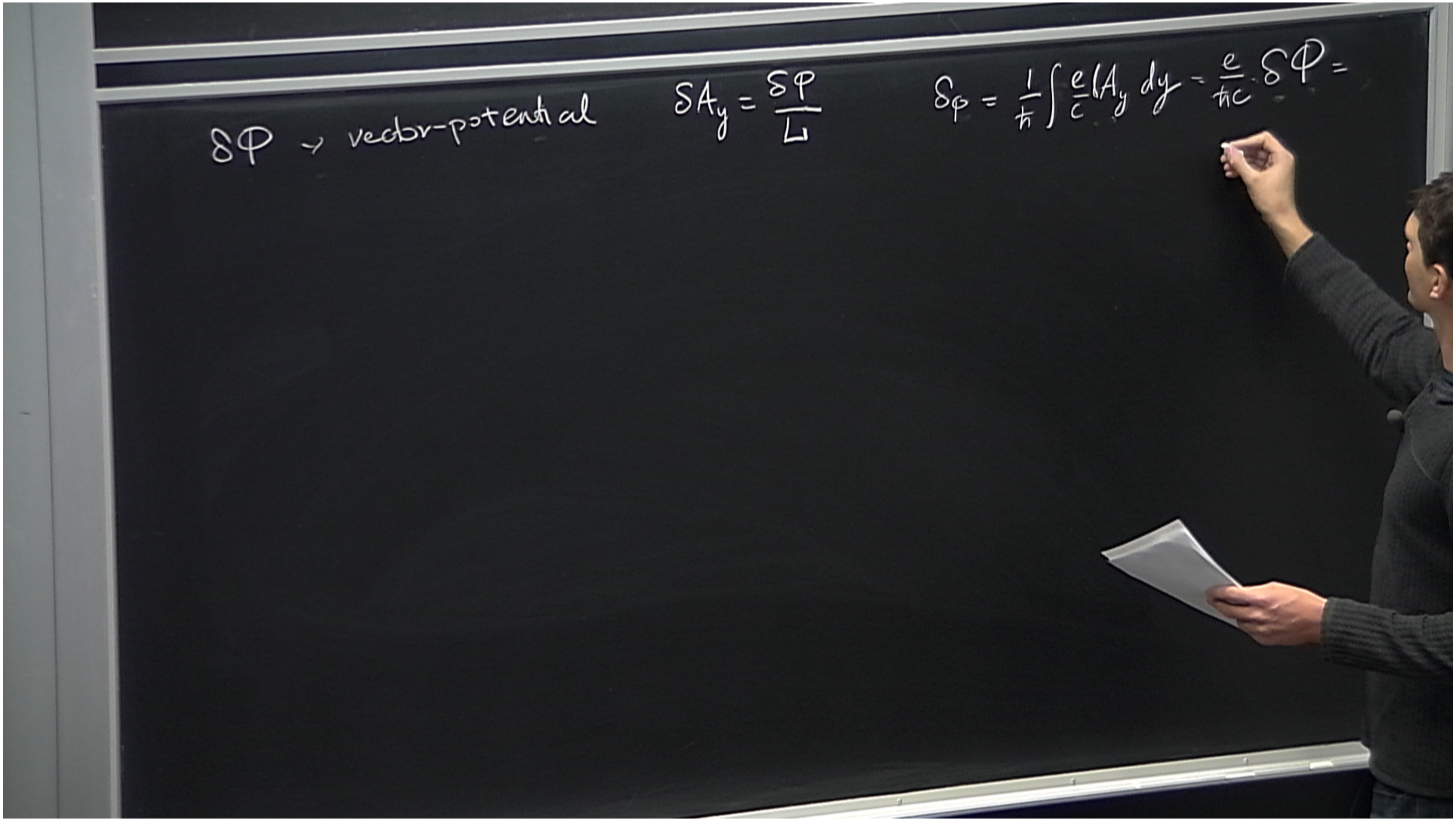

E

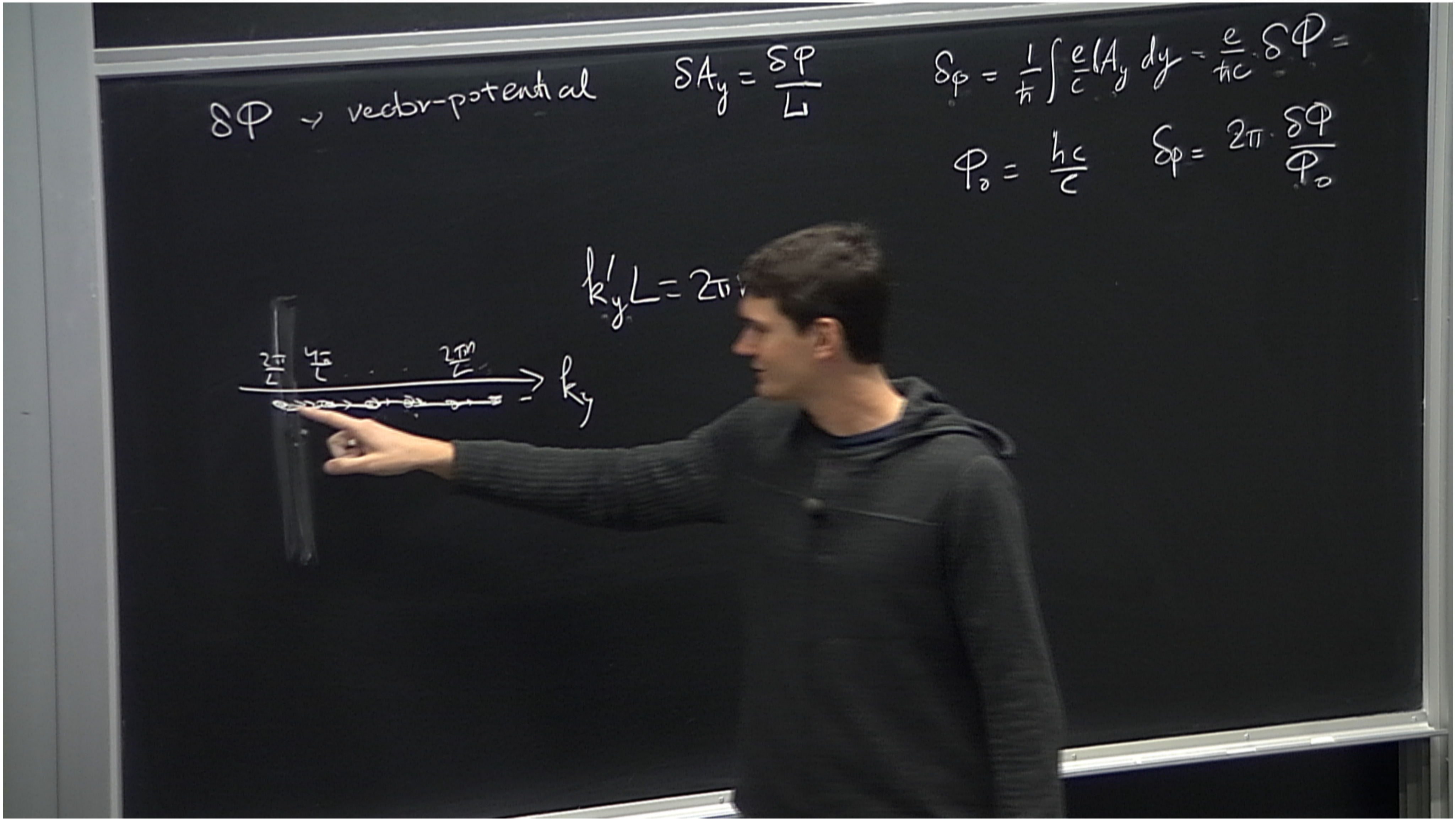


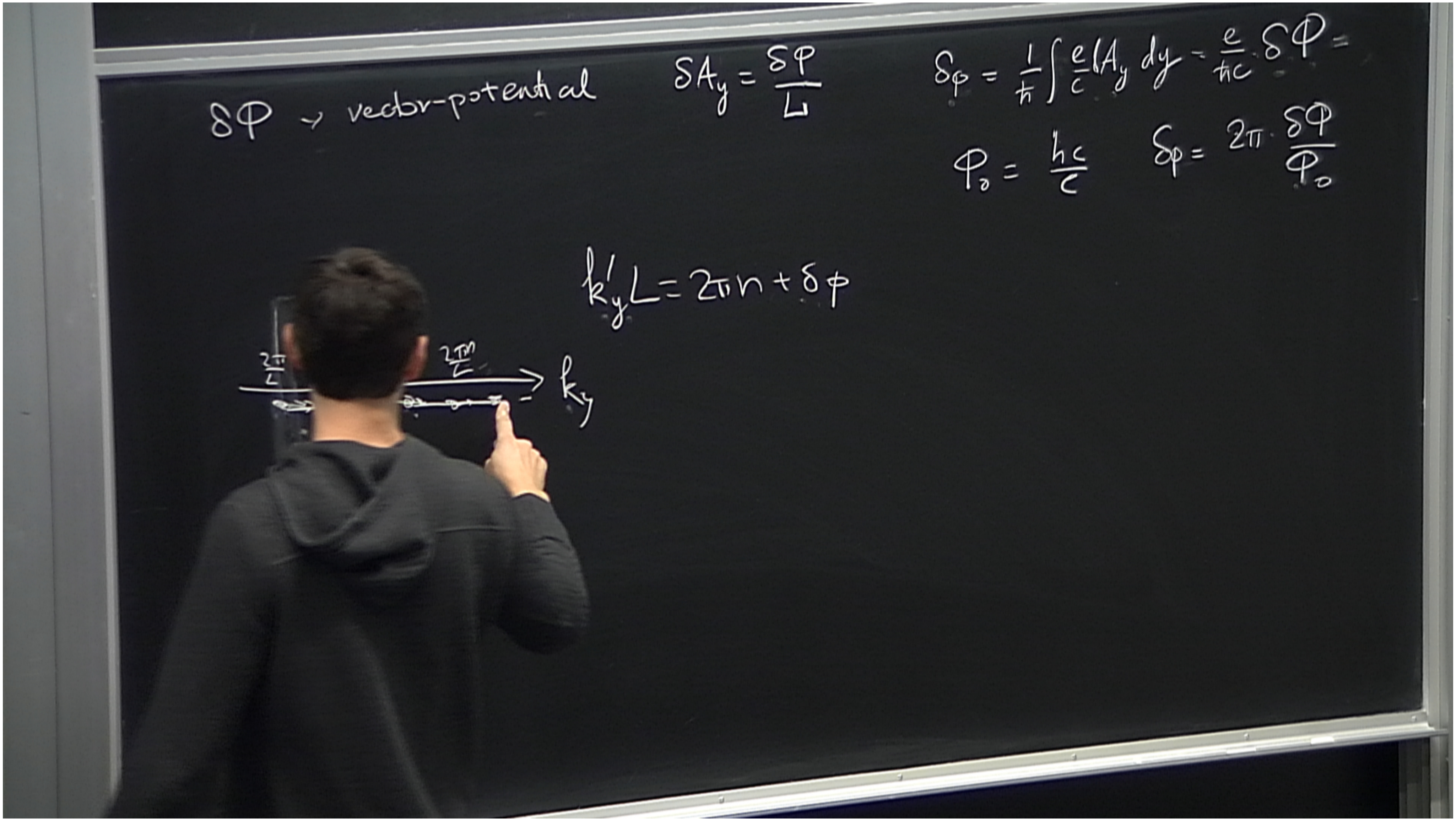
E
L
y
x
ψ(x,y) =

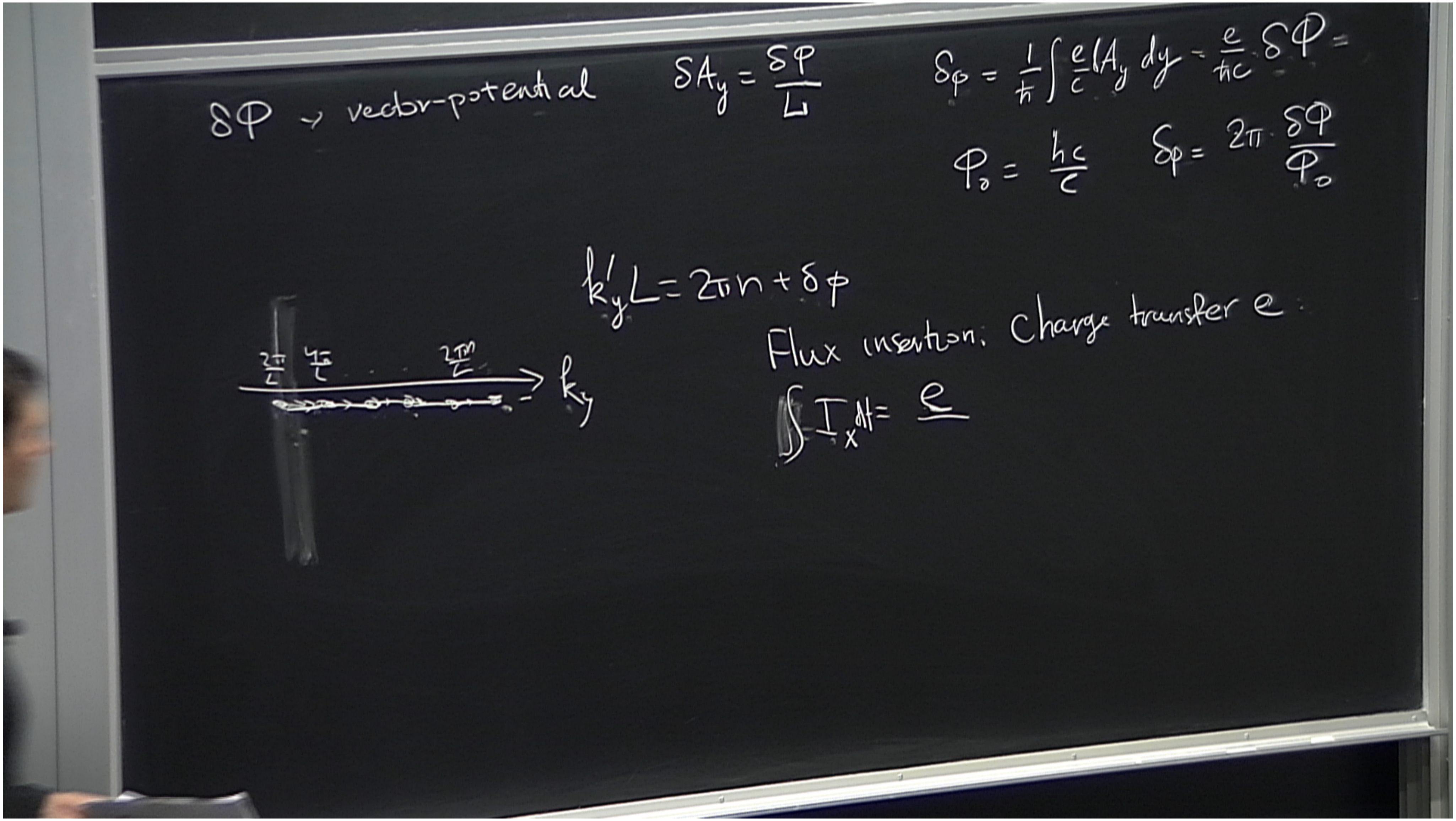

L
y
x
$k_y L = 2\pi n$

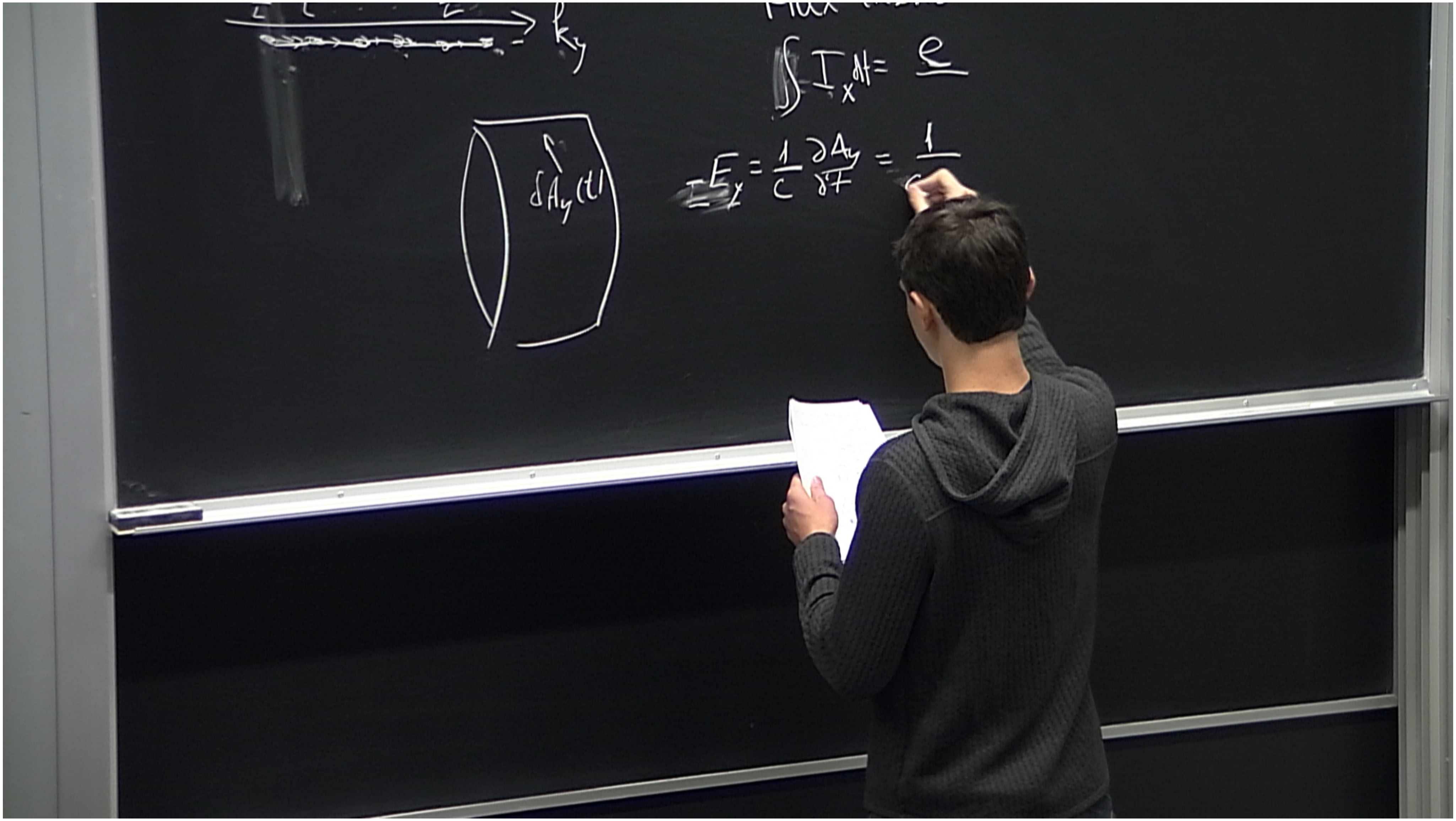

L
Φ
y
x
$k_y L = 2\pi n$
E

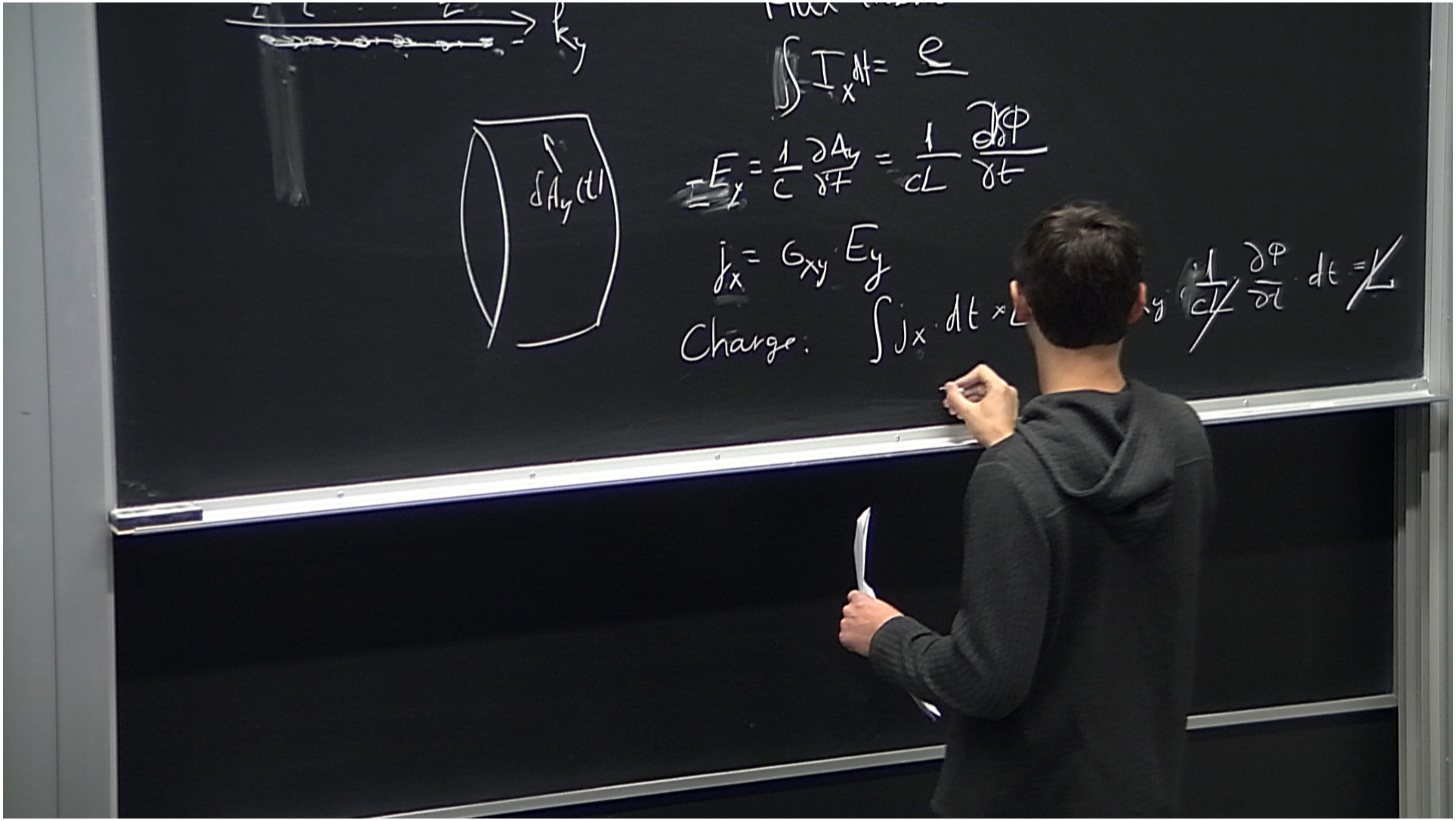

$\delta\Phi \rightarrow$ vector-potential
$\delta A_y = \frac{\delta\Phi}{L}$
$\delta\varphi = \frac{1}{\hbar}\int \frac{e}{c}\delta A_y \, dy = \frac{e}{\hbar c}\delta\Phi =$


$\delta\Phi \to$ vector-potential
$\delta A_y = \frac{\delta\Phi}{L}$
$\delta\varphi = \frac{1}{\hbar}\int \frac{e}{c}\delta A_y \, dy = \frac{e}{\hbar c}\delta\Phi =$
$\Phi_0 = \frac{hc}{e}$
$\delta\varphi = 2\pi \cdot \frac{\delta\Phi}{\Phi_0}$
$k'_y L = 2\pi$
$\frac{2\pi}{L}$ $\frac{4\pi}{L}$ $\frac{2\pi n}{L}$
k_y

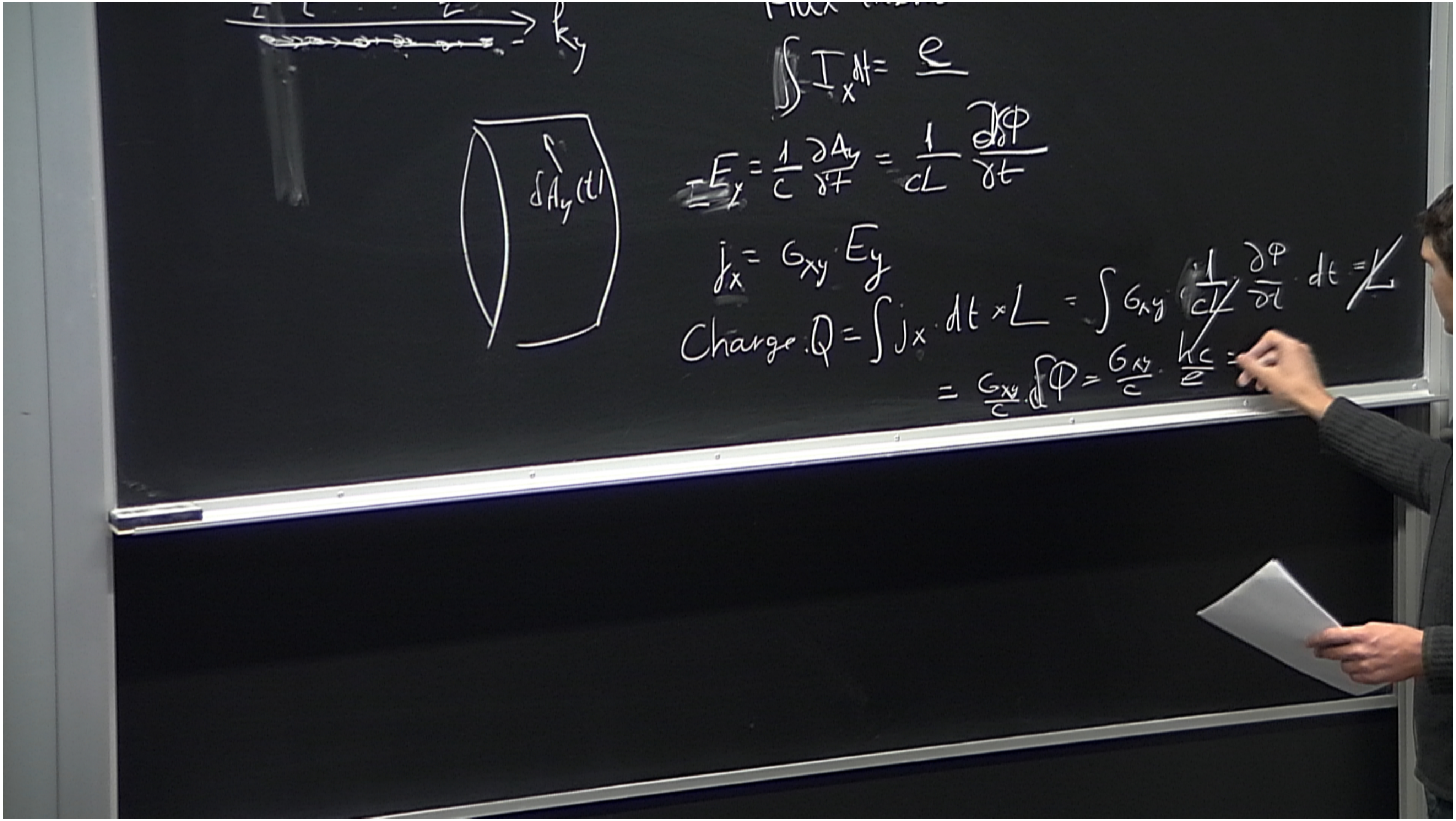

$\delta\Phi \to$ vector-potential
$\delta A_y = \frac{\delta\Phi}{L}$
$\delta\varphi = \frac{1}{\hbar}\int \frac{e}{c}\delta A_y\, dy = \frac{e}{\hbar c}\delta\Phi =$
$\Phi_0 = \frac{hc}{e}$
$\delta\varphi = 2\pi \cdot \frac{\delta\Phi}{\Phi_0}$
$k_y' L = 2\pi n + \delta\varphi$
$\frac{2\pi n}{L}$
k_y

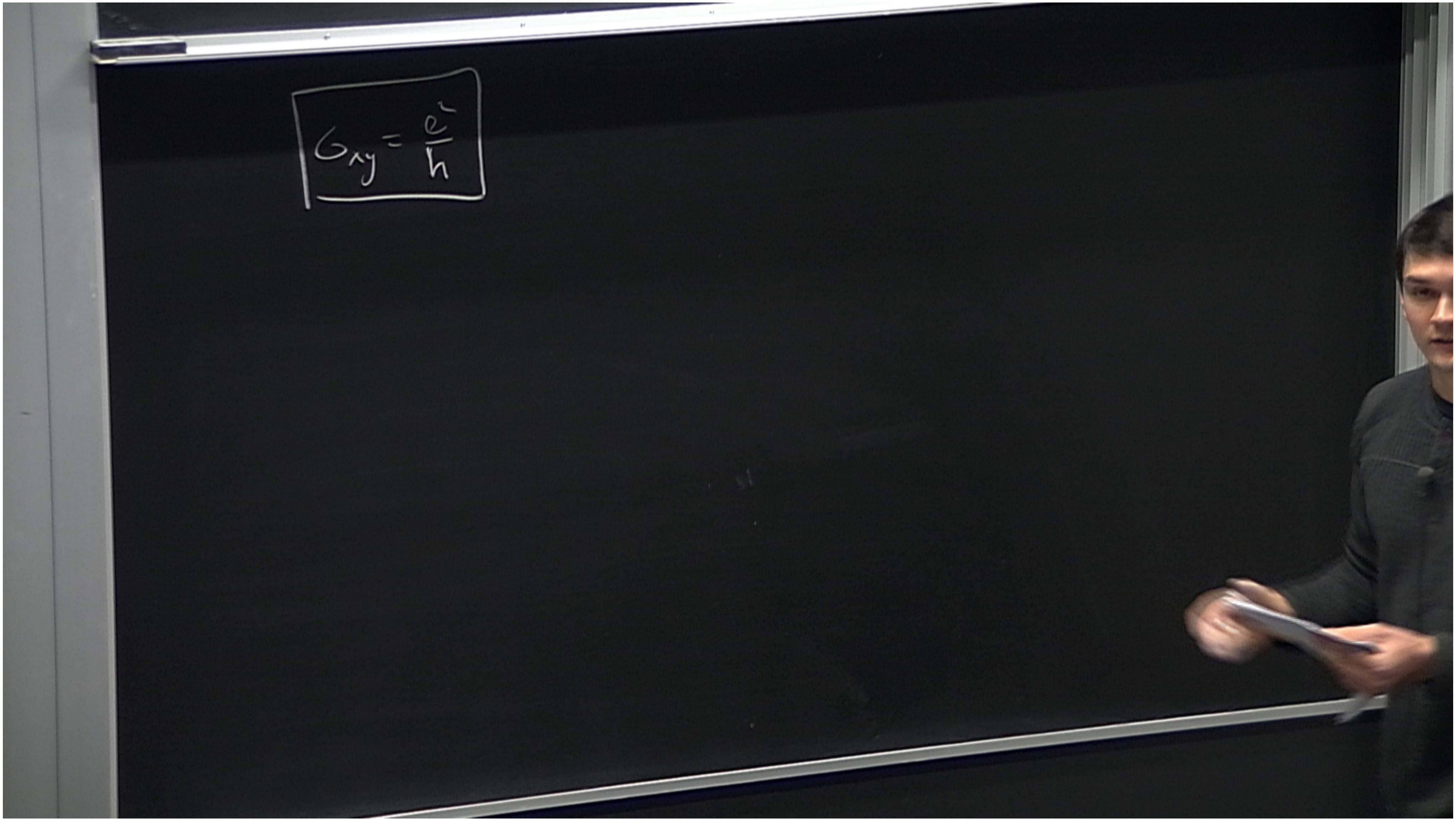

δΦ → vector-potential
$\delta A_y = \frac{\delta \Phi}{L}$
$\delta\varphi = \frac{1}{\hbar}\int \frac{e}{c}\,\delta A_y\, dy = \frac{e}{\hbar c}\,\delta\Phi =$
$\Phi_0 = \frac{hc}{e}$
$\delta\varphi = 2\pi \cdot \frac{\delta\Phi}{\Phi_0}$
$k_y' L = 2\pi n + \delta\varphi$
$\frac{2\pi}{L}$ $\frac{4\pi}{L}$ $\frac{2\pi n}{L}$
k_y
Flux insertion: Charge transfer e:
$\int I_x\, dt = e$

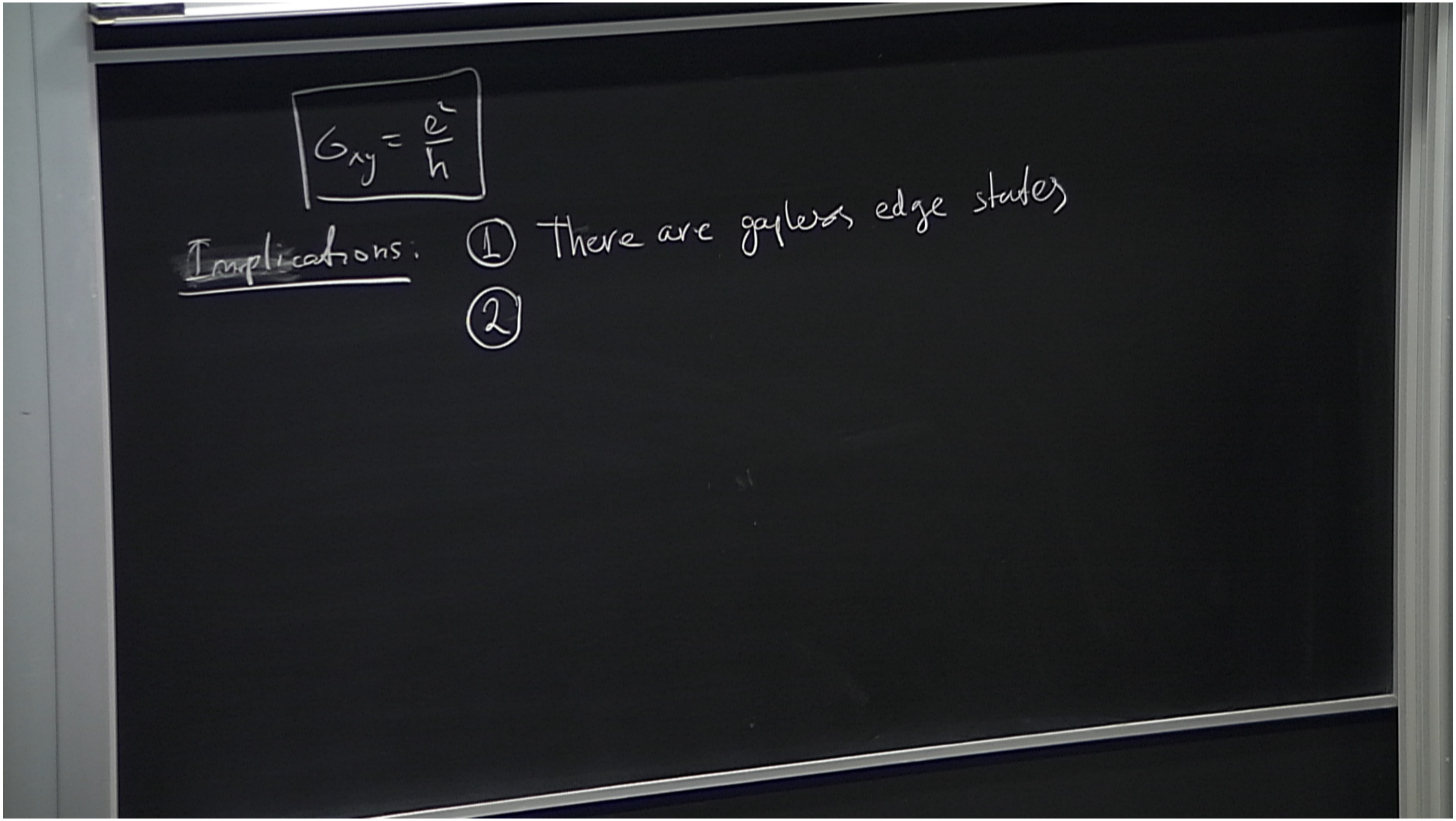

k_y
$\int I_x dt = e$
$\delta A_y(t)$
$E_x = \frac{1}{c}\frac{\partial A_y}{\partial t} = \frac{1}{c}$



k_y
$\delta A_y(t)$
$\int I_x dt = e$
$E_x = \frac{1}{c}\frac{\partial A_y}{\partial t} = \frac{1}{cL}\frac{\partial \delta\varphi}{\partial t}$
$j_x = \sigma_{xy} E_y$
Charge:


∫ I_x dt = e
E_x = 1/c ∂A_y/∂t = 1/cL ∂Φ/∂t
δA_y(t)
j_x = σ_xy E_y
Charge Q = ∫ j_x dt × L = ∫ σ_xy 1/cL ∂Φ/∂t dt × L
= σ_xy/c ∫dΦ = σ_xy/c · hc/e


$\sigma_{xy} = \frac{e^2}{h}$


$\sigma_{xy} = \frac{e^2}{h}$
Implications:
① There are gapless edge states
②

$$\sigma_{xy} = \frac{e^2}{h}$$

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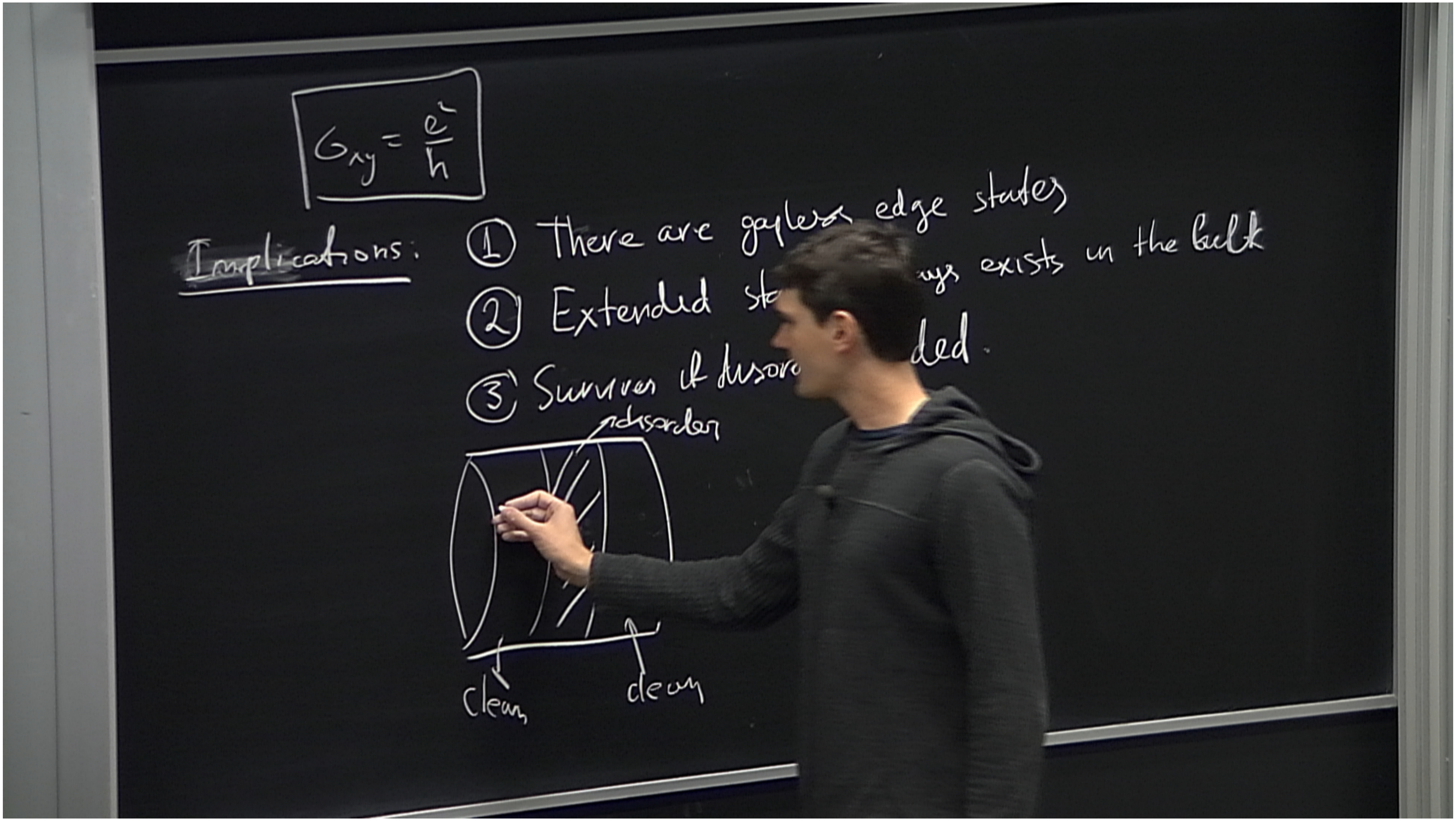
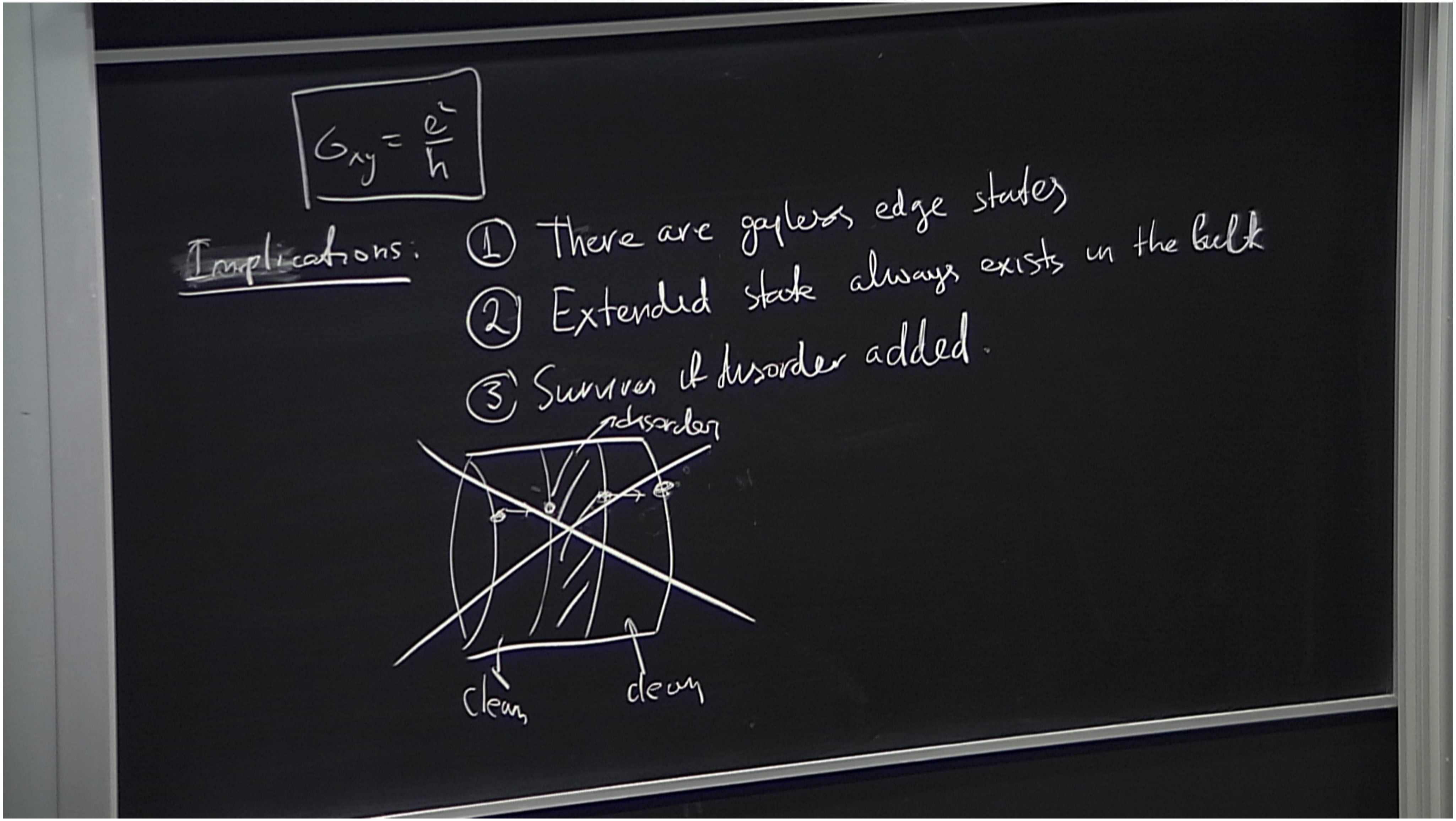
② Extended state always exists in the bulk


$G_{xy} = \frac{e^2}{h}$
Implications:
① There are gapless edge states
② Extended st... ays exists in the bulk
③ Survives if disor... ded.
disorder
clean
clean


σxy = e²/h
Implications:
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disorder
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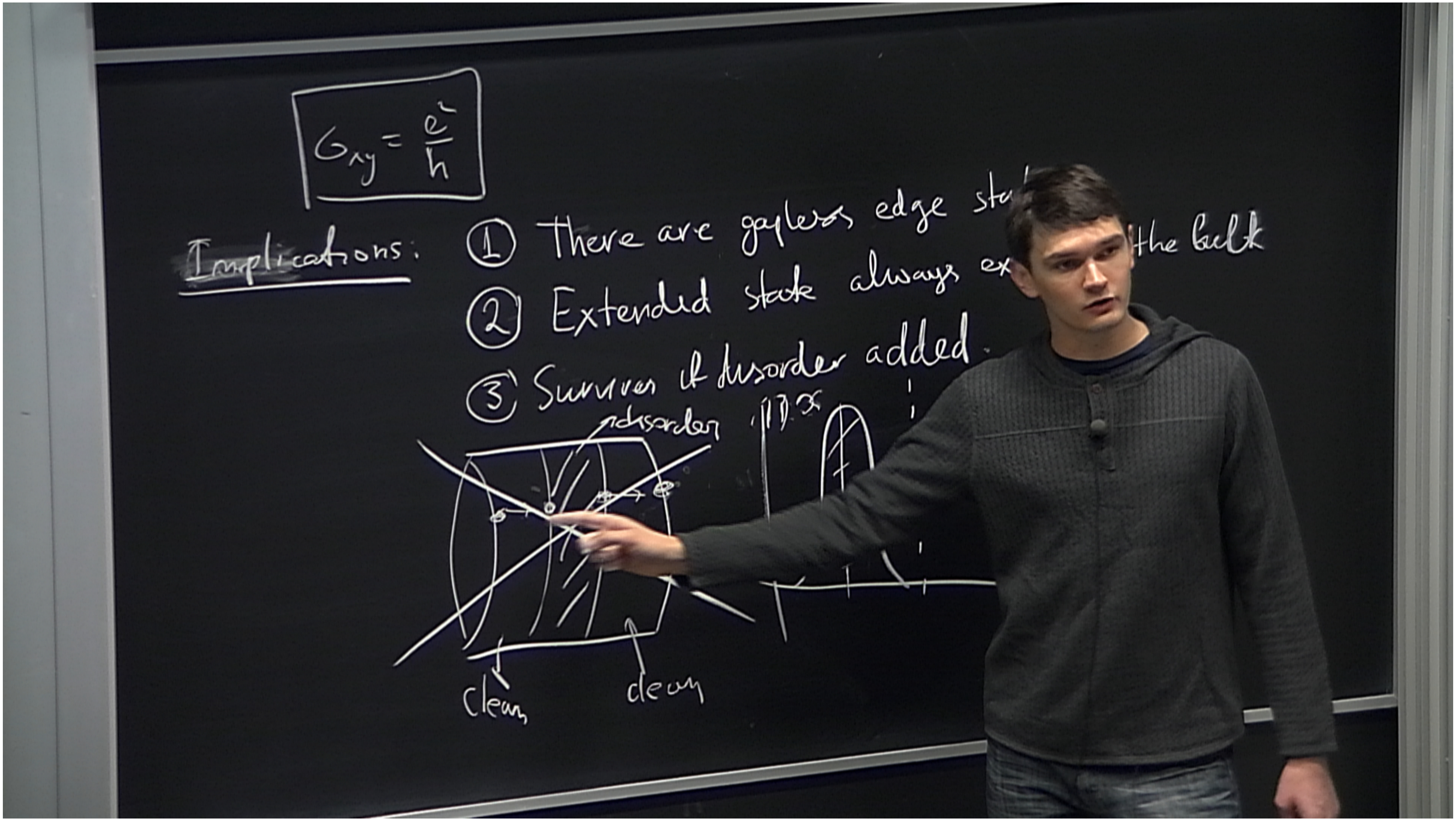

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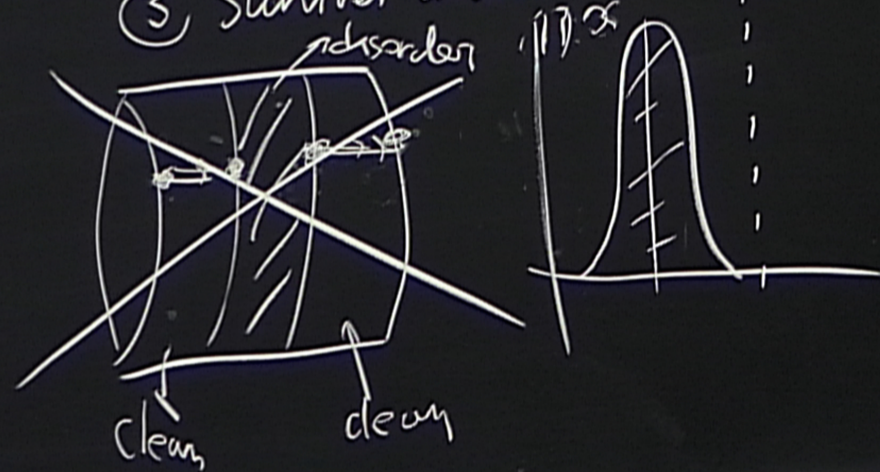

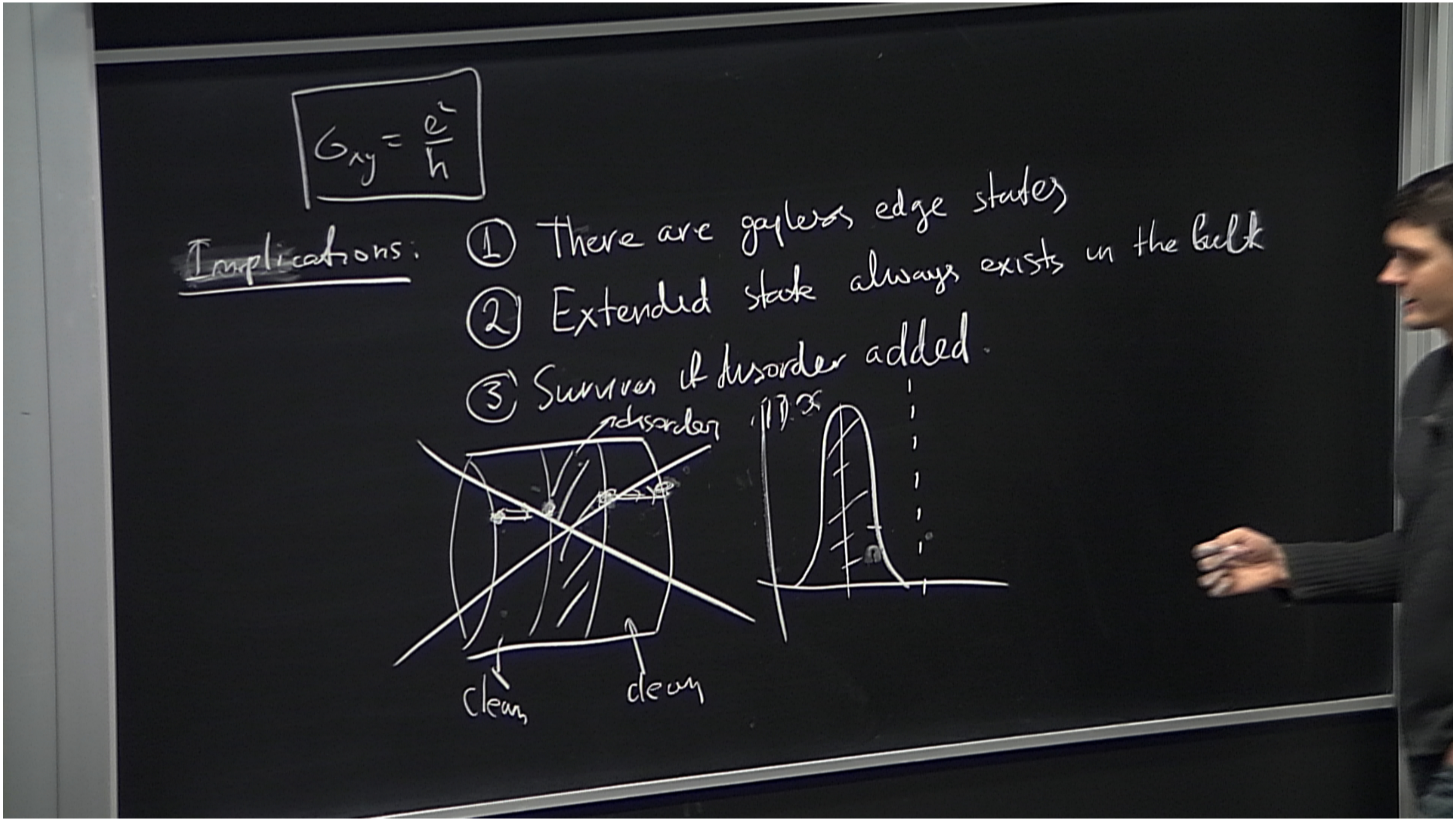

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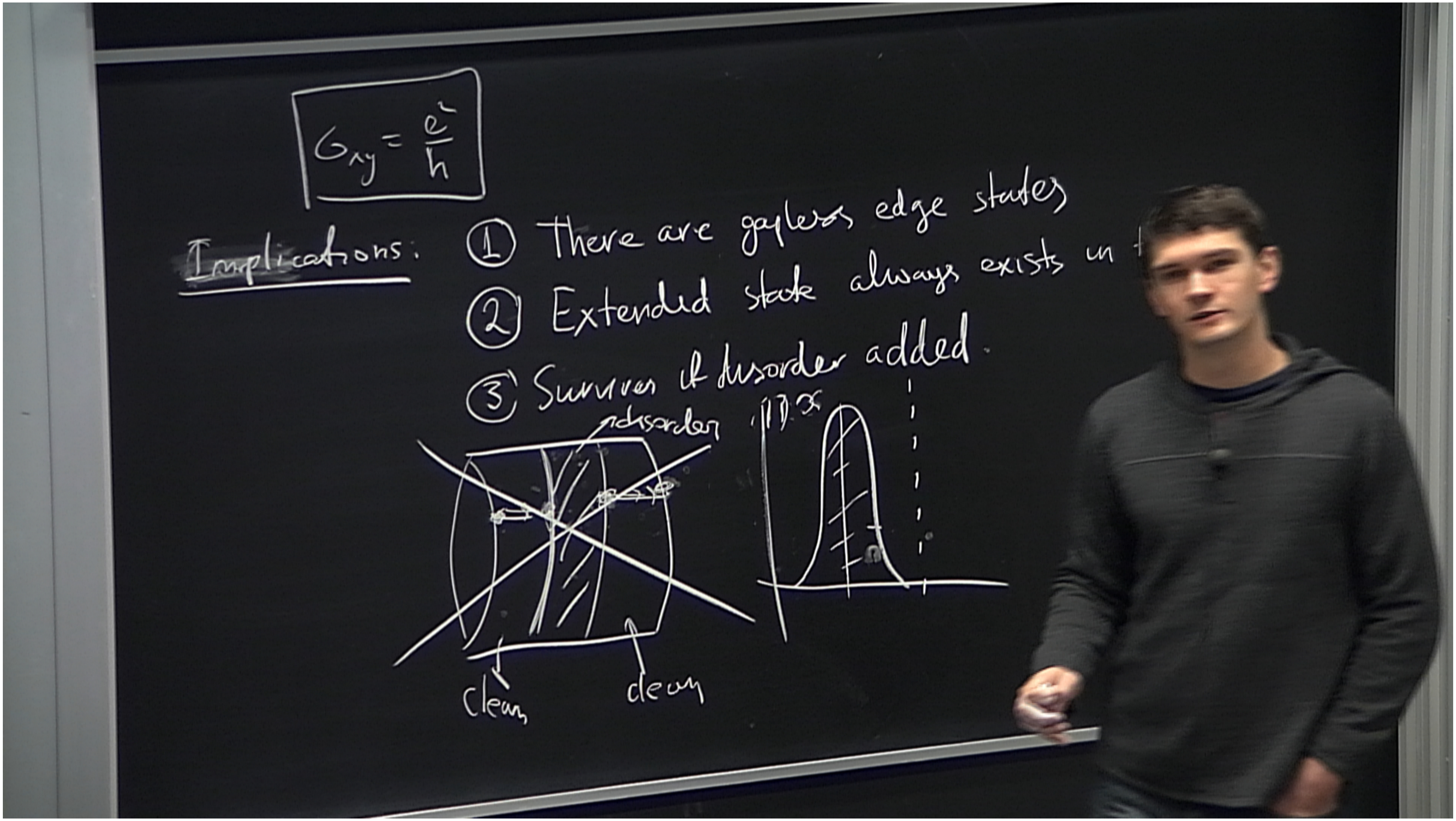
clean



G_xy = e^2/h
Implications:
① There are gapless edge states
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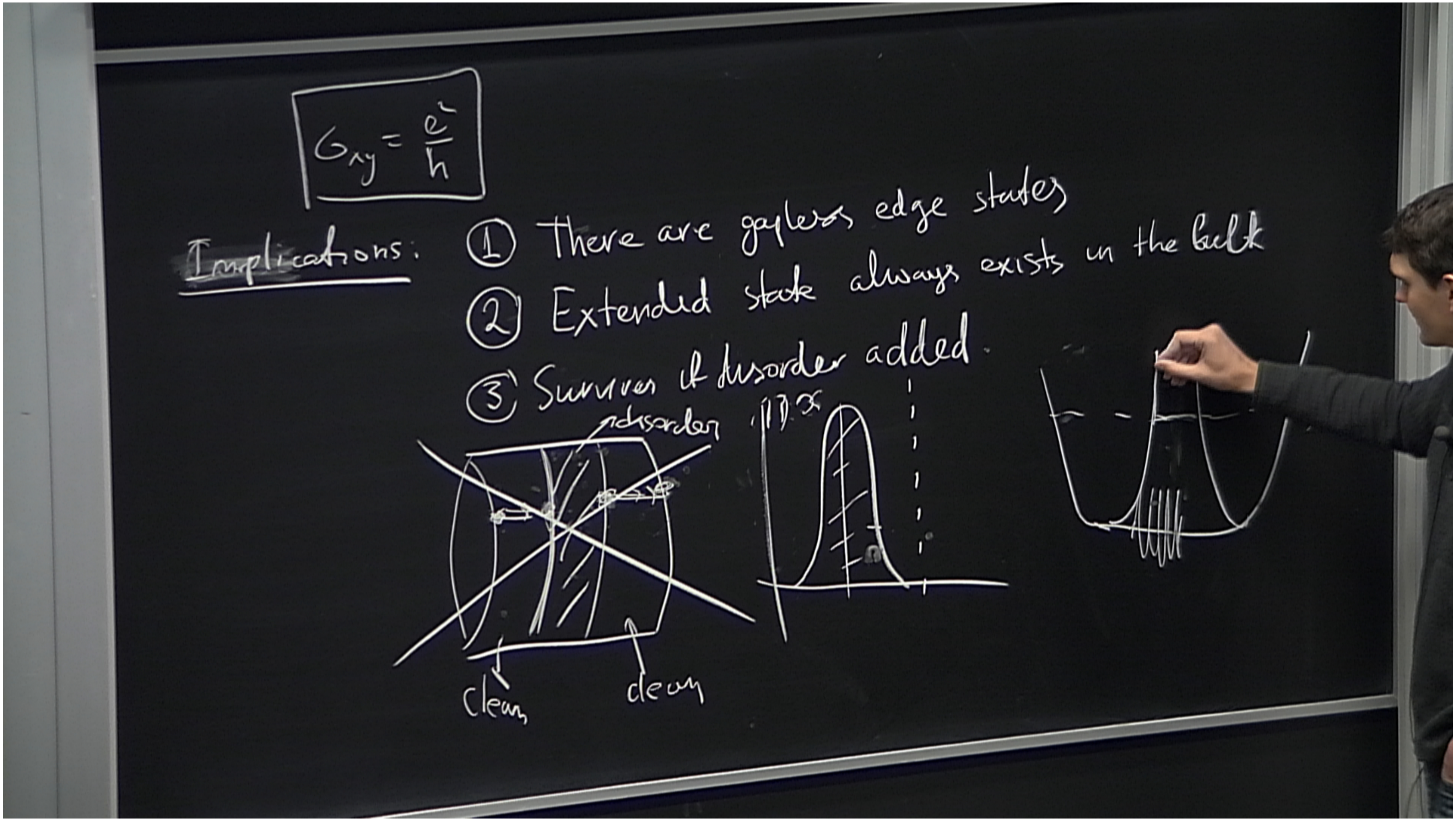
③ Survives if disorder added
disorder
clean
clean


$\sigma_{xy} = \frac{e^2}{h}$
Implications:
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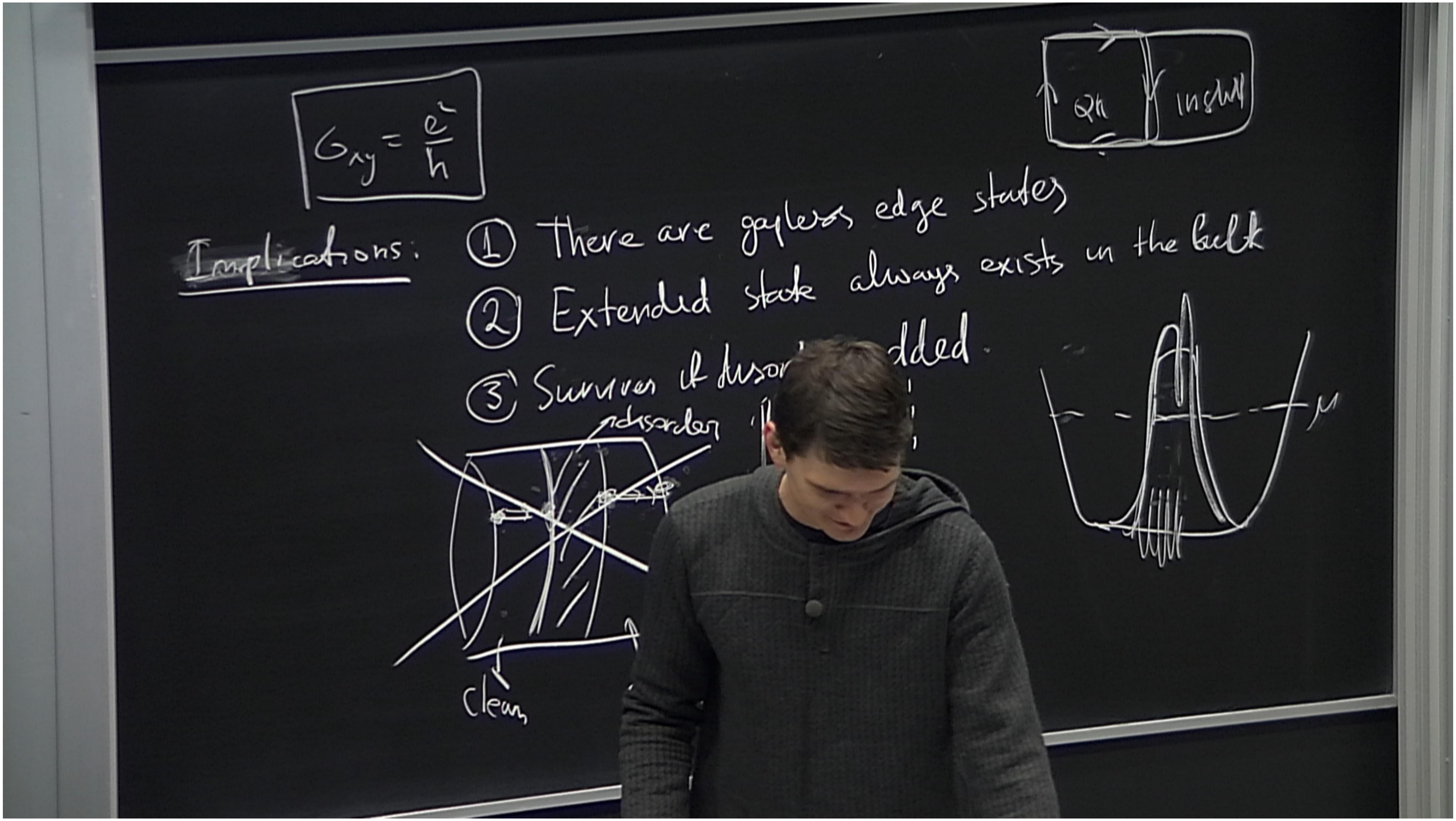
disorder
clean
clean



$G_{xy} = \frac{e^2}{h}$
QH
insul
Implications:
① There are gapless edge states
② Extended state always exists in the bulk
③ Survives if disorder added.
disorder
clean
μ