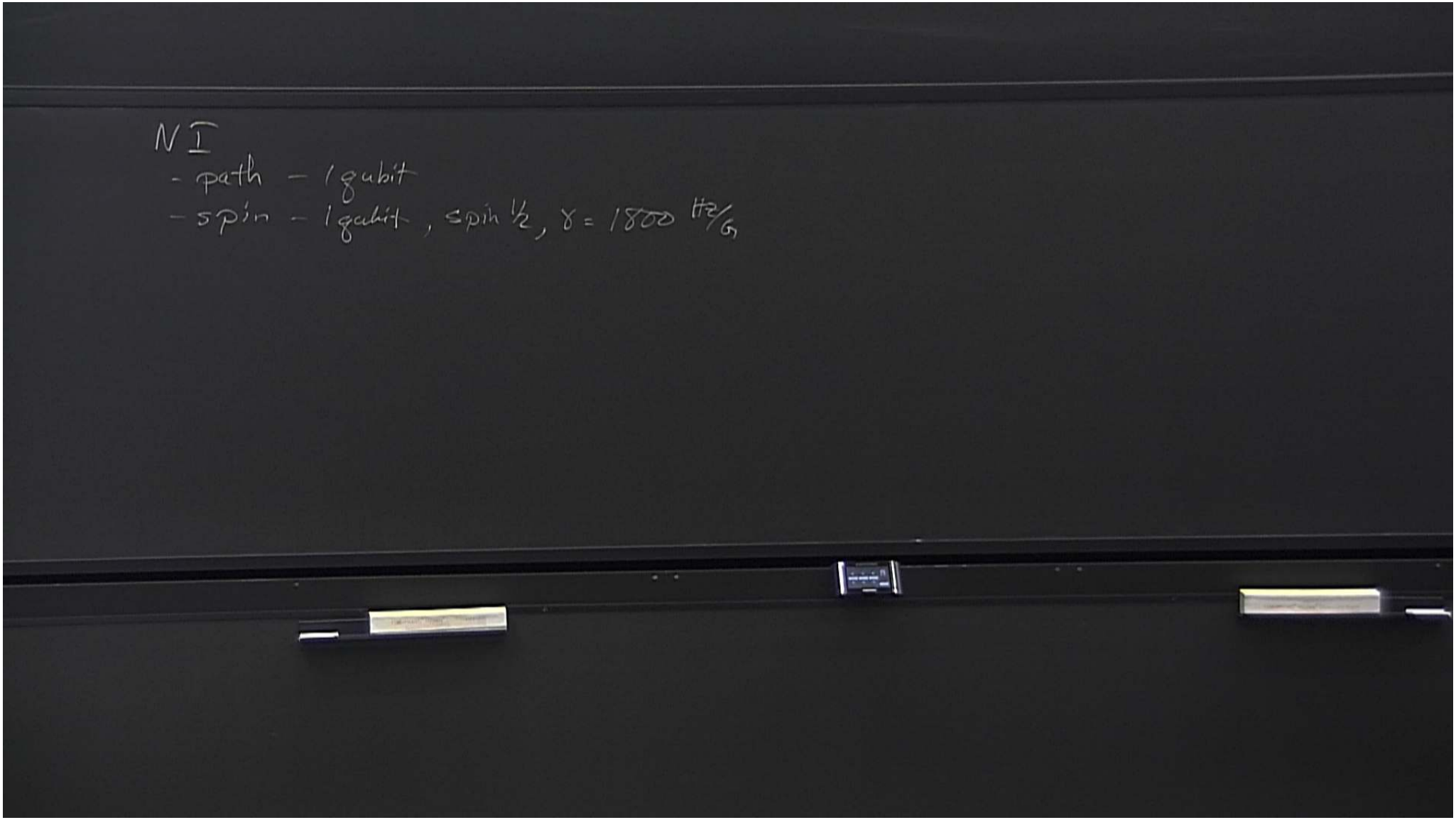
Title: 12/13 PSI - Explorations on Quantum Information Lecture 5

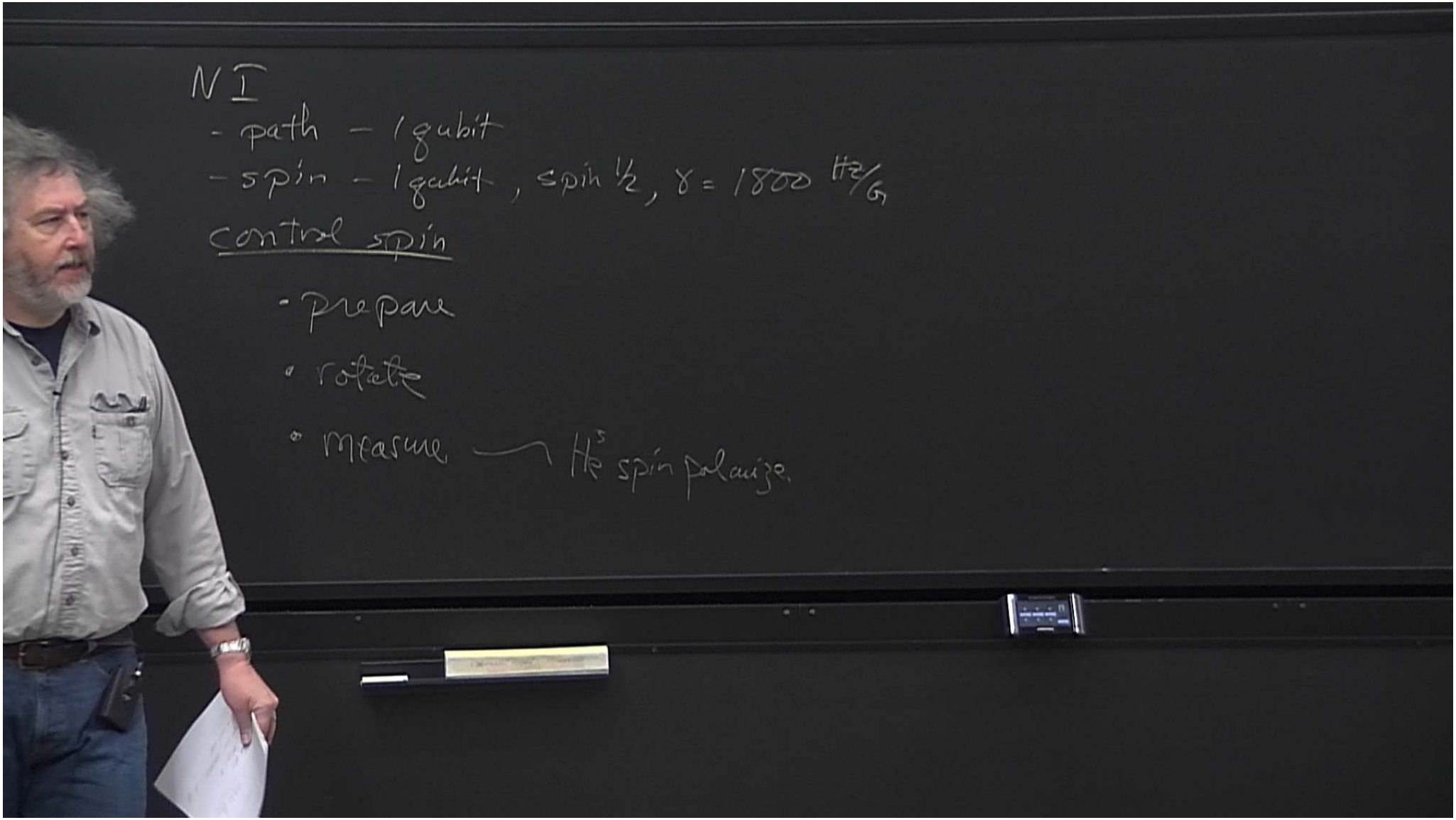
Date: Mar 22, 2013 09:00 AM

URL: http://www.pirsa.org/13030058

Abstract:

NI
- path – 1 qubit
-


NI
- path - 1 qubit
- spin - 1 qubit, spin 1/2, γ = 1800 Hz/G

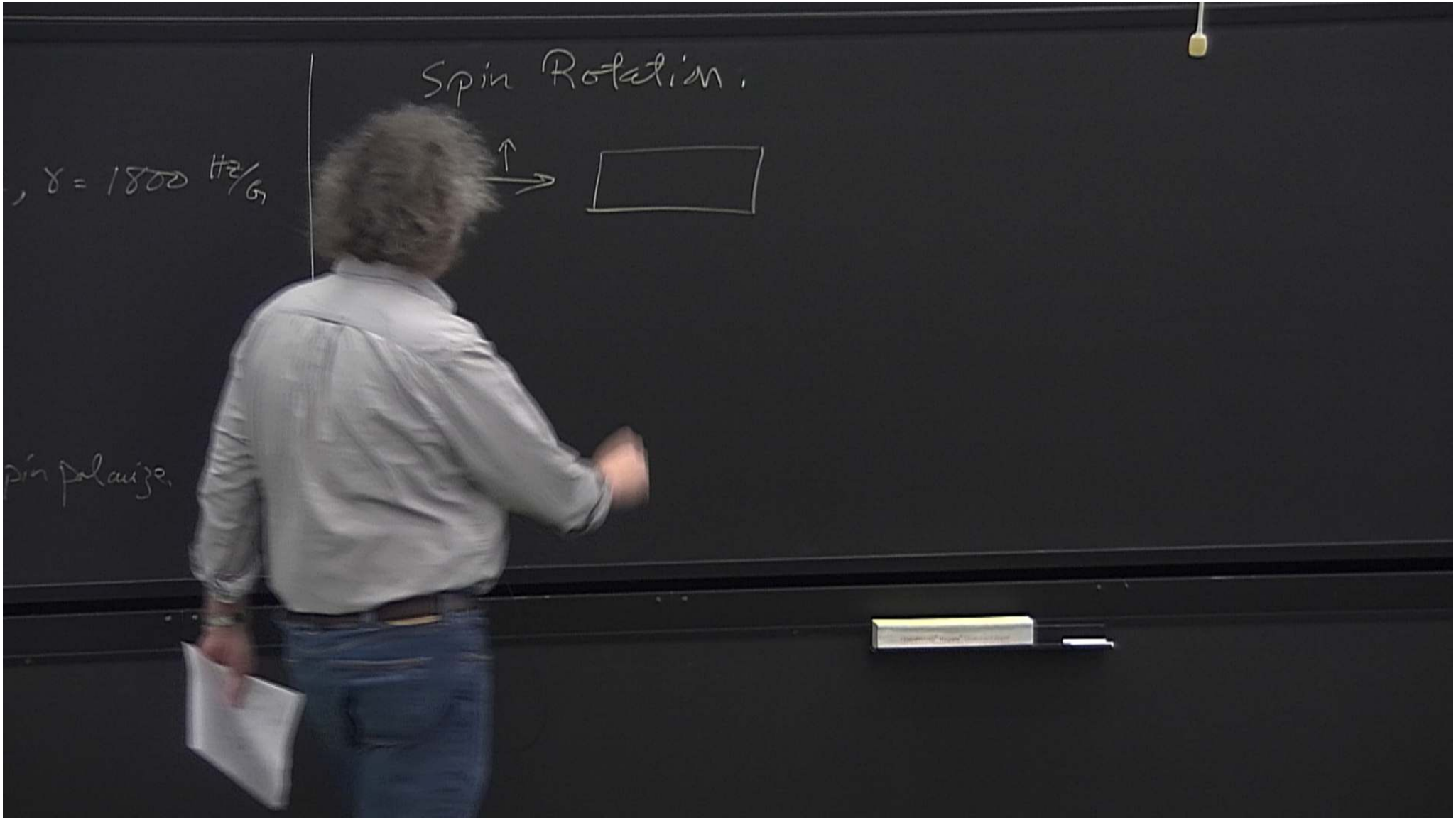

NI
- path - 1 qubit
- spin - 1 qubit, spin 1/2, γ = 1800 Hz/G
control spin
- prepare
- rotate
- measure → He^3 spin polarize.

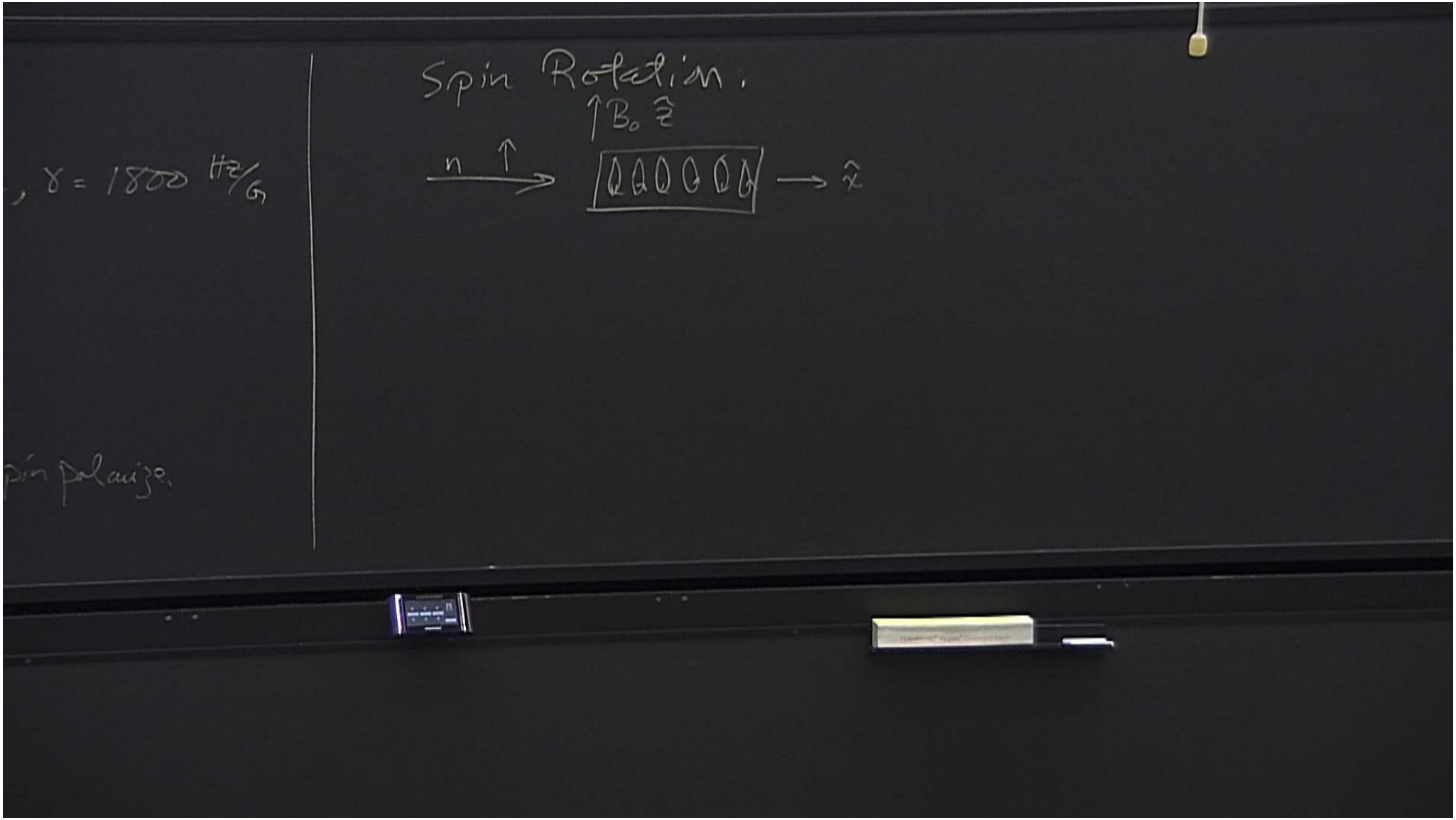
NI

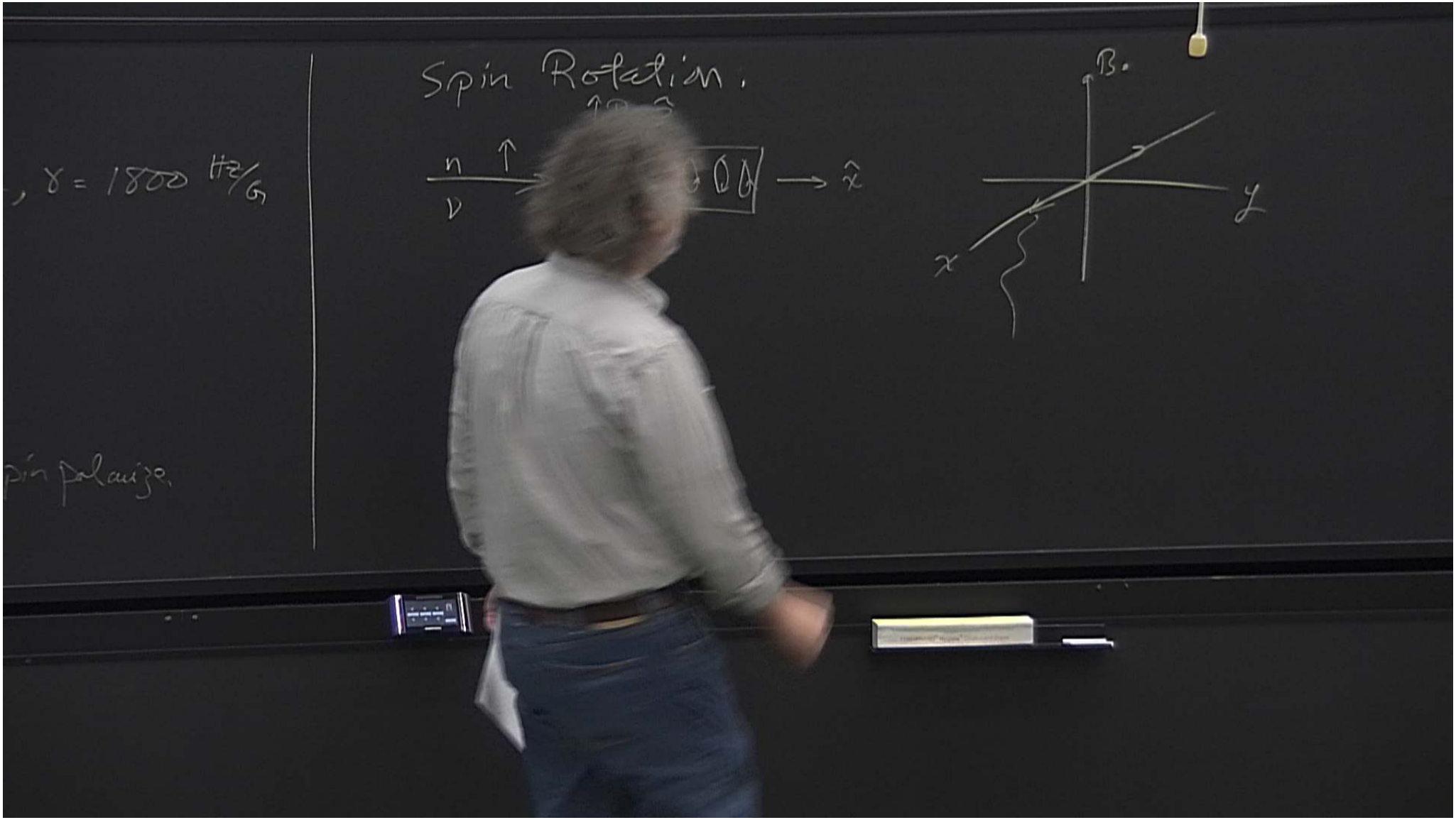
- path – 1 qubit
- spin – 1 qubit, spin ½, $\gamma = 1800$ Hz/G

control spin

- prepare ✓
- rotate
- measure → He^3 spin polarize.


Spin Rotation.
, γ = 1800 Hz/G
pin polariza.

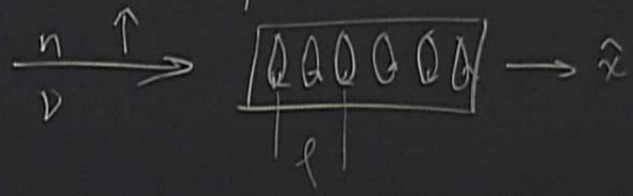

Spin Rotation.
$\uparrow B_0 \hat{z}$
n
$\hat{x}$
$\gamma = 1800$ Hz/G

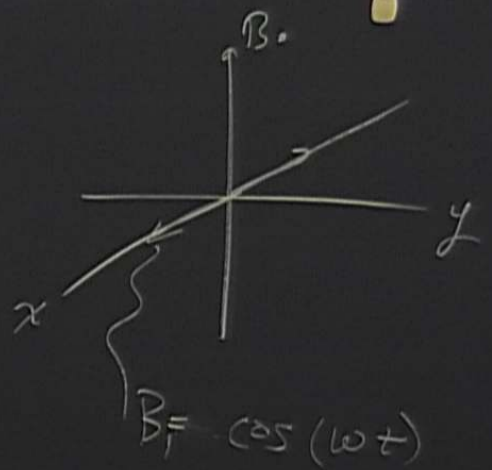

Spin Rotation.
B.
x
y

$\gamma = 1800$ Hz/G

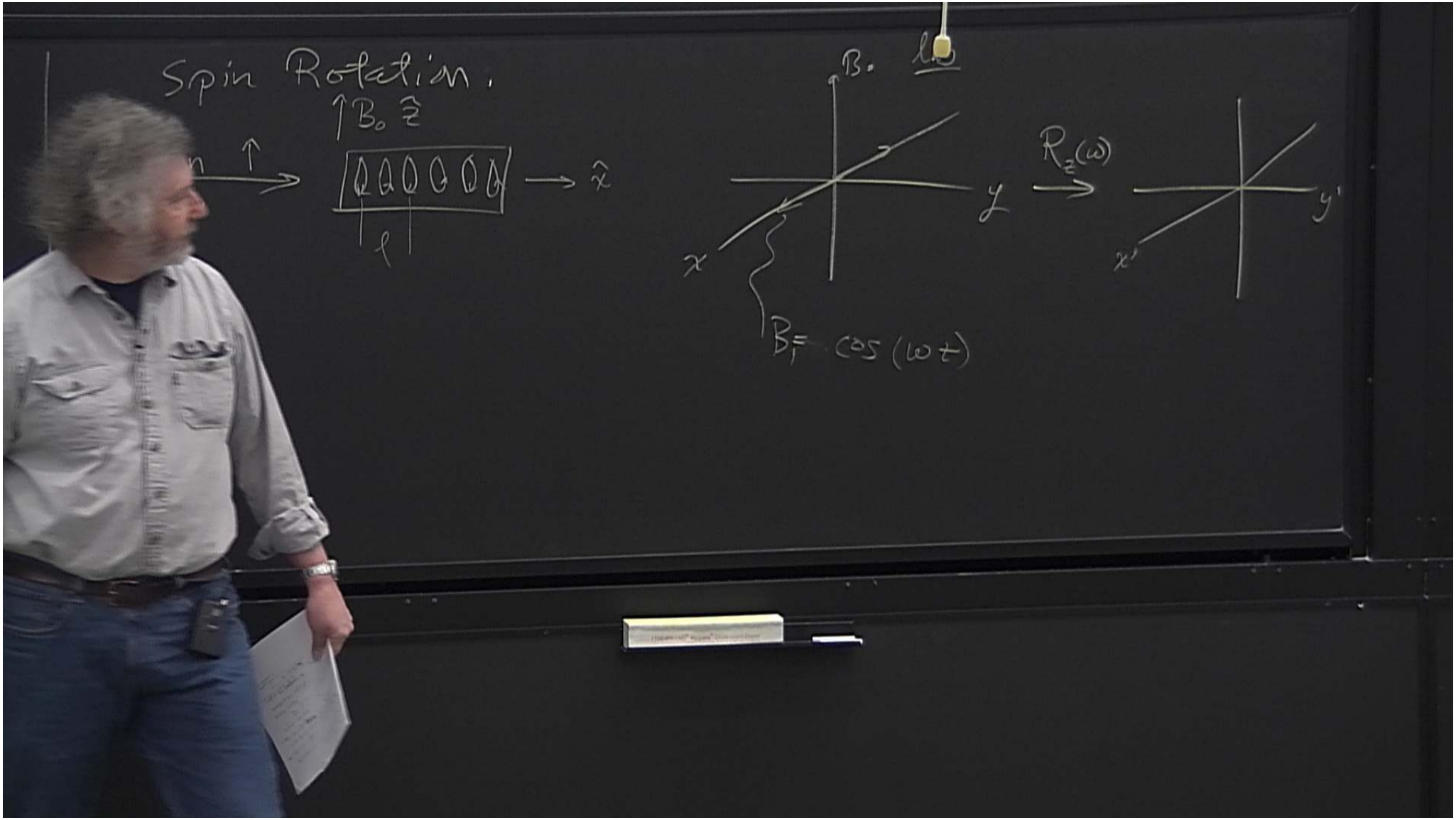
Spin Rotation.

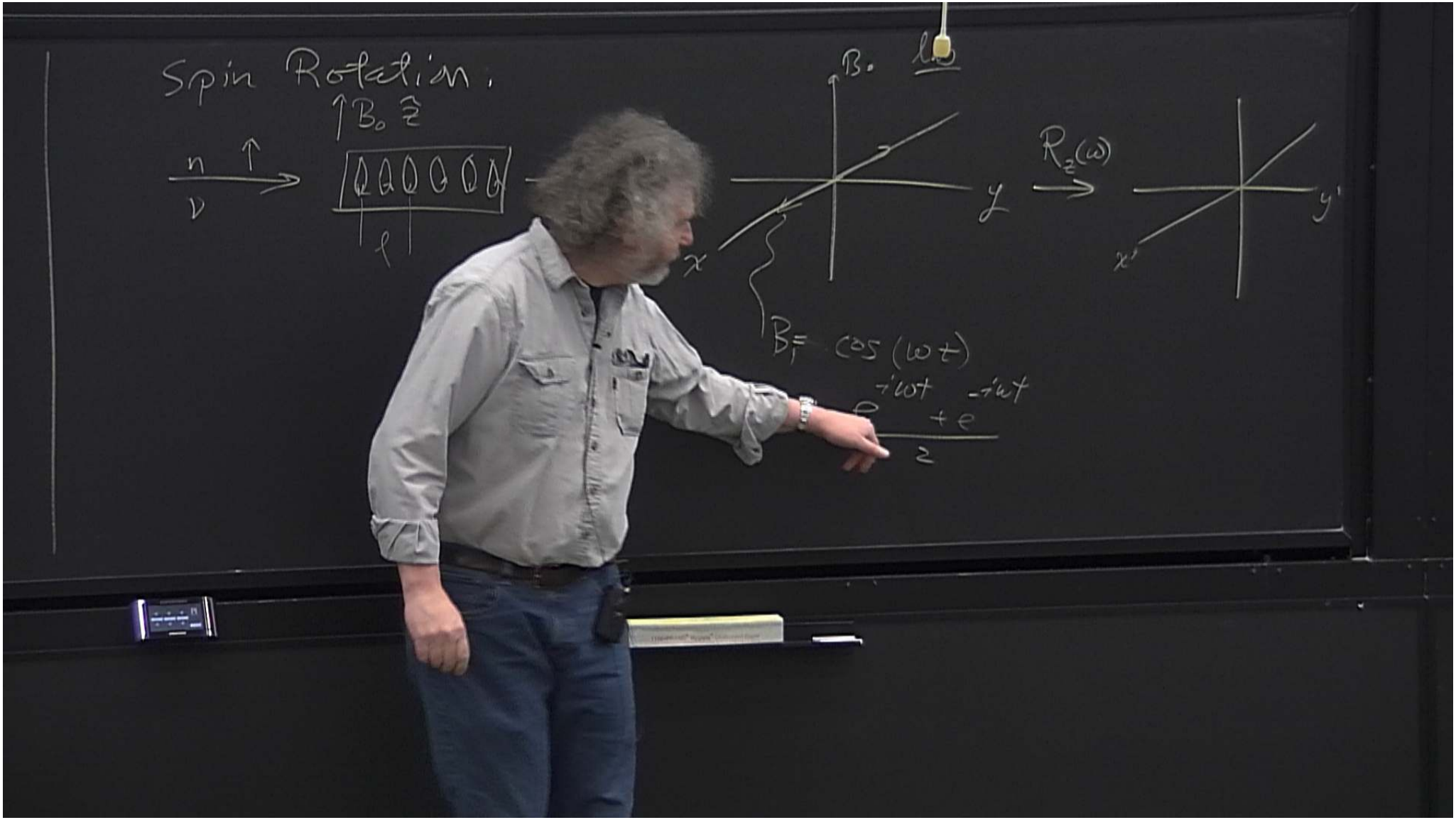
$\uparrow B_0 \hat{z}$

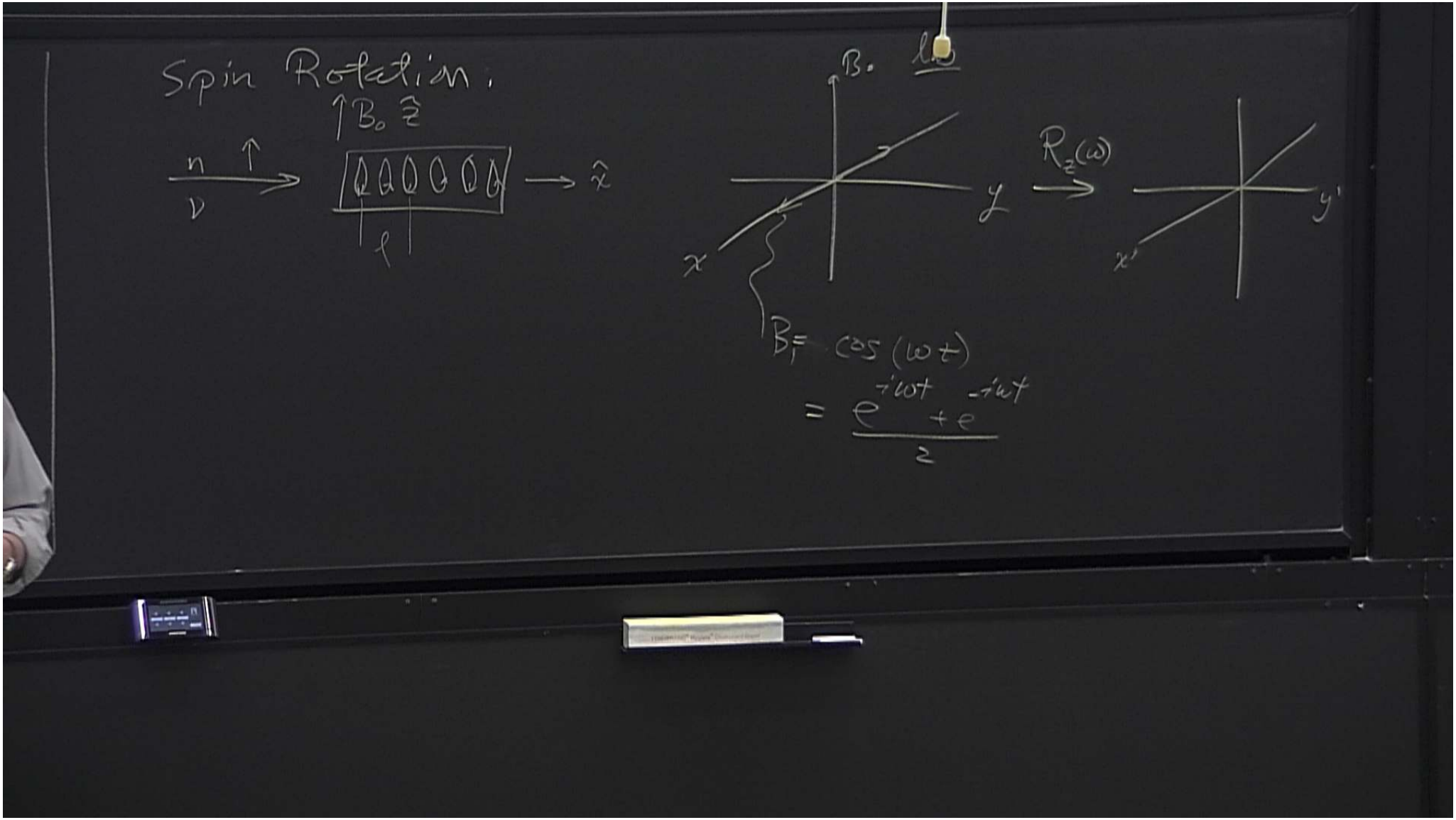


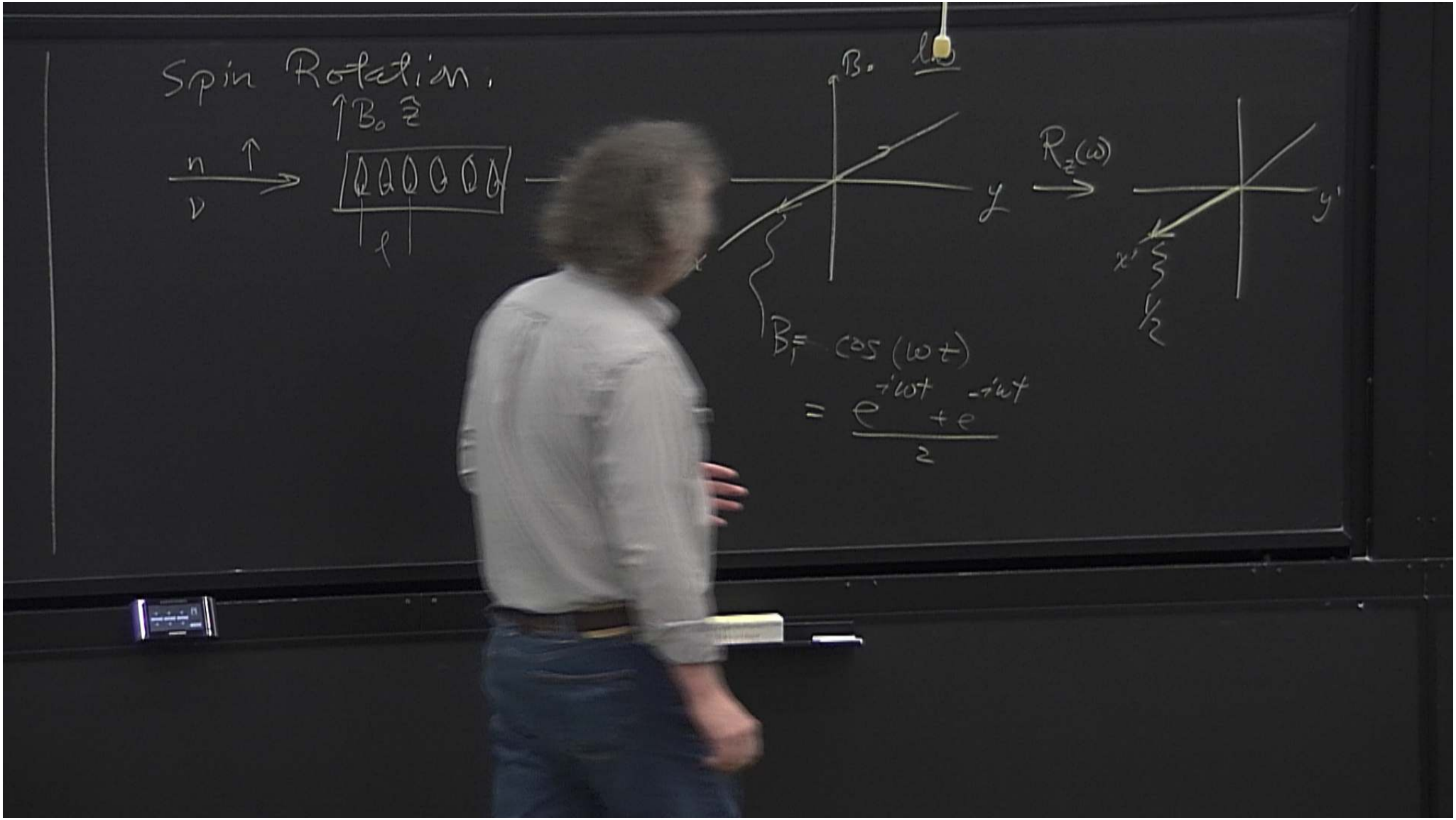


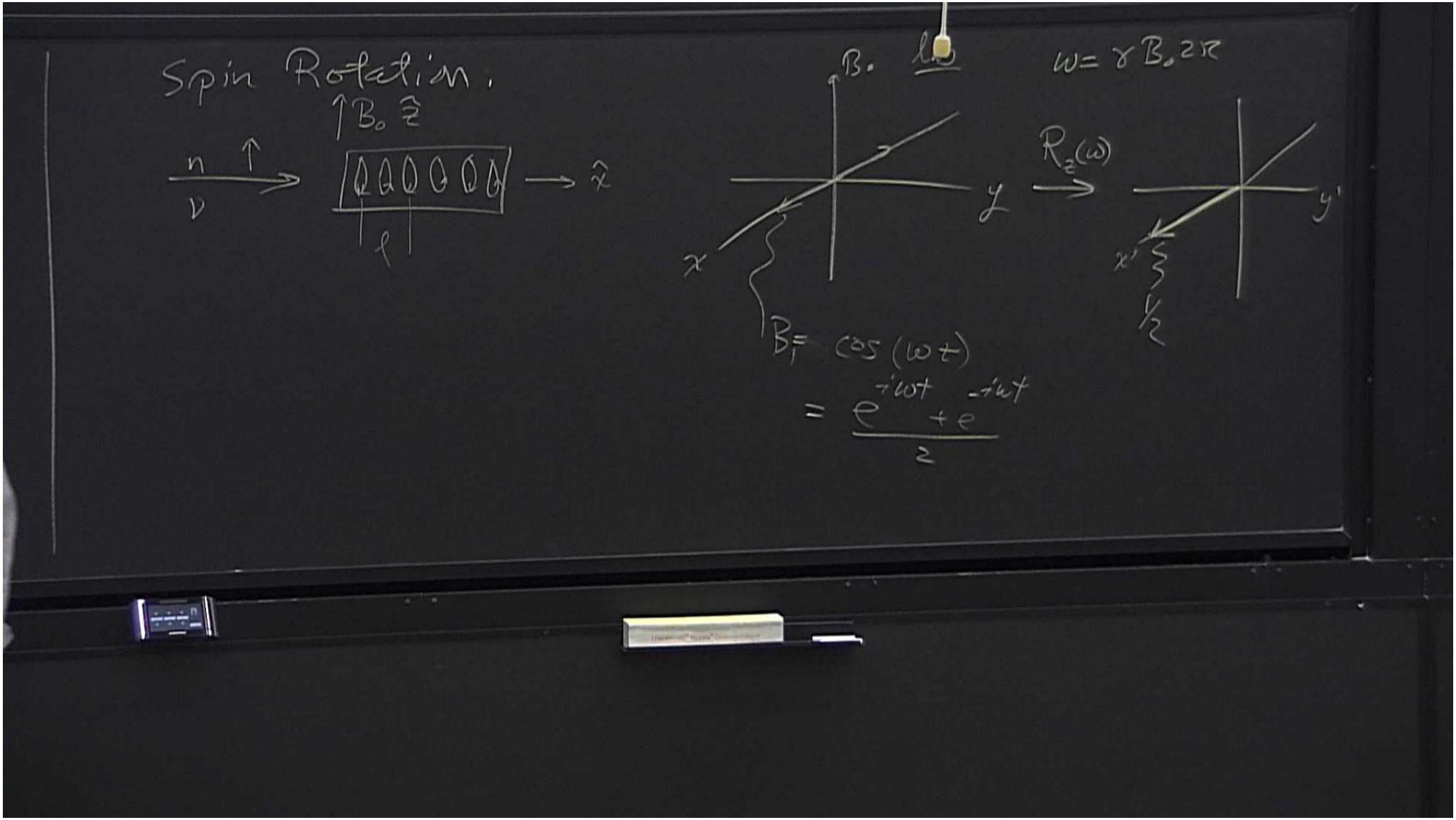
spin polarize.

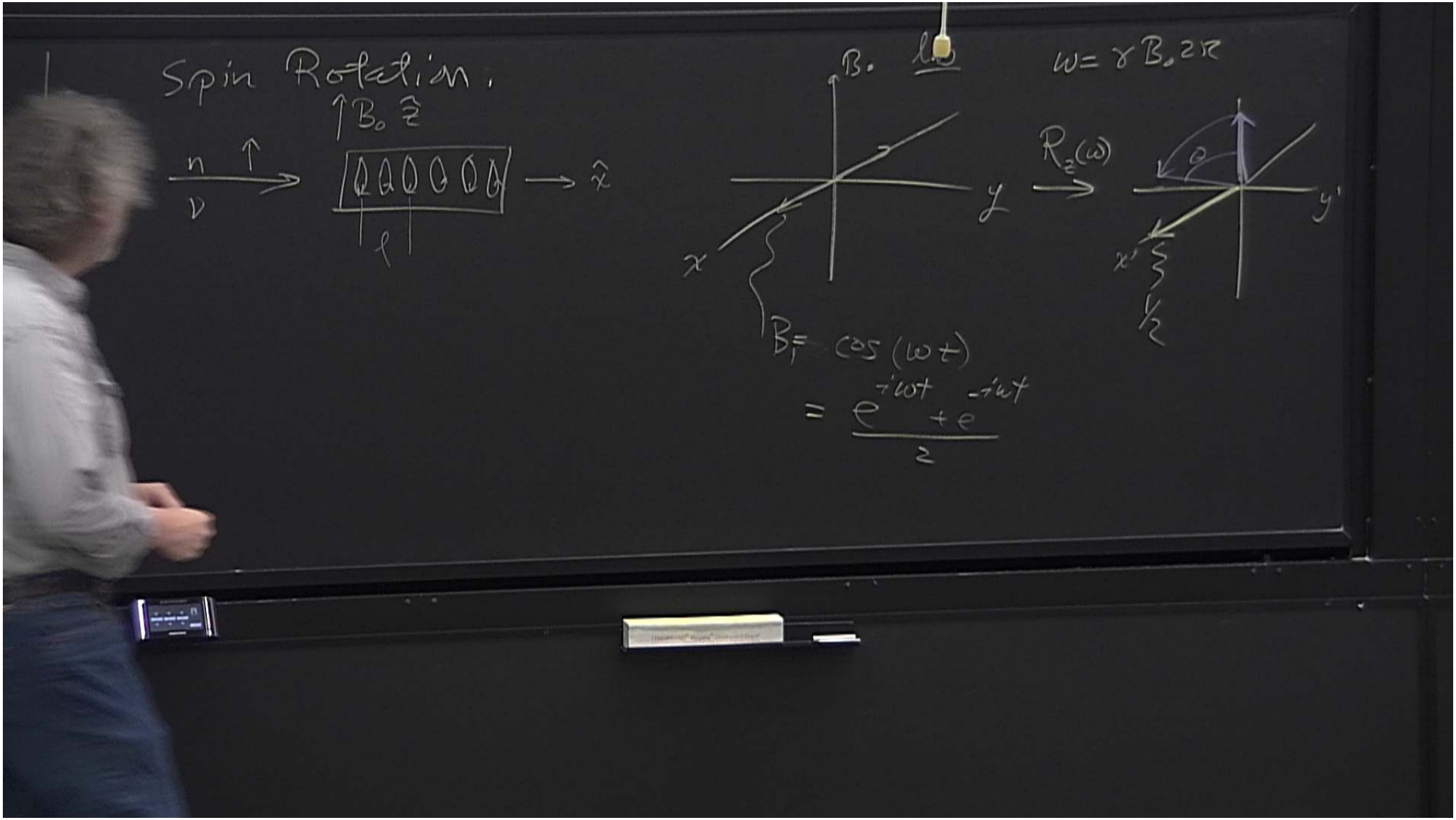

Spin Rotation.
$B_0 \hat{z}$
$\hat{x}$
B_0
$R_z(\omega)$
x
y
x'
y'
$B_1 = \cos(\omega t)$

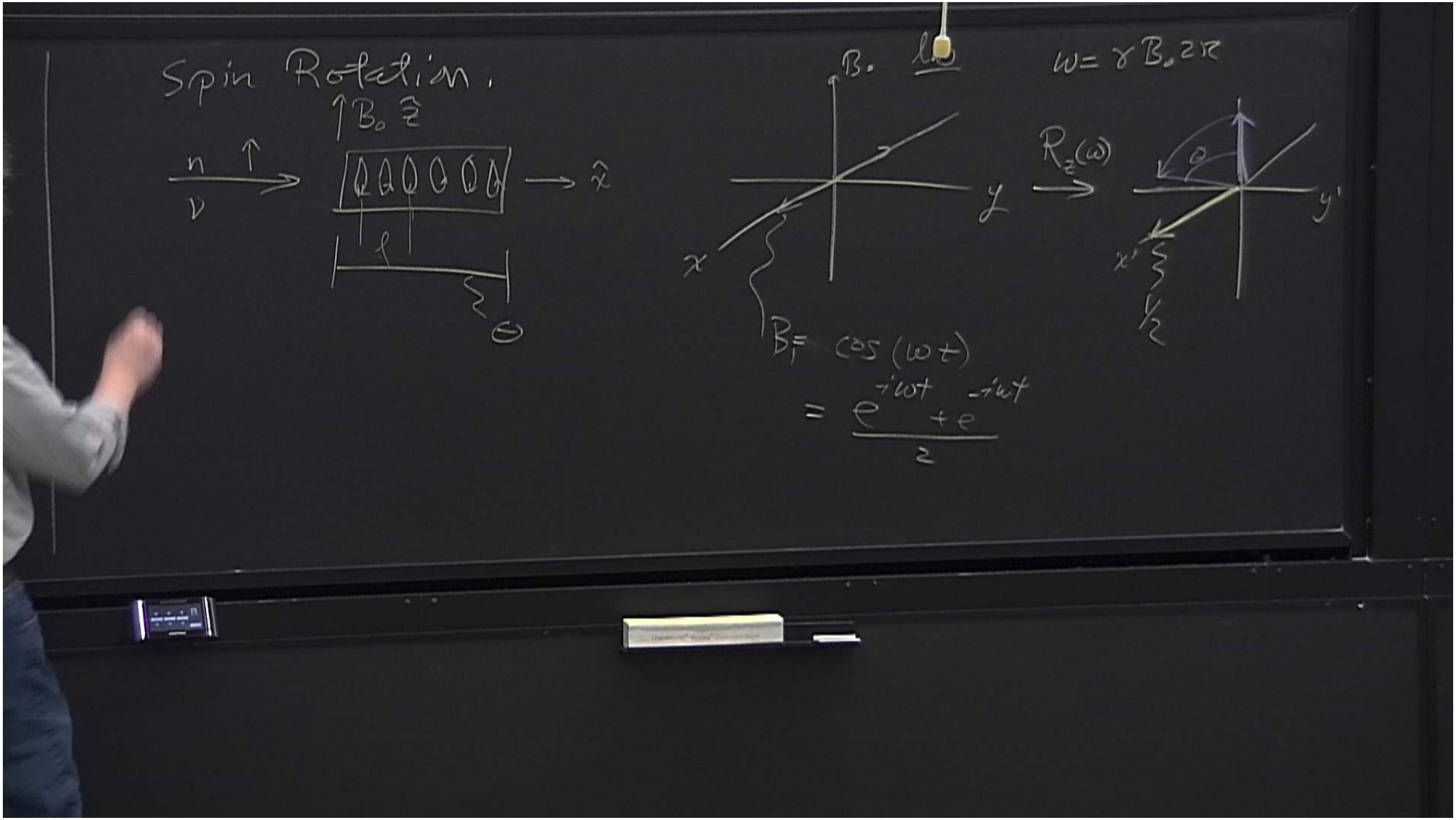

Spin Rotation.
$B_0 \hat{z}$
n
ν
ℓ
B_0
y
x
$R_z(\omega)$
y'
x'
$B_1 = \cos(\omega t)$
$\frac{e^{i\omega t} + e^{-i\omega t}}{2}$

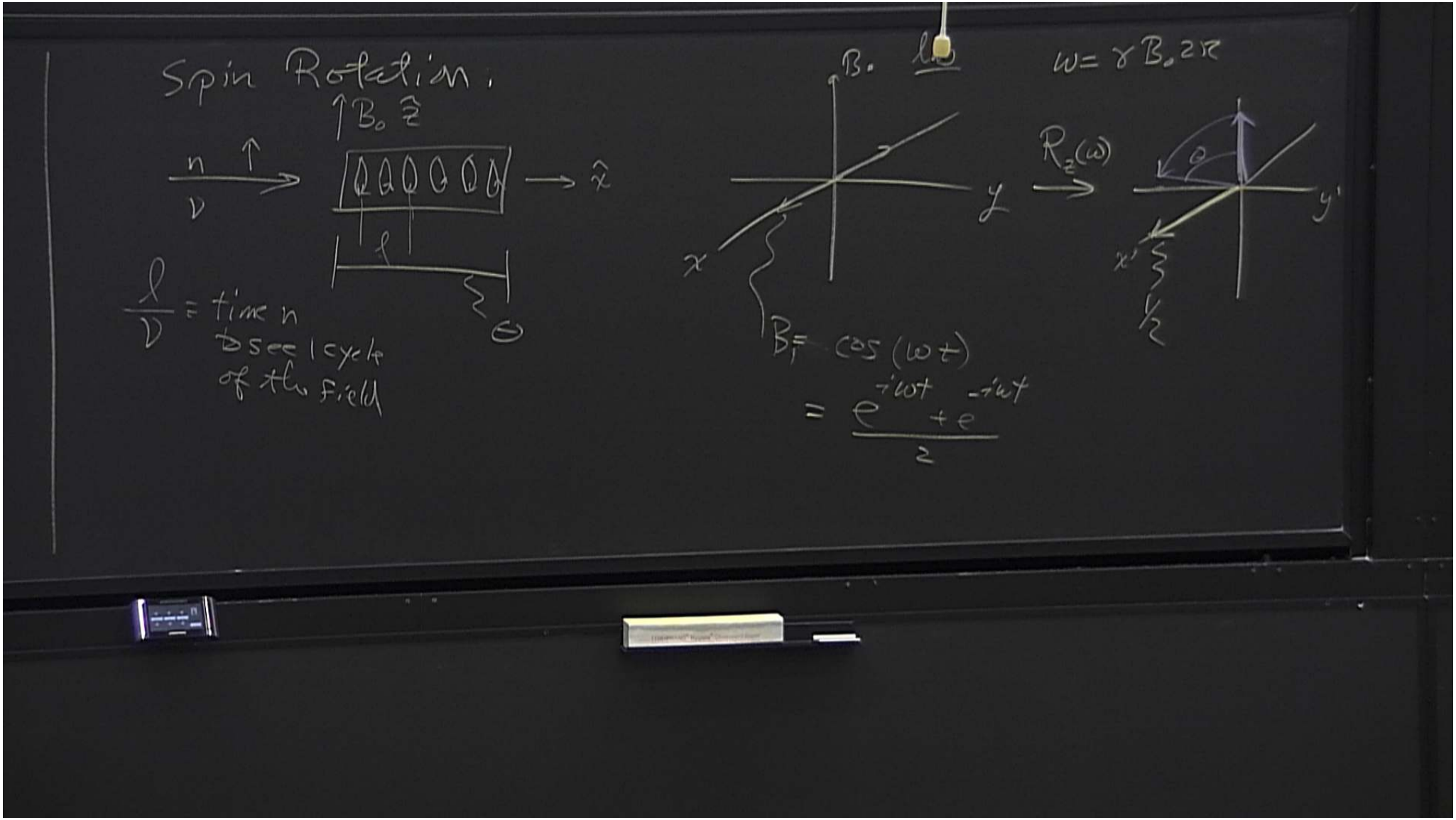

Spin Rotation:
$B_0 \hat{z}$
n
ν
$\hat{x}$
l
B_0
x
y
$R_z(\omega)$
x'
y'
$B_1 = \cos(\omega t)$
$= \frac{e^{i\omega t} + e^{-i\omega t}}{2}$


Spin Rotation.
$B_0 \hat{z}$
$B_1 = \cos(\omega t)$
$= \frac{e^{+i\omega t} + e^{-i\omega t}}{2}$
$R_z(\omega)$

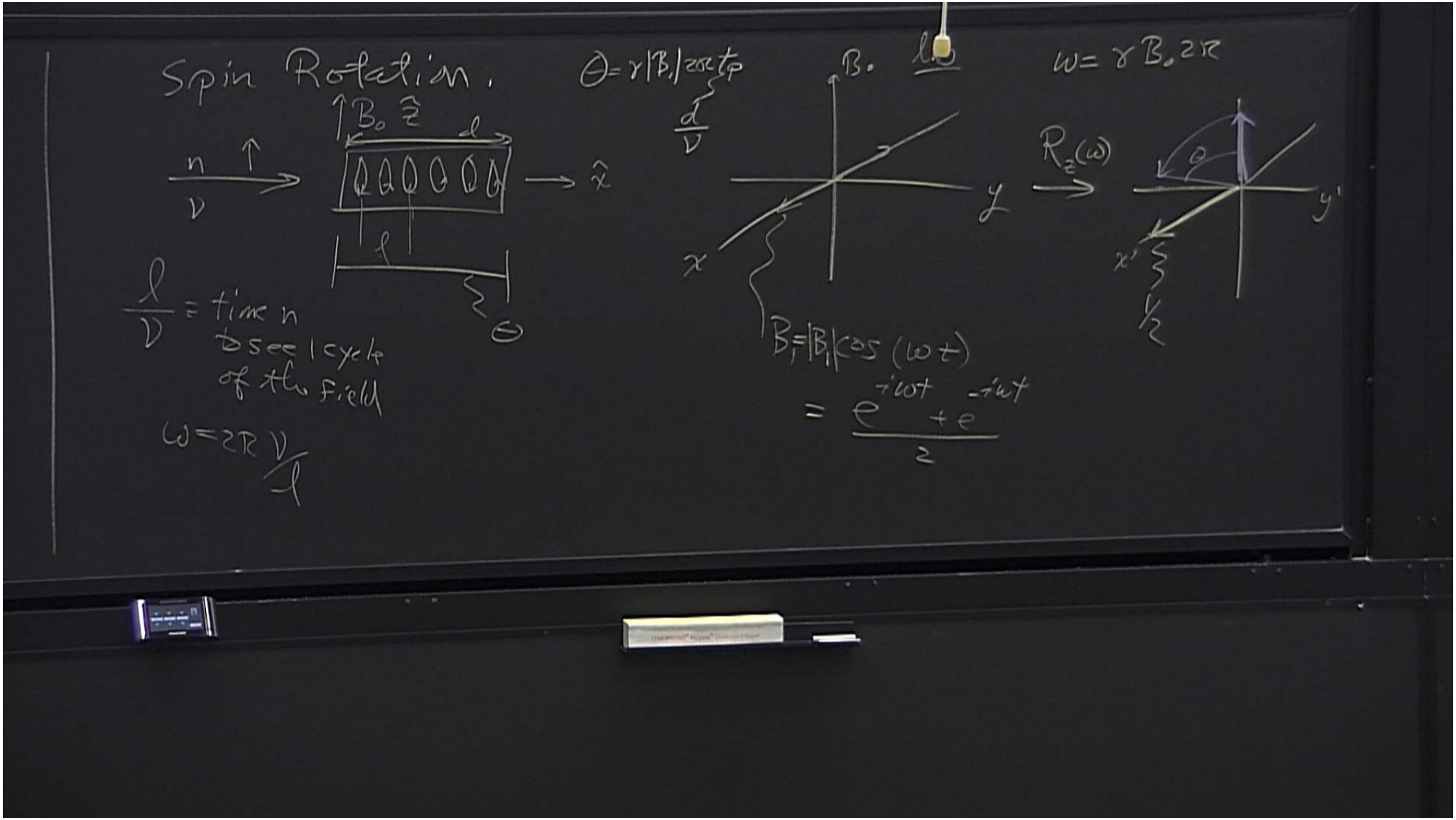

Spin Rotation.
$B_0 \hat{z}$
n
ν
$\hat{x}$
ℓ
B_0
$\omega = \gamma B_0 2\pi$
x
y
$R_z(\omega)$
x'
y'
π/2
$B_1 = \cos(\omega t)$
$= \frac{e^{+i\omega t} + e^{-i\omega t}}{2}$

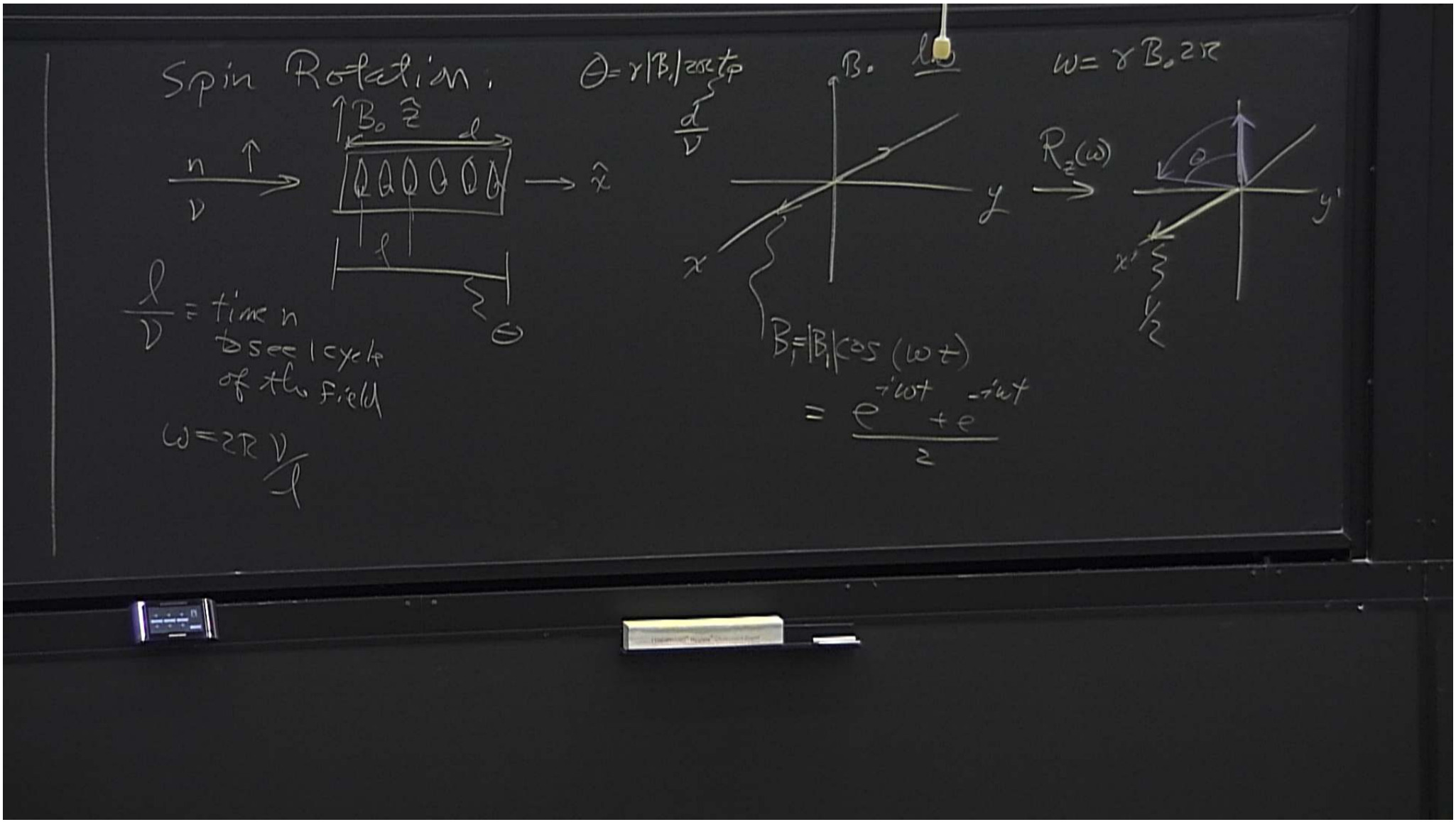

Spin Rotation.
$B_0 \hat{z}$
n
ν
$\hat{x}$
ℓ
B_0
$\omega = \gamma B_0 2\pi$
x
y
$R_z(\omega)$
x'
y'
θ
$\pi/2$
$B_1 = \cos(\omega t)$
$= \frac{e^{+i\omega t} + e^{-i\omega t}}{2}$

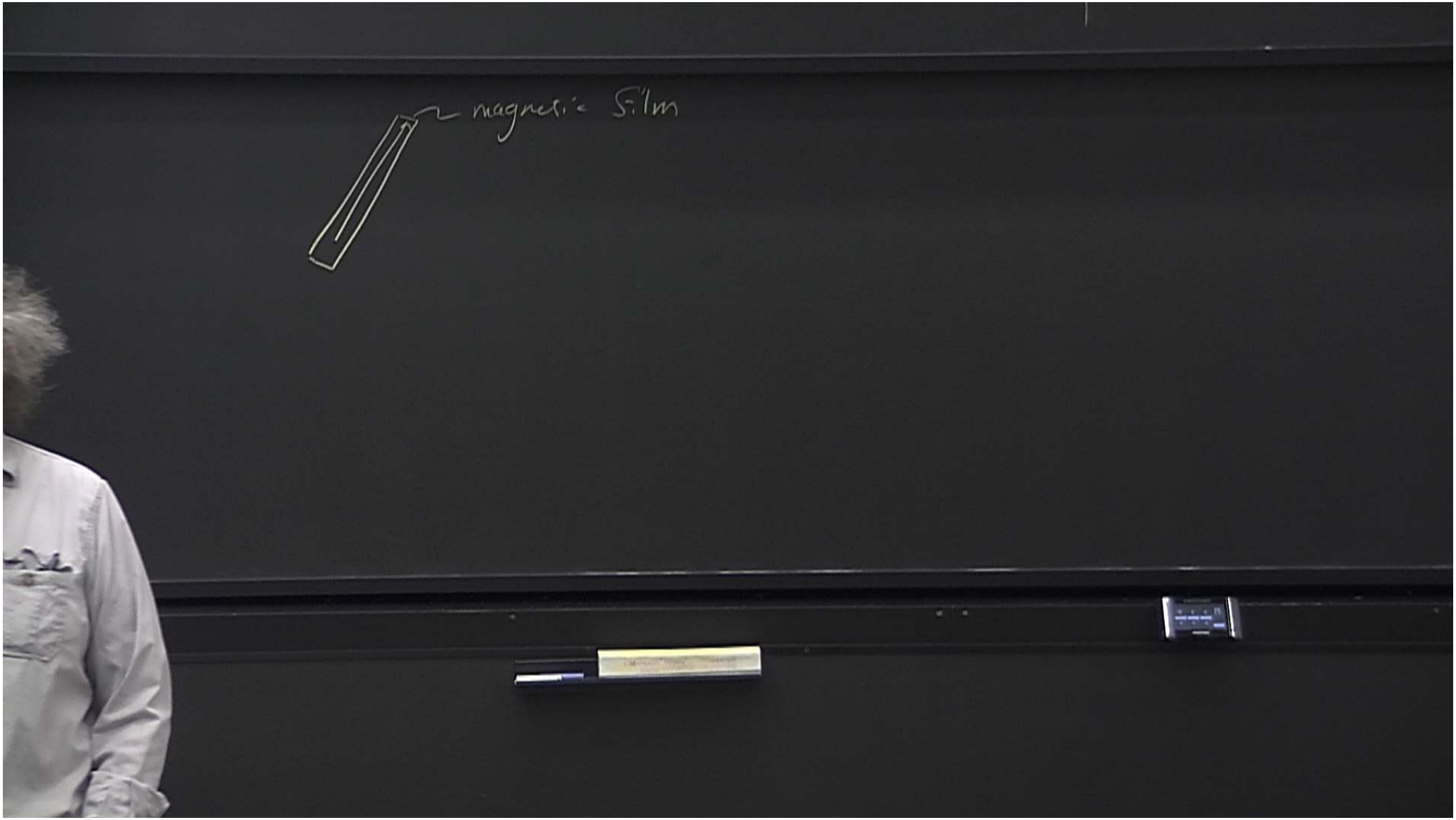

Spin Rotation.
$B_0 \hat{z}$
n
ν
$\hat{x}$
l
θ
B_0
$\omega = \gamma B_0 2\pi$
x
y
$R_z(\omega)$
θ
y'
x'
π/2
$B_1 = \cos(\omega t)$
$= \frac{e^{+i\omega t} + e^{-i\omega t}}{2}$

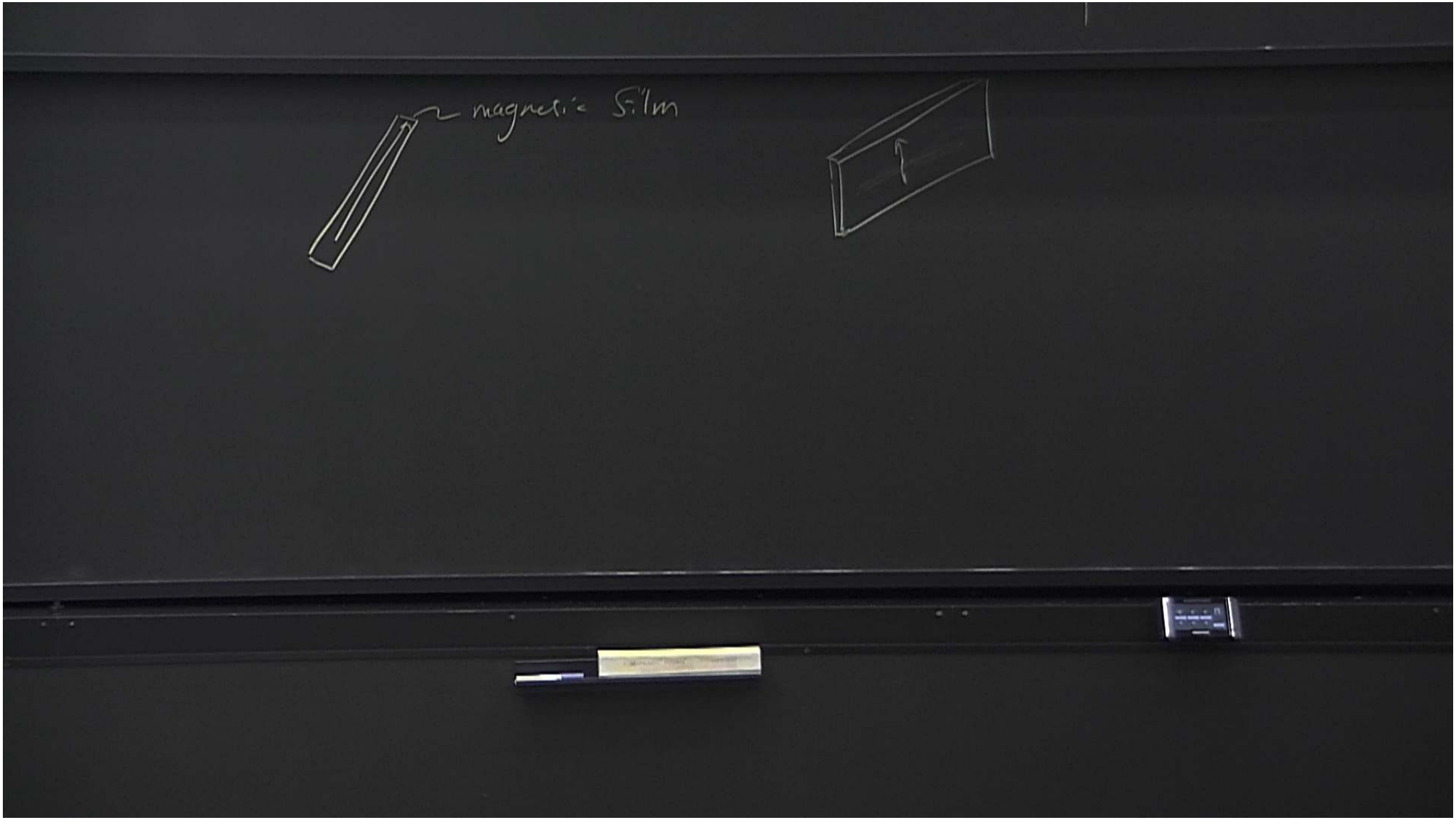

Spin Rotation:
$\uparrow B_0 \hat{z}$
n
v
$\hat{x}$
l
$\frac{l}{v}$ = time n to see 1 cycle of the field
0
B_0
$\omega = \gamma B_0 2\pi$
x
y
$B_1 = \cos(\omega t)$
$= \frac{e^{+i\omega t} + e^{-i\omega t}}{2}$
$R_z(\omega)$
θ
x'
y'
1/2

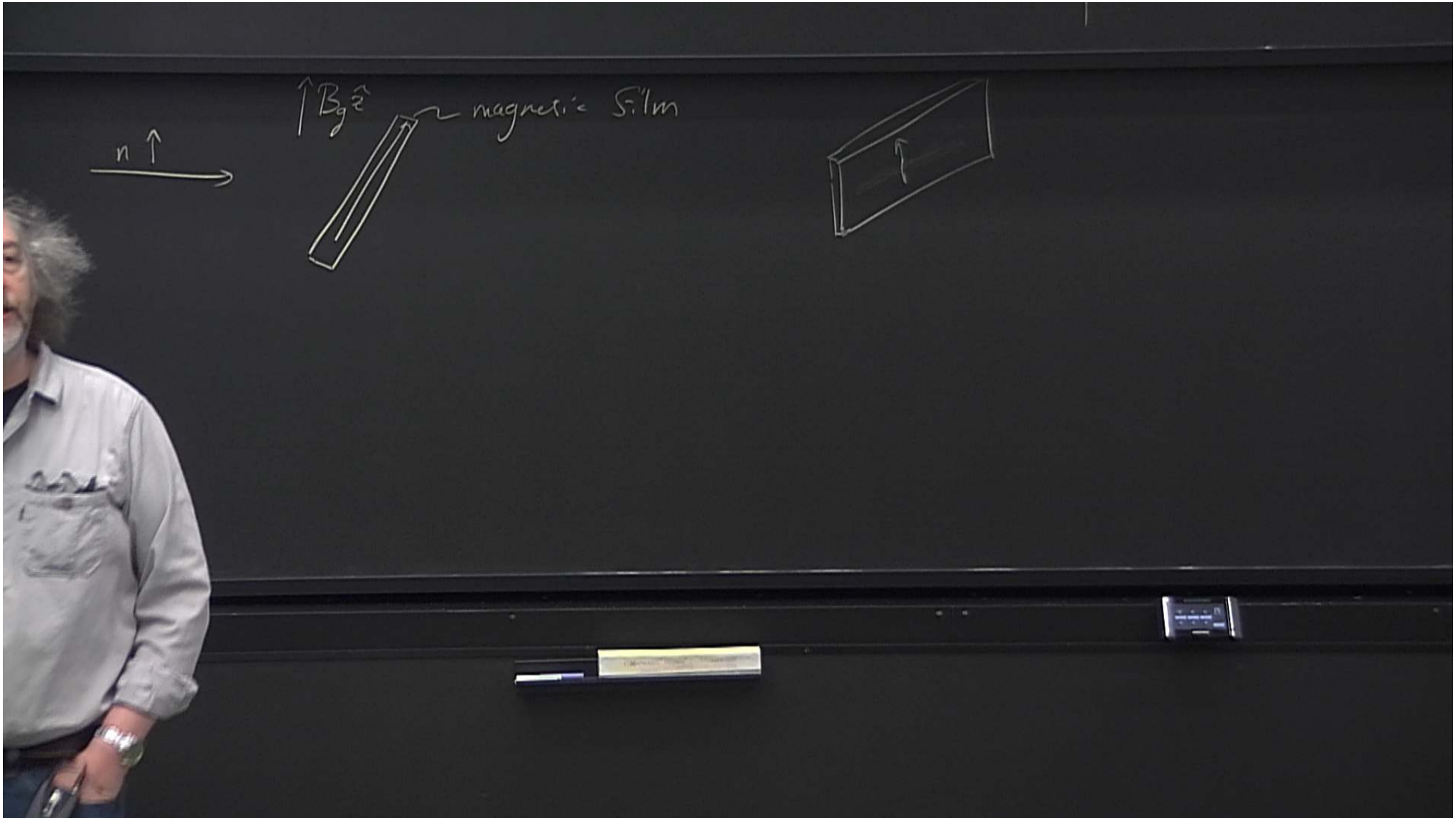
Spin Rotation.

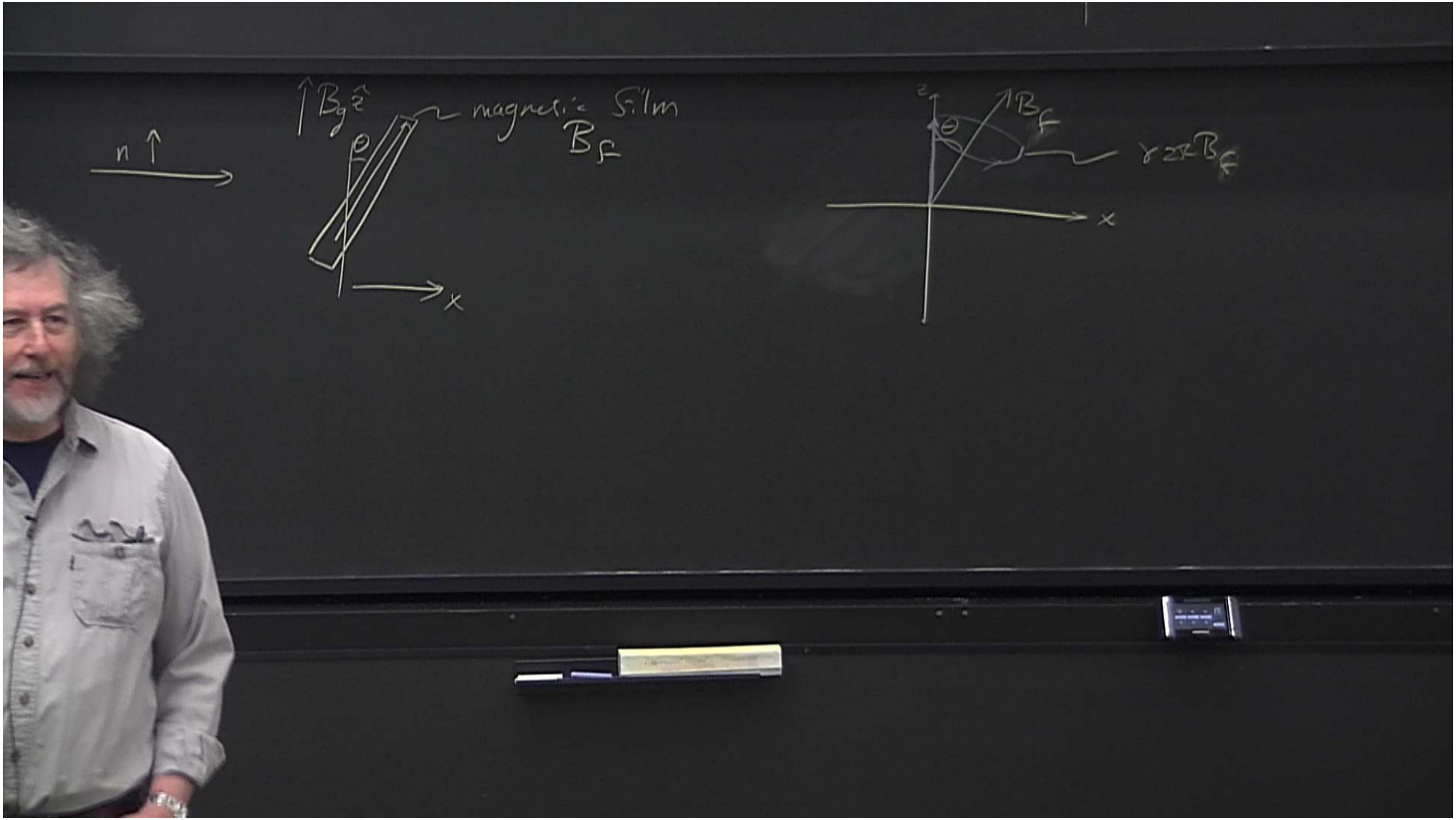

Spin Rotation.
$\theta = \gamma |B_1| \cos\omega t \, \frac{d}{v}$
B_0 $\hat{z}$
l
n
v
$\hat{x}$
θ
$\frac{l}{v}$ = time n to see 1 cycle of the field
$\omega = 2\pi \frac{v}{l}$
B_0
$\omega = \gamma B_0 2\pi$
$R_z(\omega)$
x
y
x'
y'
θ
$\pi/2$
$B_1 = |B_1| \cos(\omega t)$
$= \frac{e^{i\omega t} + e^{-i\omega t}}{2}$

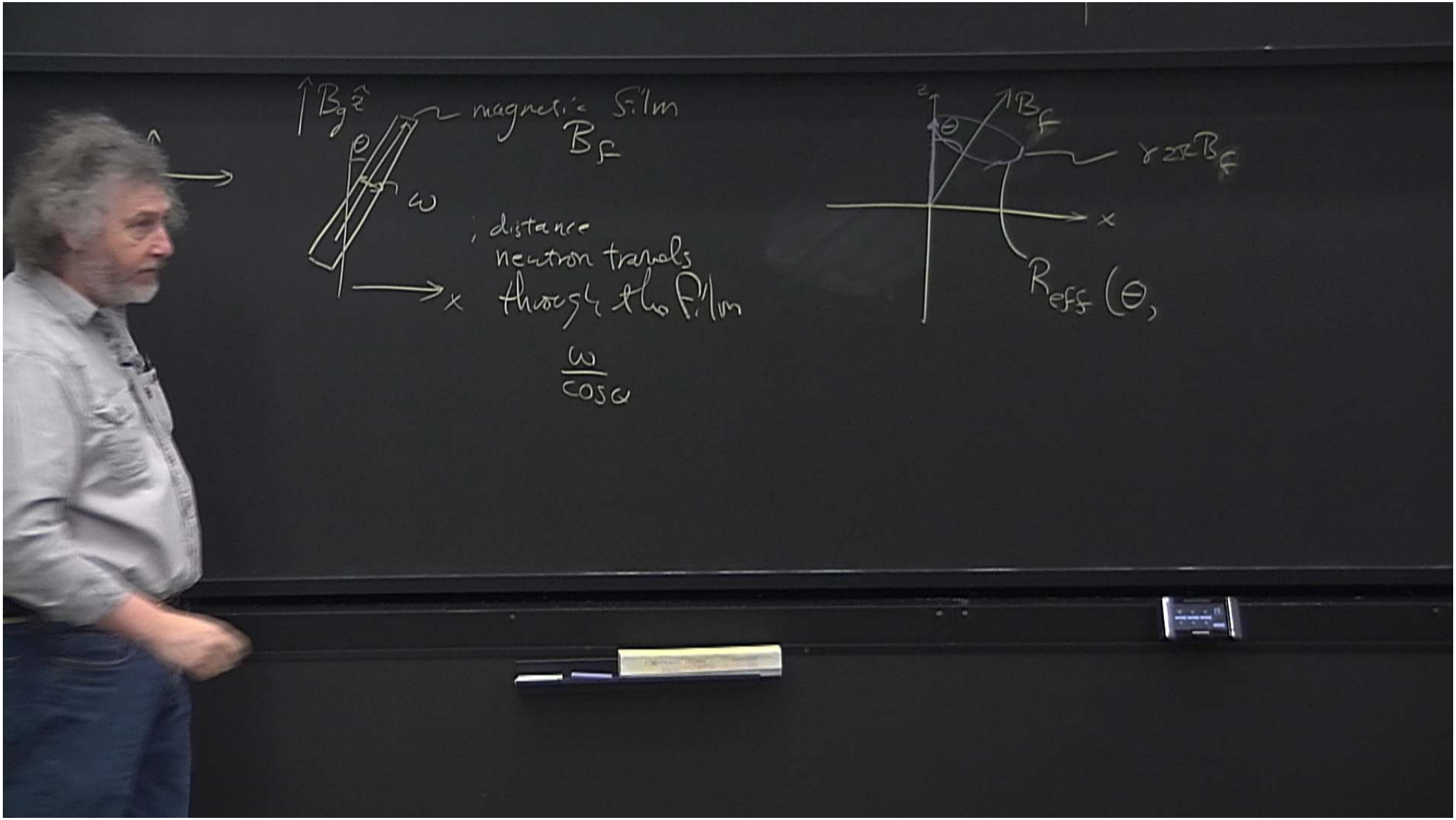

Spin Rotation:
$\theta = \gamma |B_1| \cos\omega t \, \tau_p$
$\tau_p = \frac{d}{v}$
$B_0 \hat{z}$
n
v
l
$\hat{x}$
θ
$\frac{l}{v}$ = time n to see 1 cycle of the field
$\omega = 2\pi \frac{v}{l}$
B_0
$\omega = \gamma B_0 2\pi$
$R_z(\omega)$
x
y
x'
y'
θ
$\pi/2$
$B_1 = |B_1| \cos(\omega t)$
$= \frac{e^{+i\omega t} + e^{-i\omega t}}{2}$

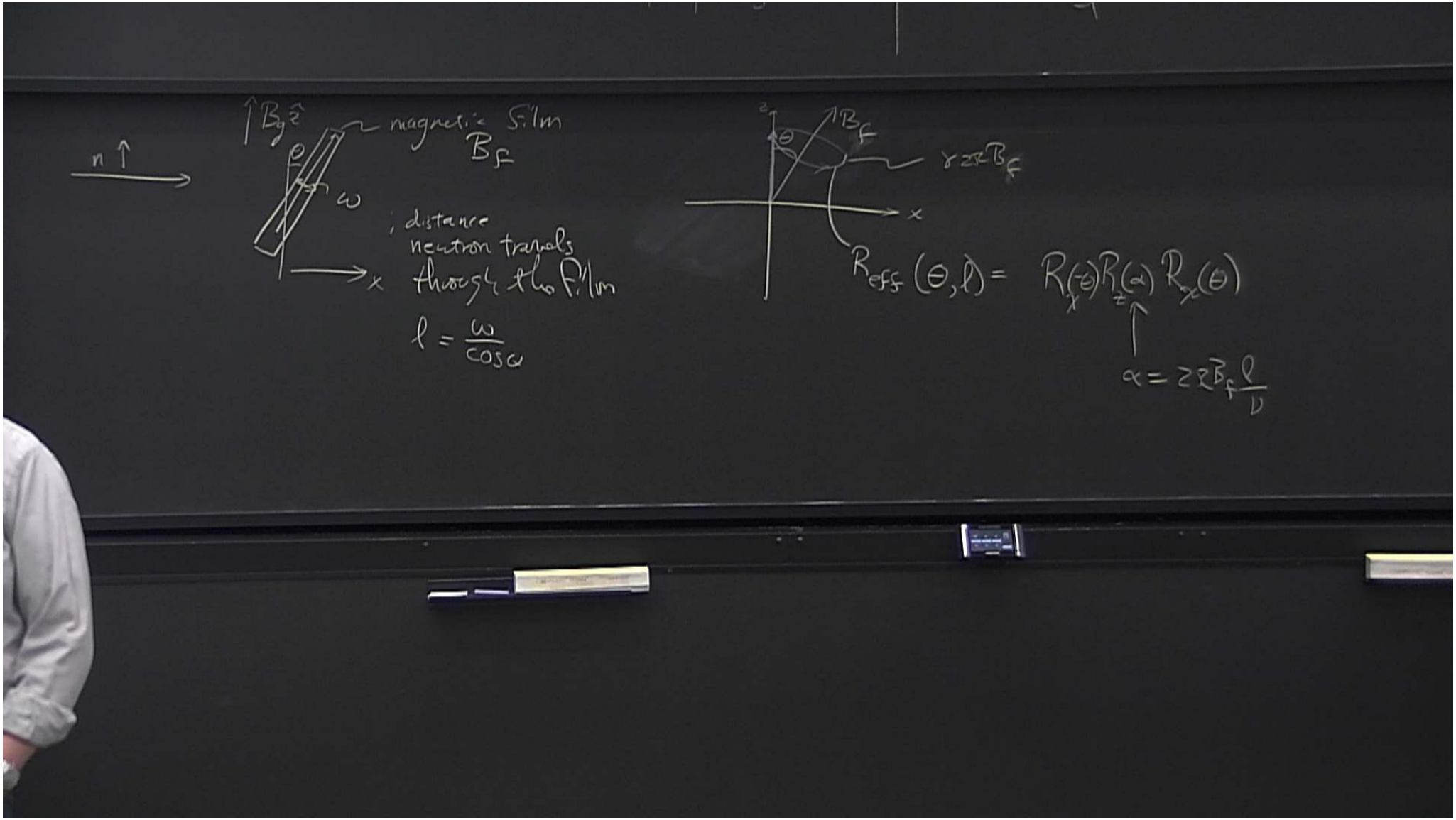

magnetic film

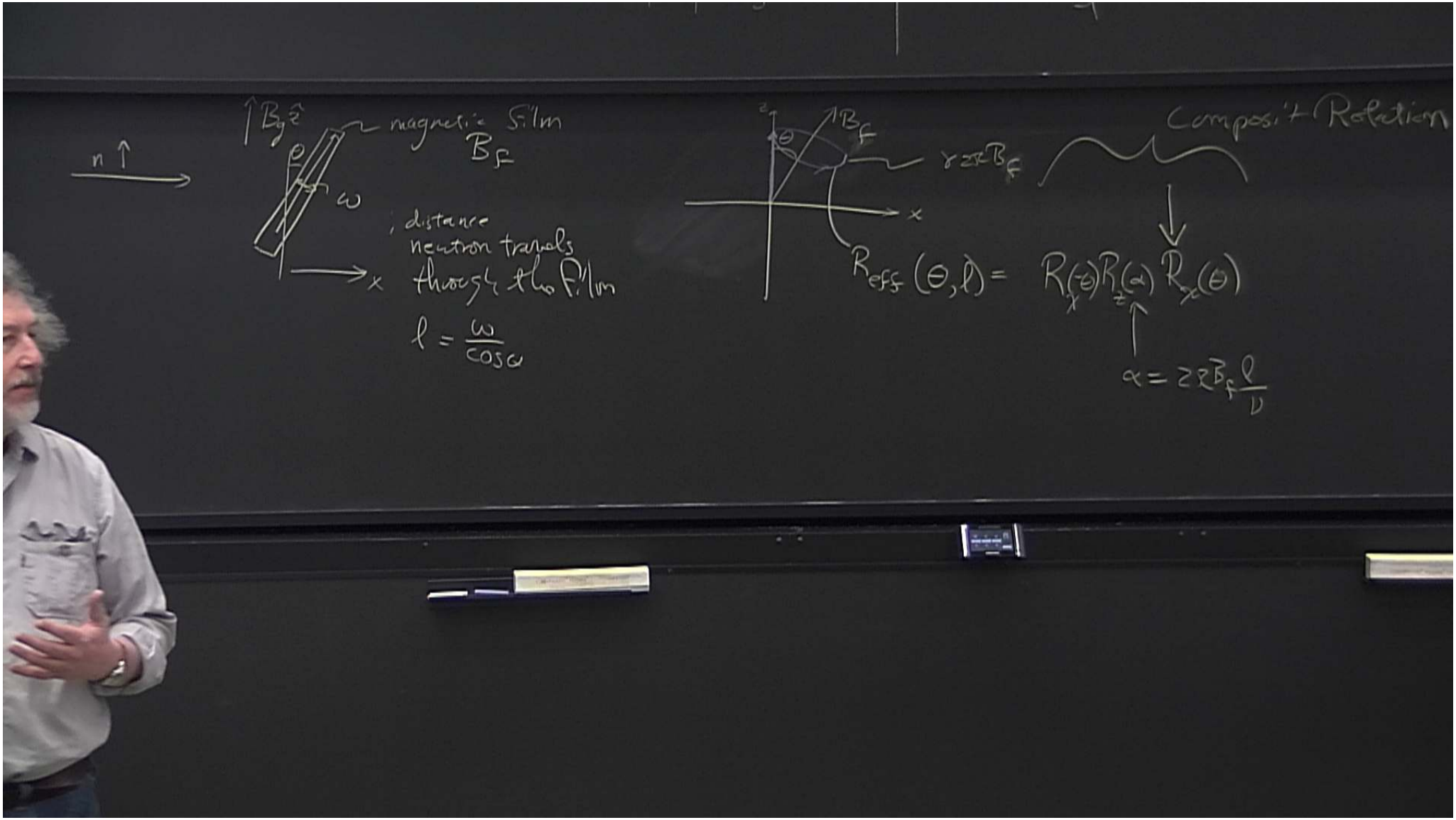

magnetic film

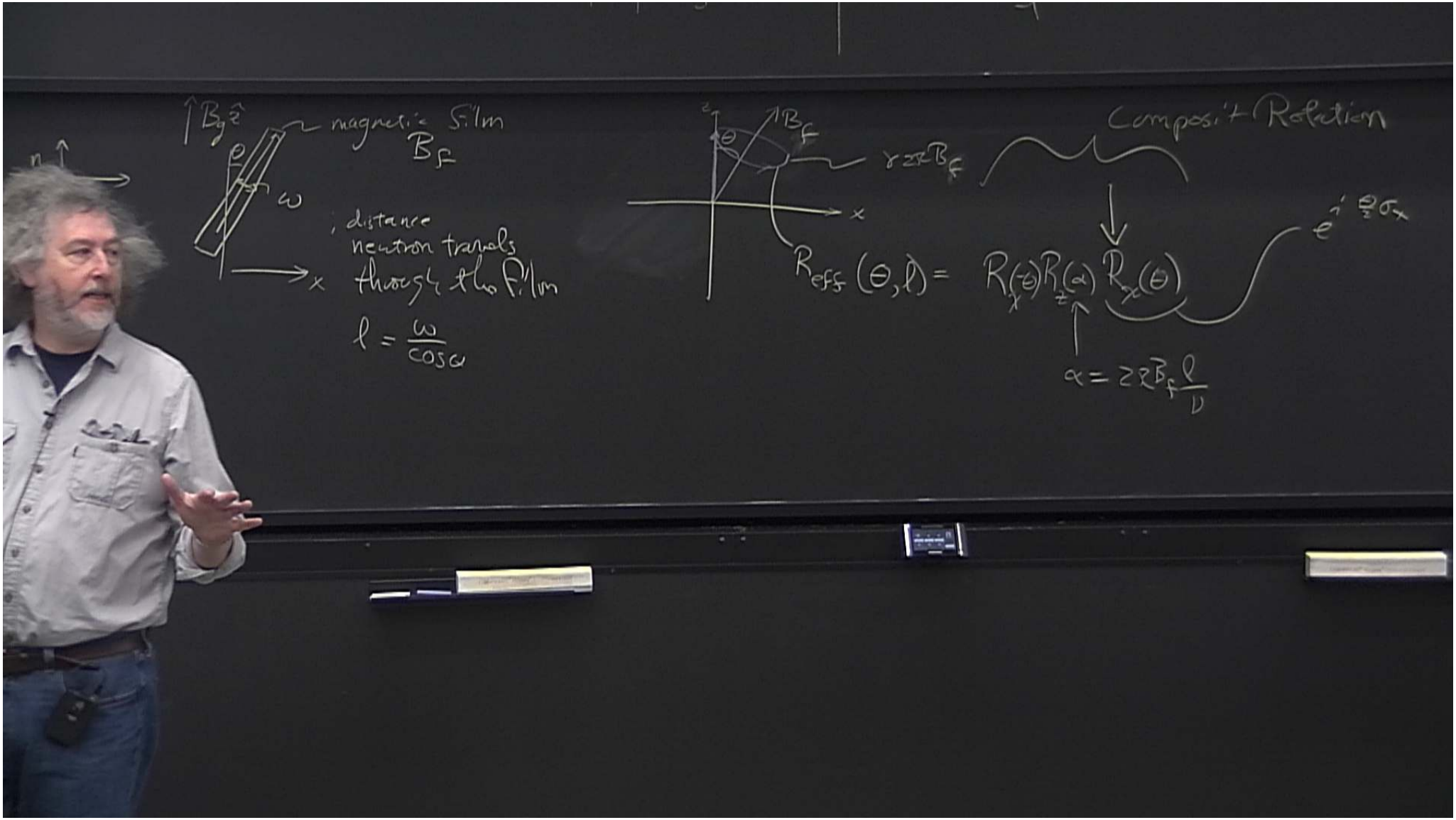

$B_g \hat{z}$
magnetic Film
n

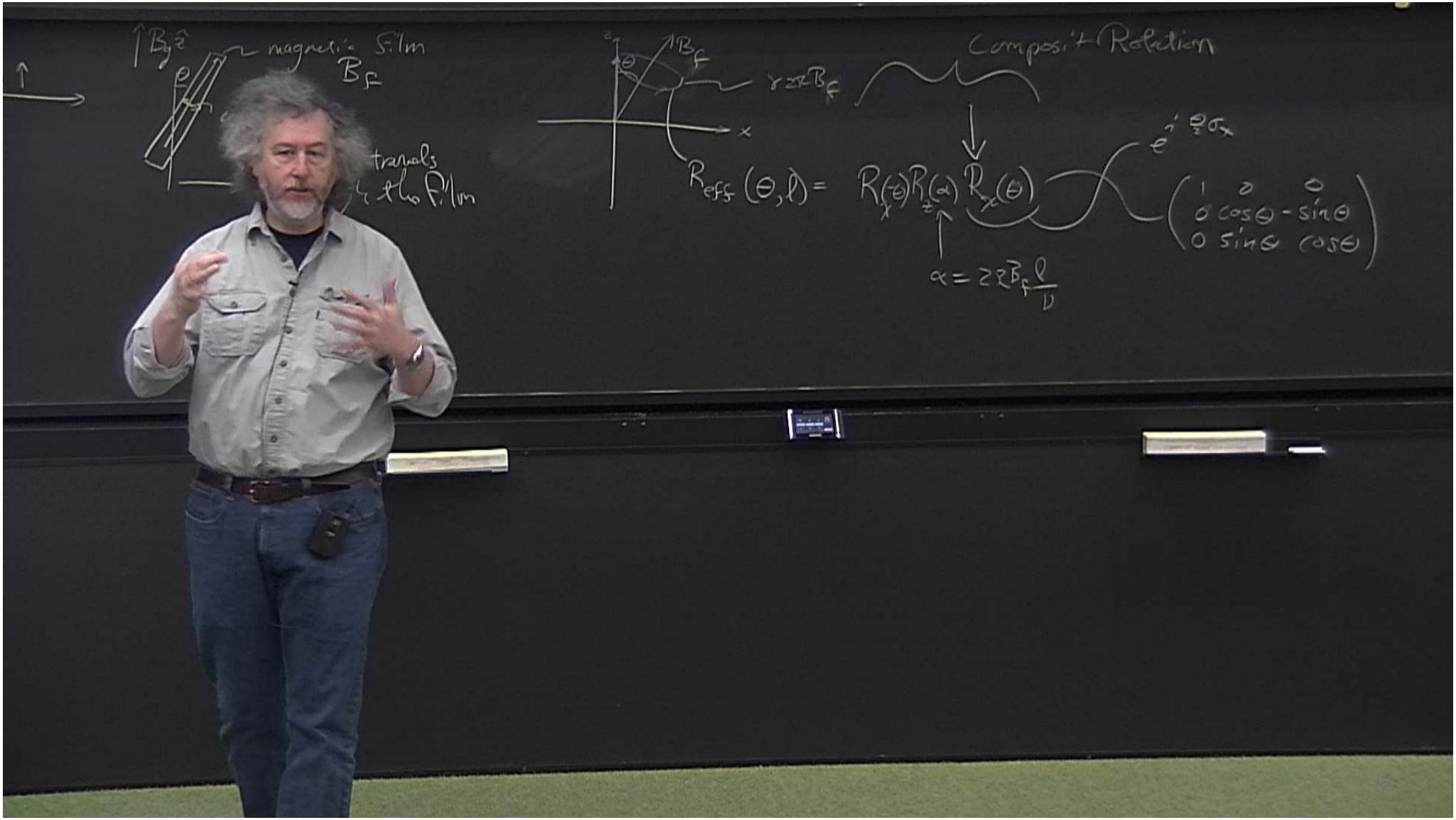

n
$B_g \hat{z}$
magnetic film
B_f
x
z
B_f
θ
$\gamma \hbar B_f$
x

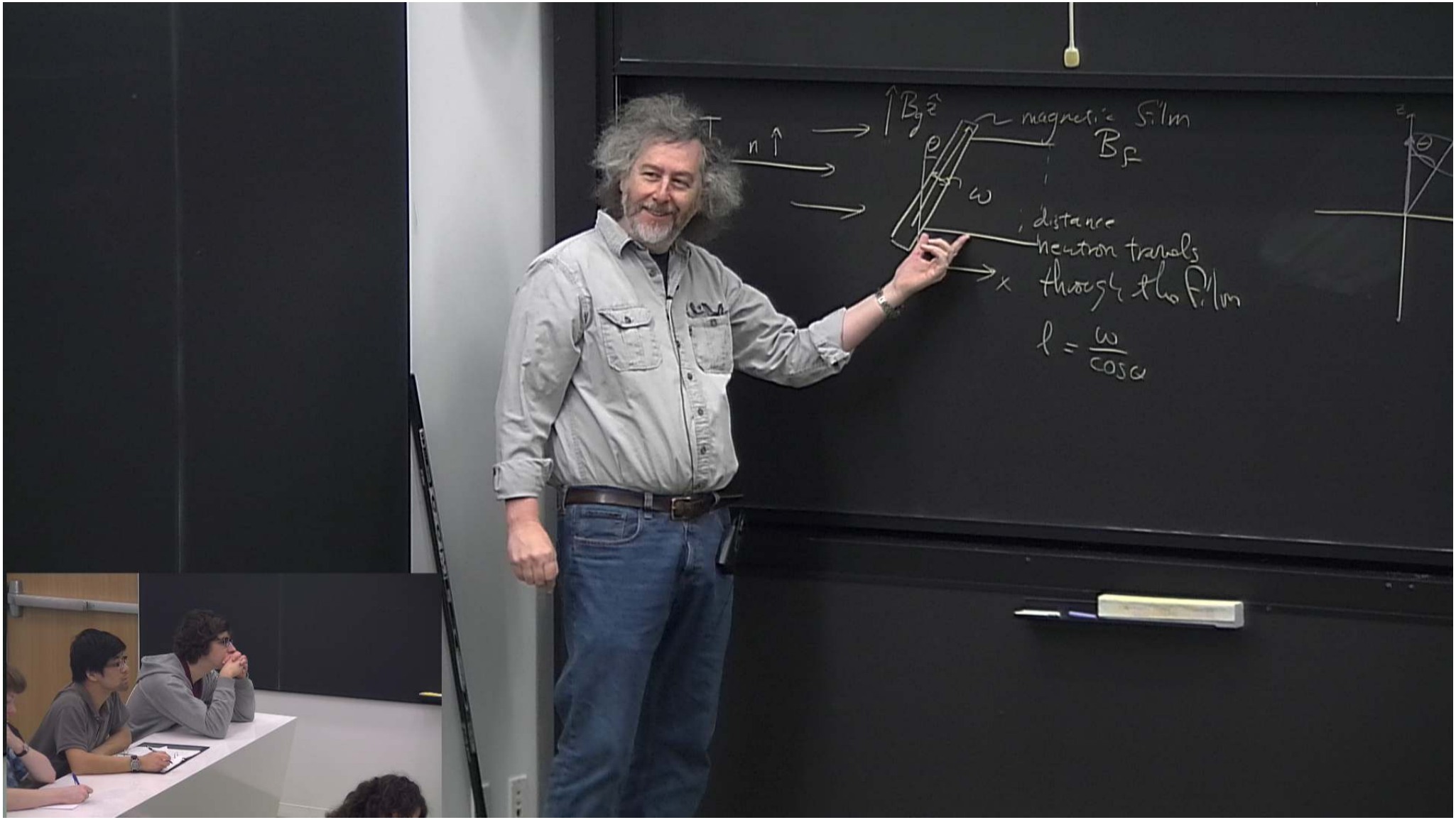

$B_g \hat{z}$
magnetic film
B_f
θ
ω
; distance neutron travels through the film
$\frac{\omega}{\cos\alpha}$
z
B_f
θ
$\gamma \pi B_f$
x
$R_{eff}(\theta,$

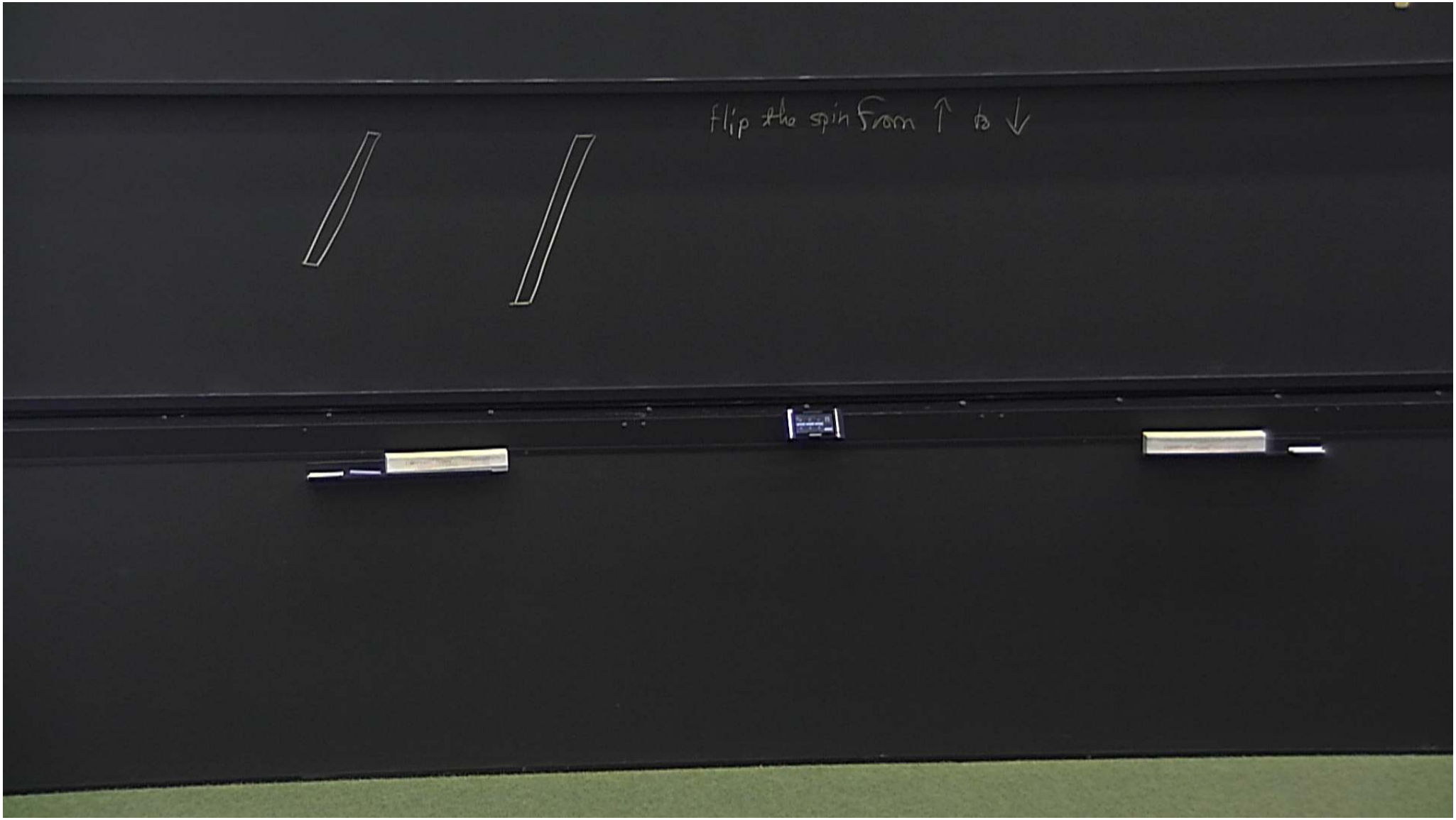

n
$B_f \hat{z}$
magnetic film
B_f
ω
x
; distance neutron travels through the film
$l = \frac{\omega}{\cos\alpha}$
z
B_f
θ
$\gamma 2\pi B_f$
x
$R_{eff}(\theta, l) = R_x(\theta) R_z(\alpha) R_x(\theta)$
$\alpha = 2\pi B_f \frac{l}{v}$

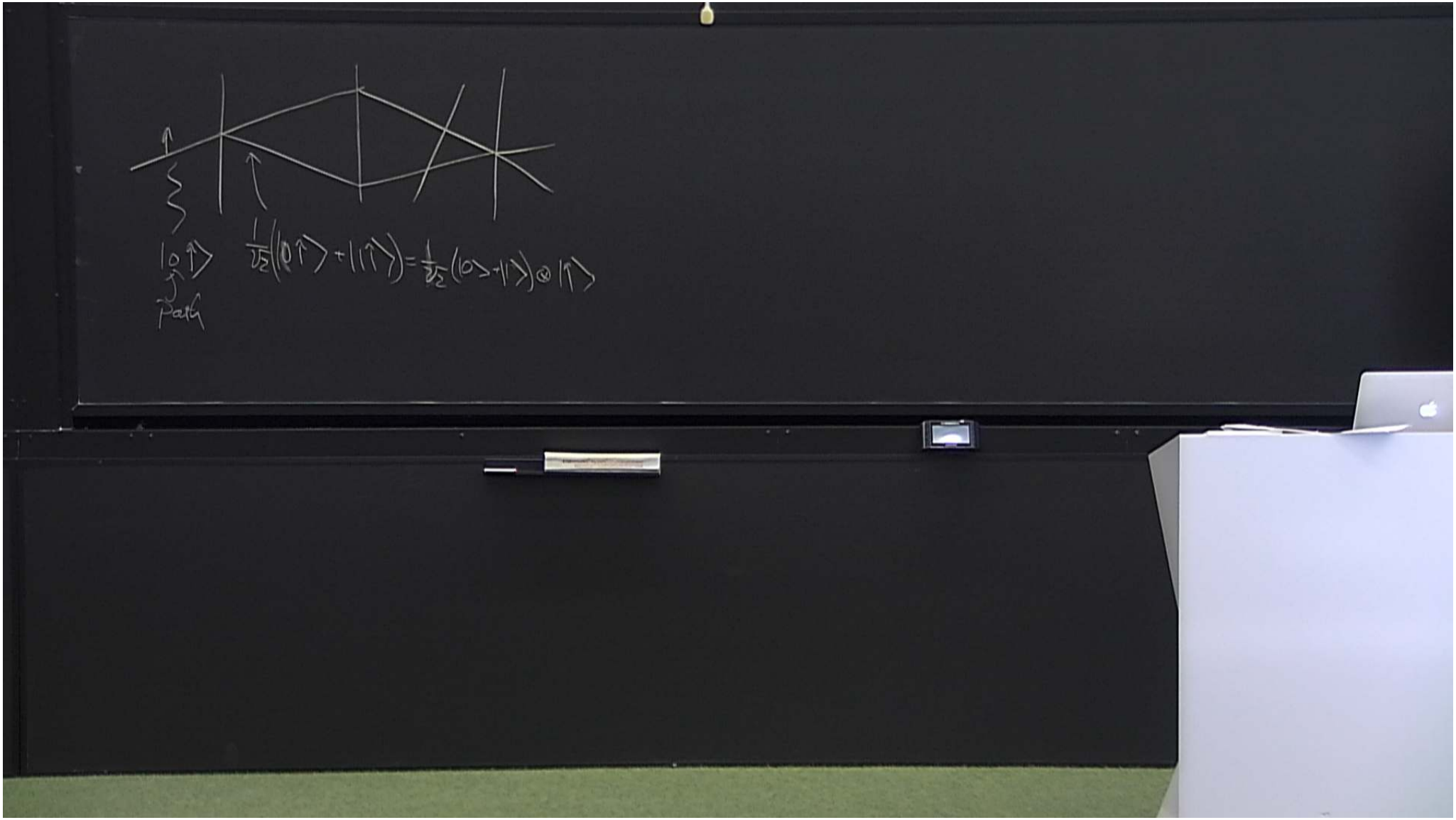

n ↑
$B_g \hat{z}$
magnetic film
B_f
θ
ω
x
; distance
neutron travels
through the film
$\ell = \frac{\omega}{\cos\alpha}$
z
θ
B_f
$\gamma 2\pi B_f$
x
Composit Rotation
$R_{eff}(\theta, \ell) = R_x(-\theta) R_z(\alpha) R_x(\theta)$
$\alpha = 2\pi B_f \frac{\ell}{v}$

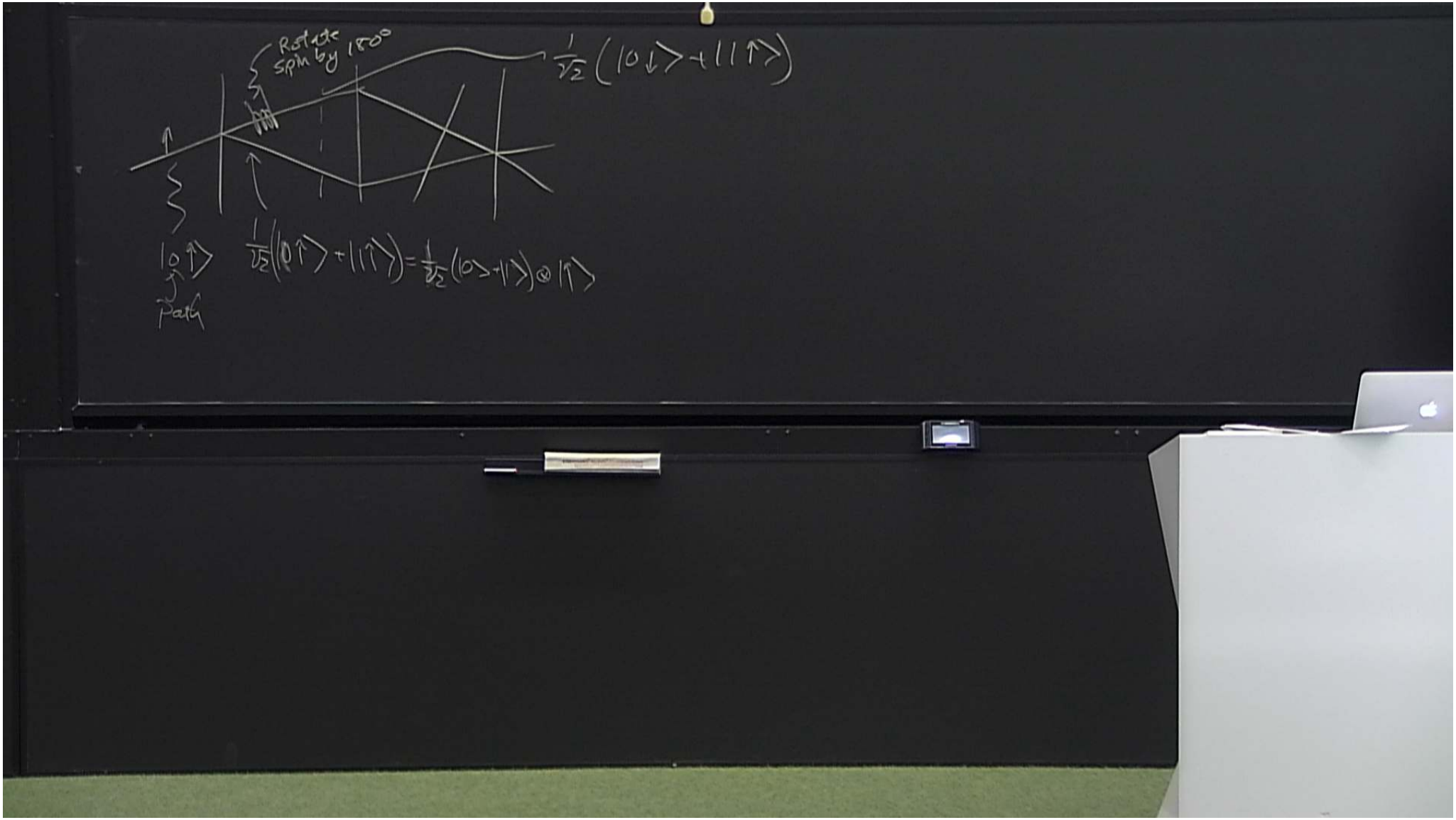

$B_g \hat{z}$
magnetic Film
B_f
ω
x
; distance
neutron travels
through the Film
$l = \frac{\omega}{\cos\alpha}$
z
B_f
θ
x
$\gamma \hbar B_f$
$R_{eff}(\theta, l) =$
Composite Rotation
$R_x(-\theta) R_z(\alpha) R_x(\theta)$
$e^{i \frac{\theta}{2} \sigma_x}$
$\alpha = \gamma \hbar B_f \frac{l}{v}$

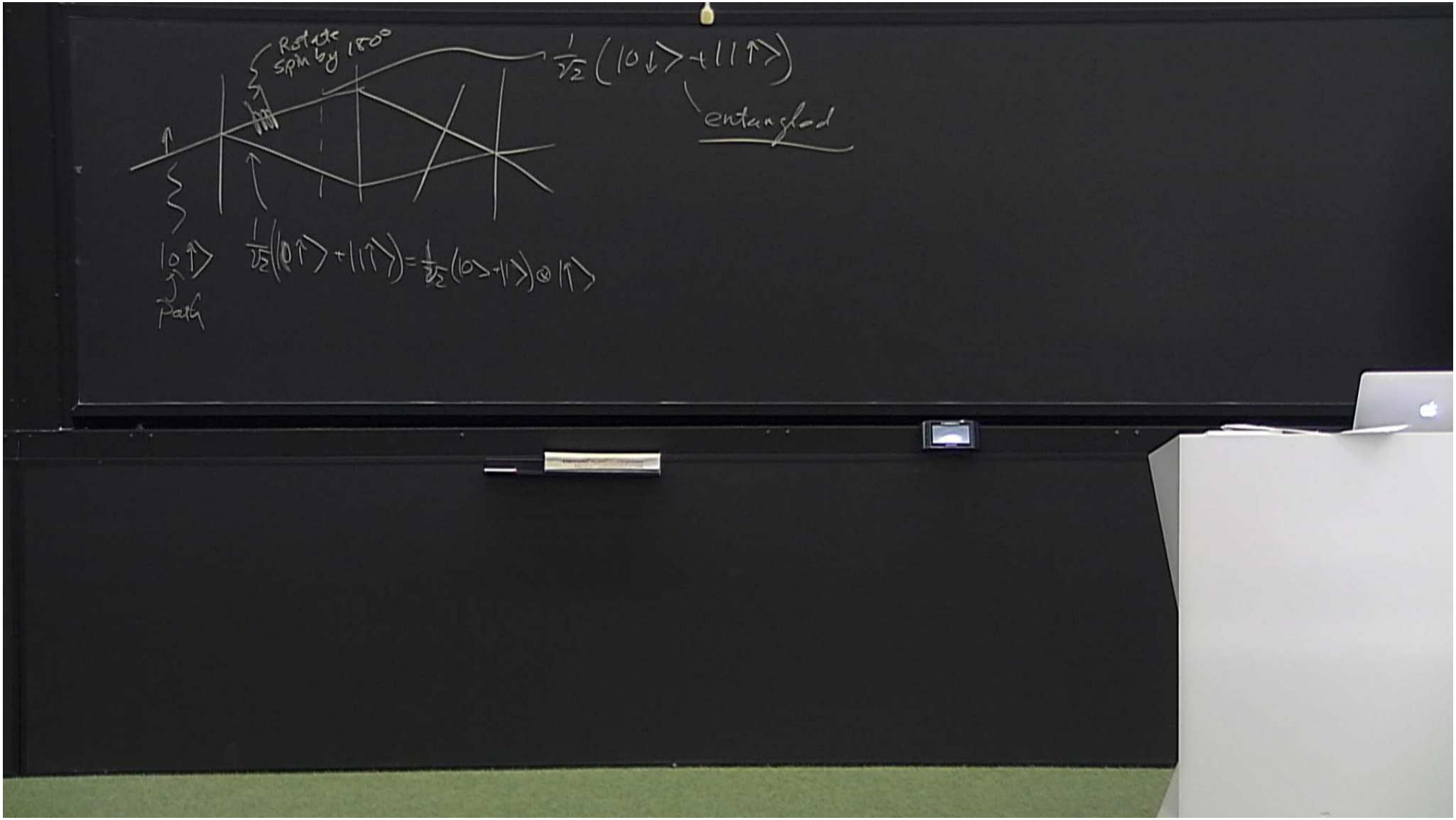

magnetic film
B_f
travels
the film
B_f
$\gamma 2\pi B_f$
Composit Rotation
$R_{eff}(\theta, l) = R_x(-\theta) R_z(\alpha) R_x(\theta)$
$e^{i \frac{\theta}{2} \sigma_x}$
$\begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix}$
$\alpha = 2\pi B_f \frac{l}{v}$

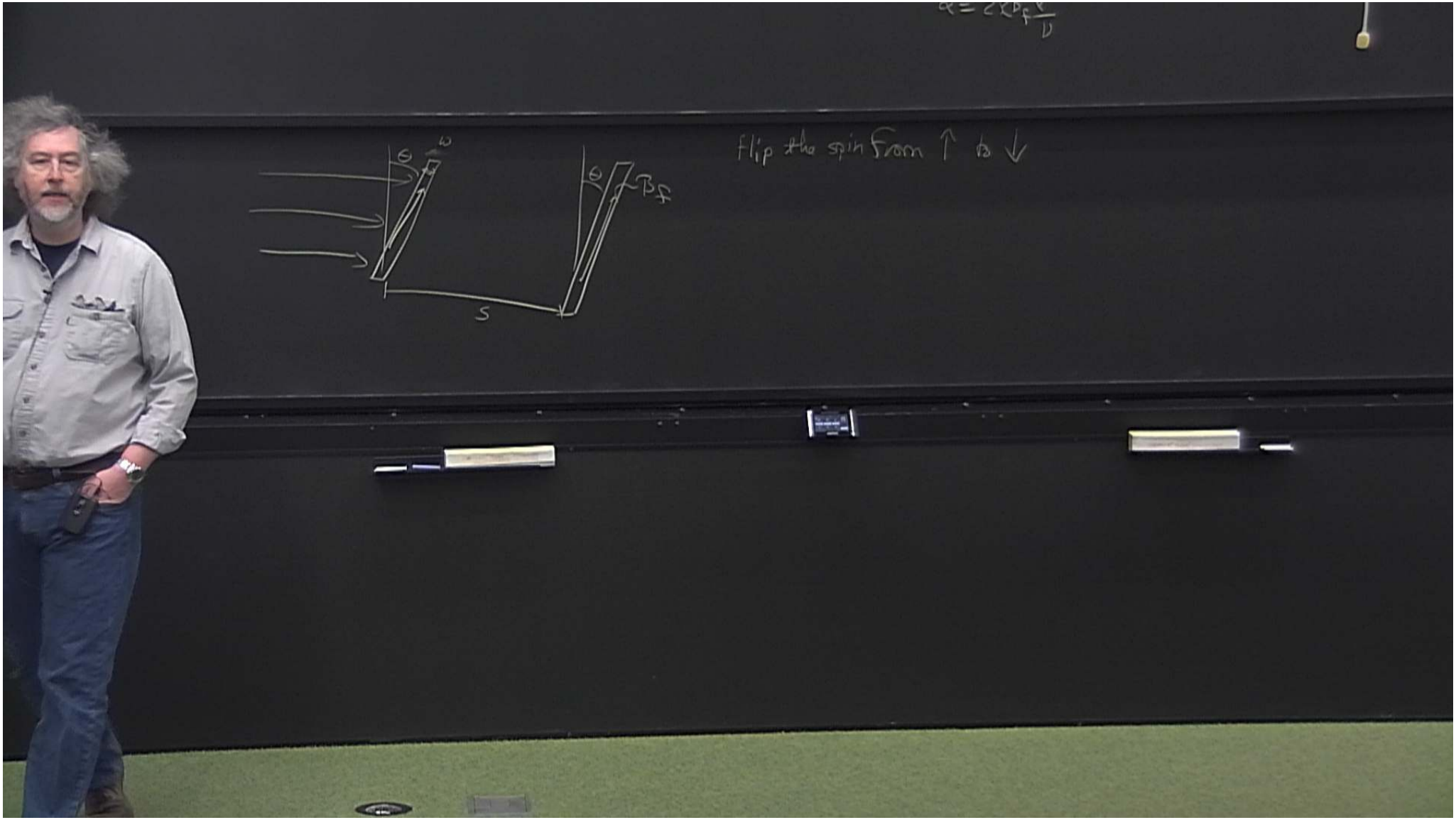

magnetic film
distance
neutron travels
through the film
$l = \frac{w}{\cos\alpha}$

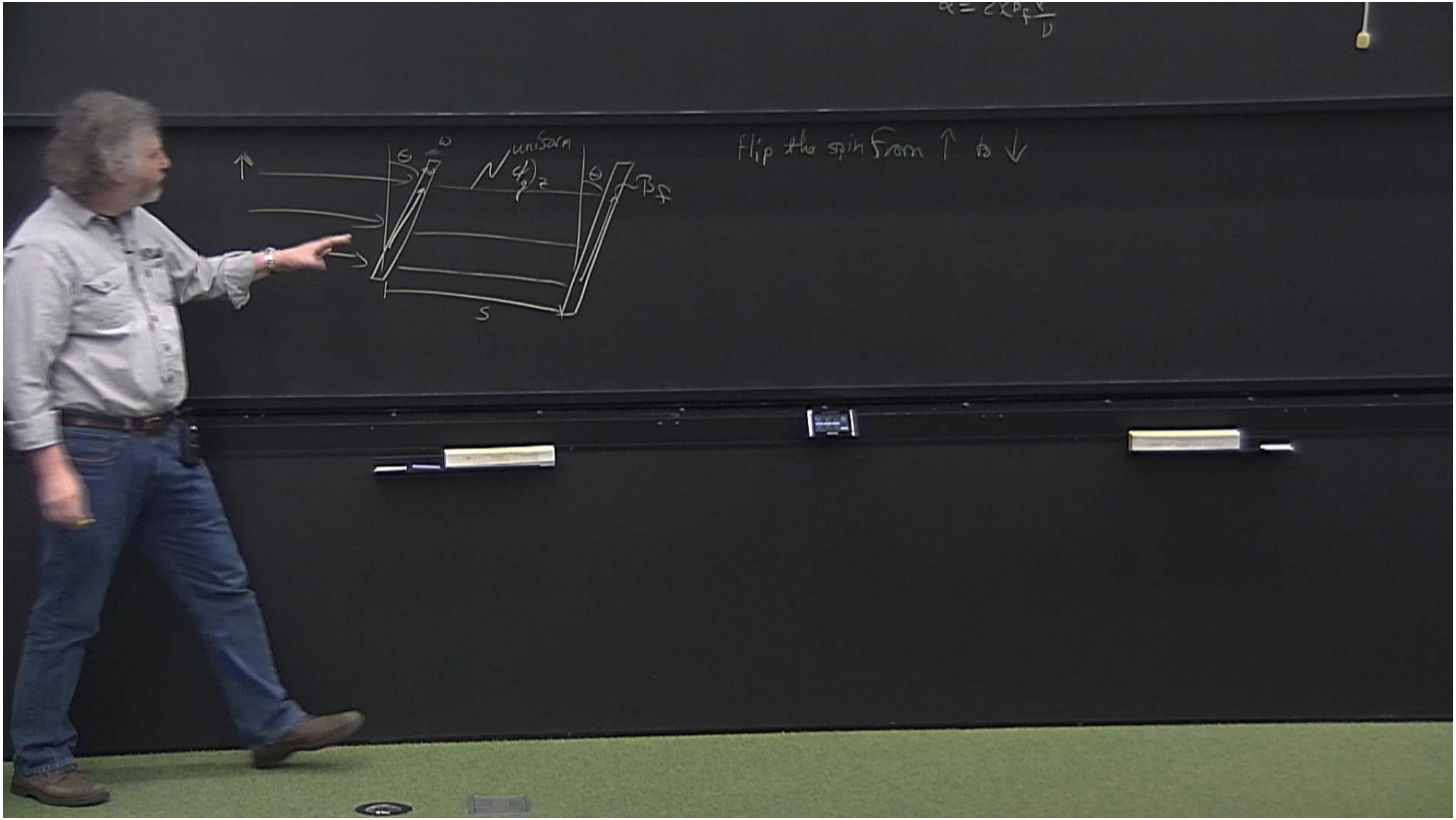

flip the spin from ↑ to ↓

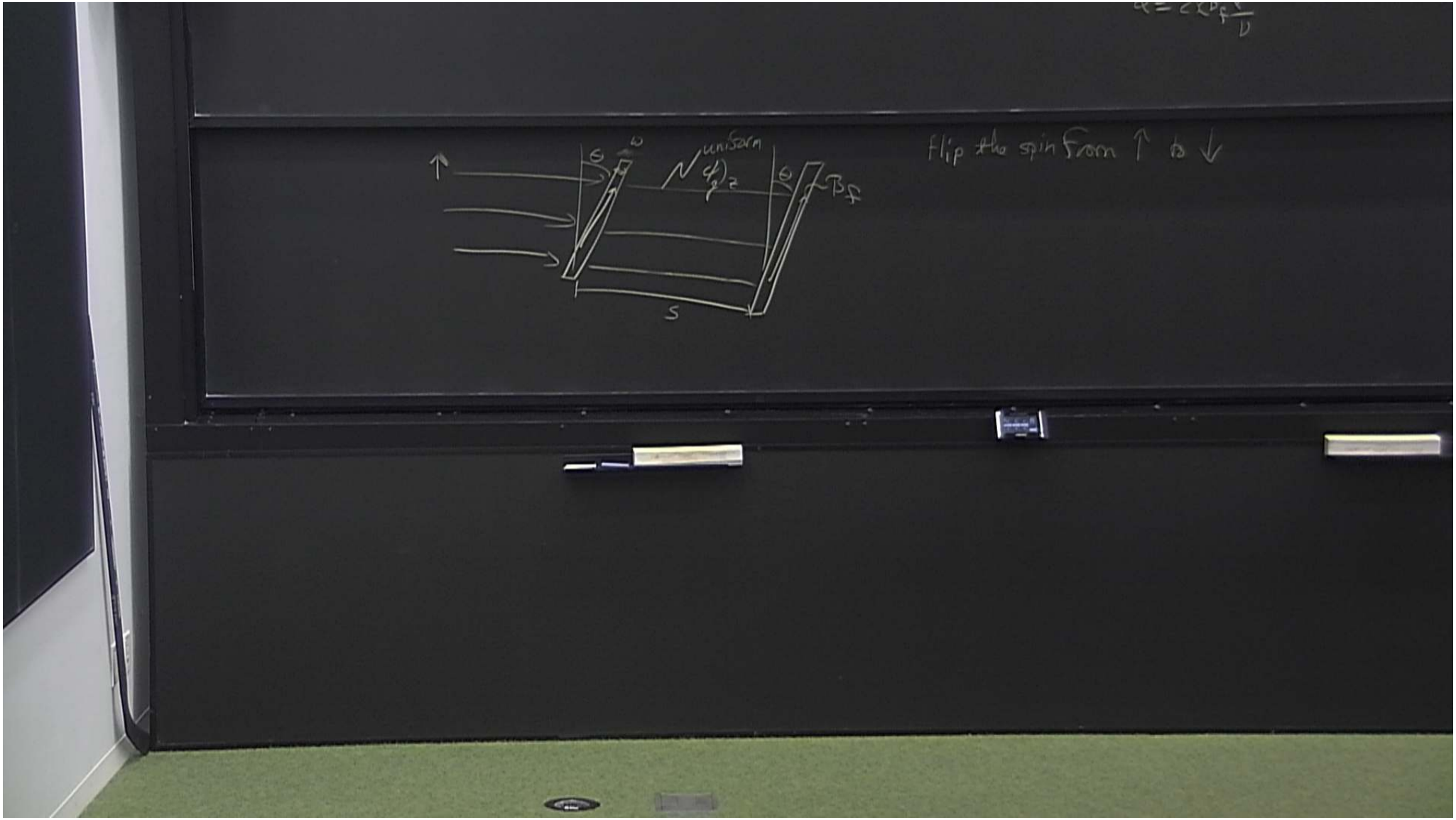

$|0\uparrow\rangle$
$\frac{1}{\sqrt{2}}(|0\uparrow\rangle + |1\downarrow\rangle) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)\otimes|\uparrow\rangle$
Bell


Rotate spin by 180°
$\frac{1}{\sqrt{2}}(|0\downarrow\rangle + |1\uparrow\rangle)$
$|0\uparrow\rangle$
$\frac{1}{\sqrt{2}}(|0\uparrow\rangle + |1\uparrow\rangle) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \otimes |\uparrow\rangle$
Path


Rotate spin by 180°
$\frac{1}{\sqrt{2}}(|0\downarrow\rangle + |1\uparrow\rangle)$
entangled
$|0\uparrow\rangle$
$\frac{1}{\sqrt{2}}(|0\uparrow\rangle + |1\uparrow\rangle) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \otimes |\uparrow\rangle$
Path

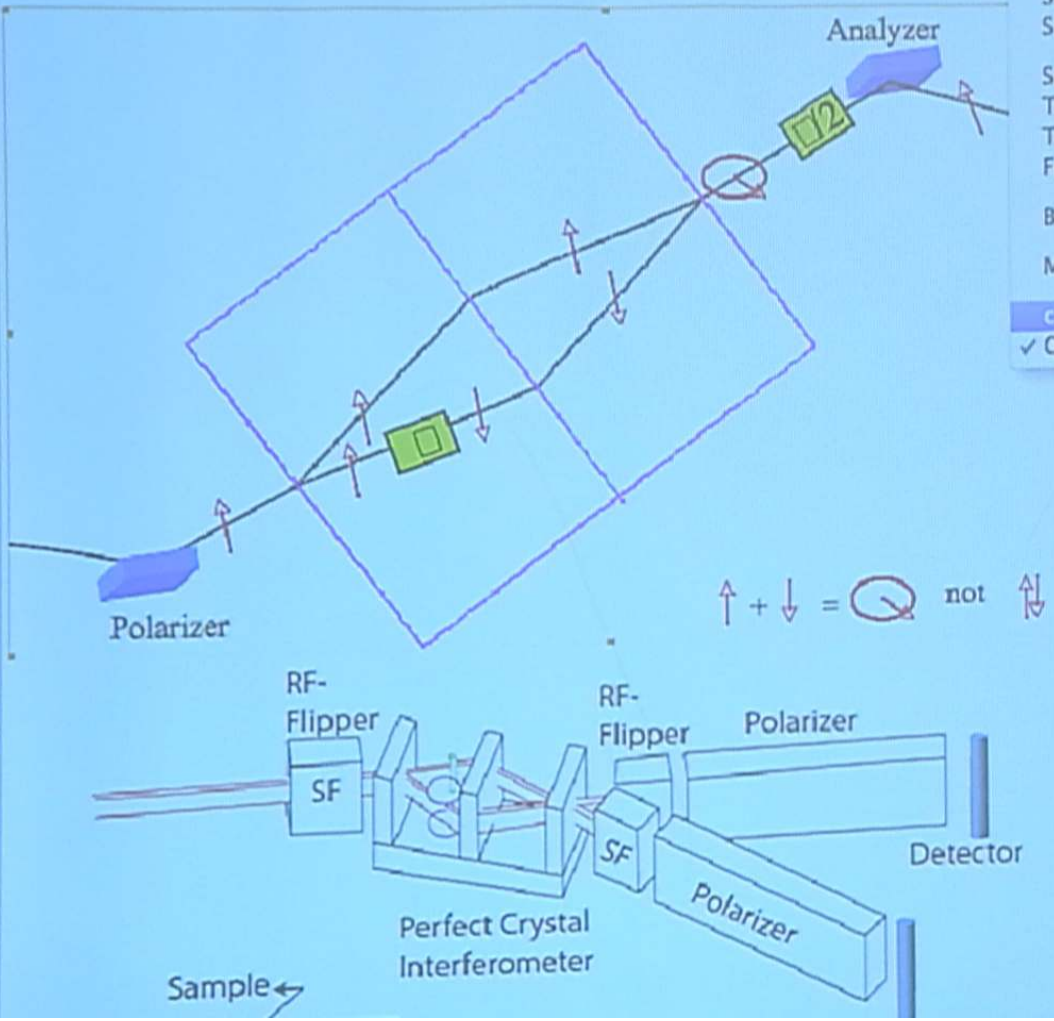

flip the spin from ↑ to ↓
θ
ω
θ
Bf
s


flip the spin from ↑ to ↓
uniform
θ
θ
S


flip the spin from ↑ to ↓

QE Lec 6.nb

Operators for various components



Minimize ⌘M
Zoom ⌥⌘/

Magnification
Show Ruler
Show Toolbar

Stack Windows
Tile Windows Wide
Tile Windows Tall
Full Screen ⌥⌘F

Bring All to Front

Messages

composite films.cdf
✓ QE Lec 6.nb

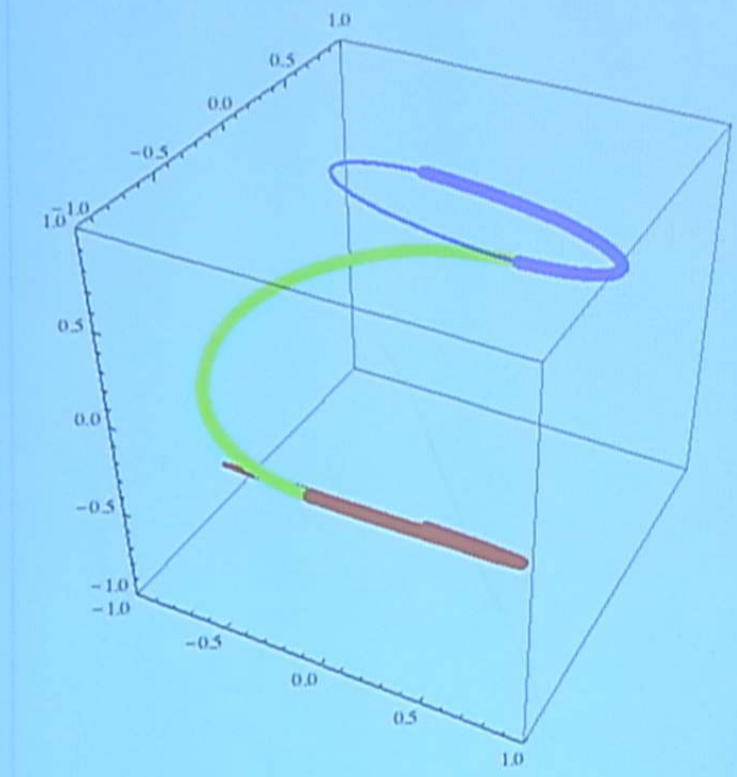
Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

composite films.cdf

```
PlotRange → {{-1, 1}, {-1, 1}, {-1, 1}}]], {α, 0, π / 4}]
```

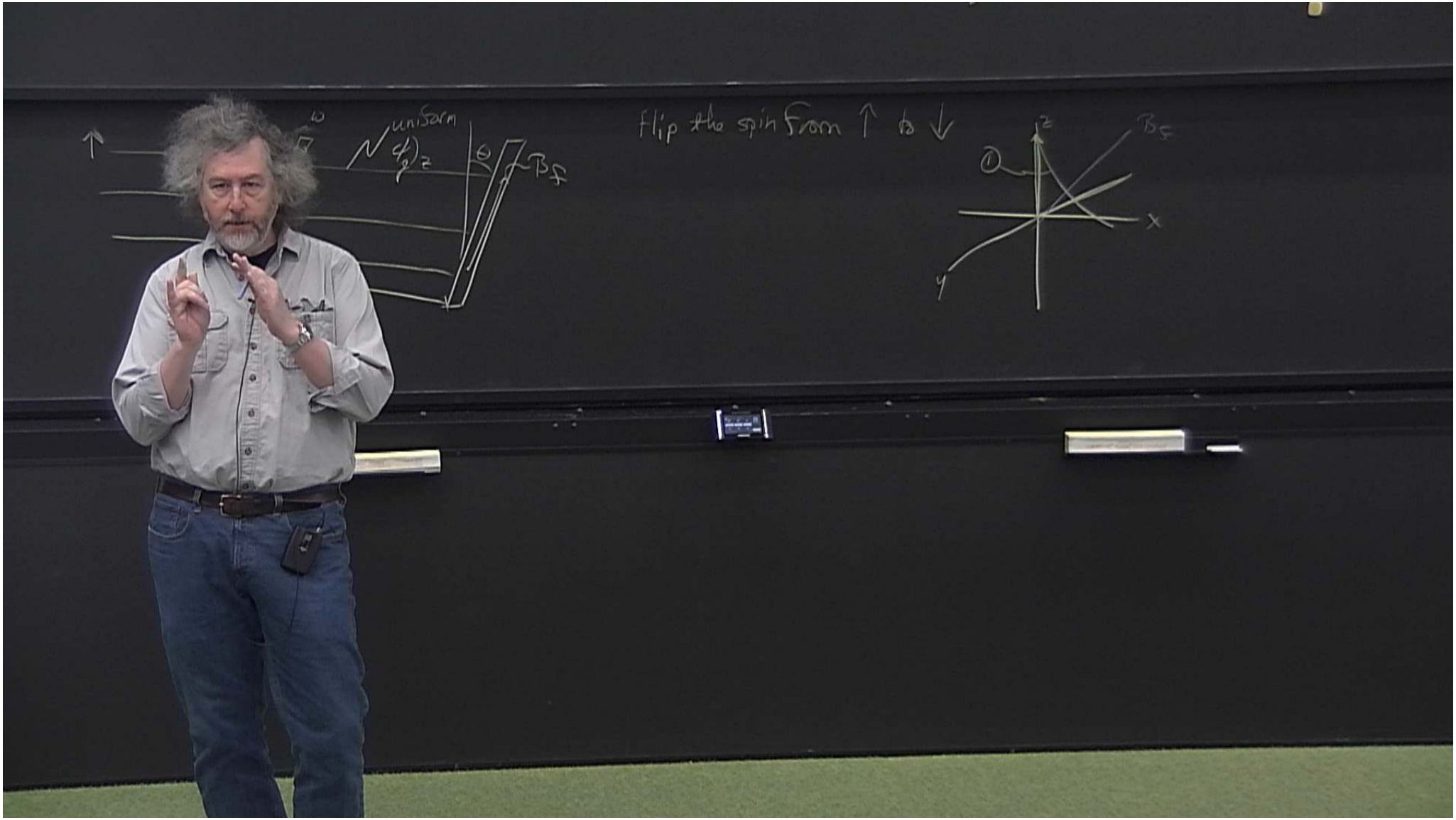
α

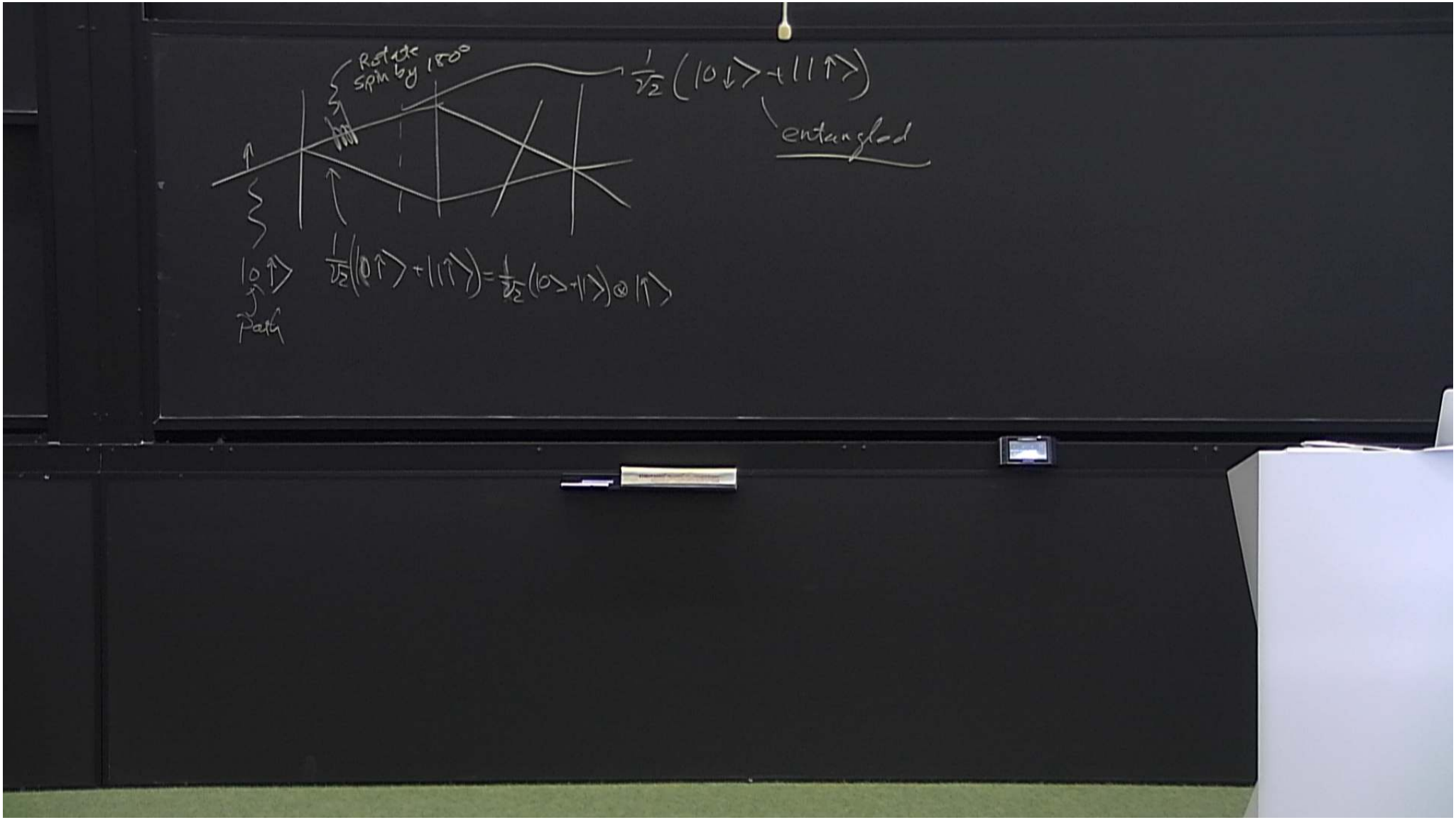
Out[14]=

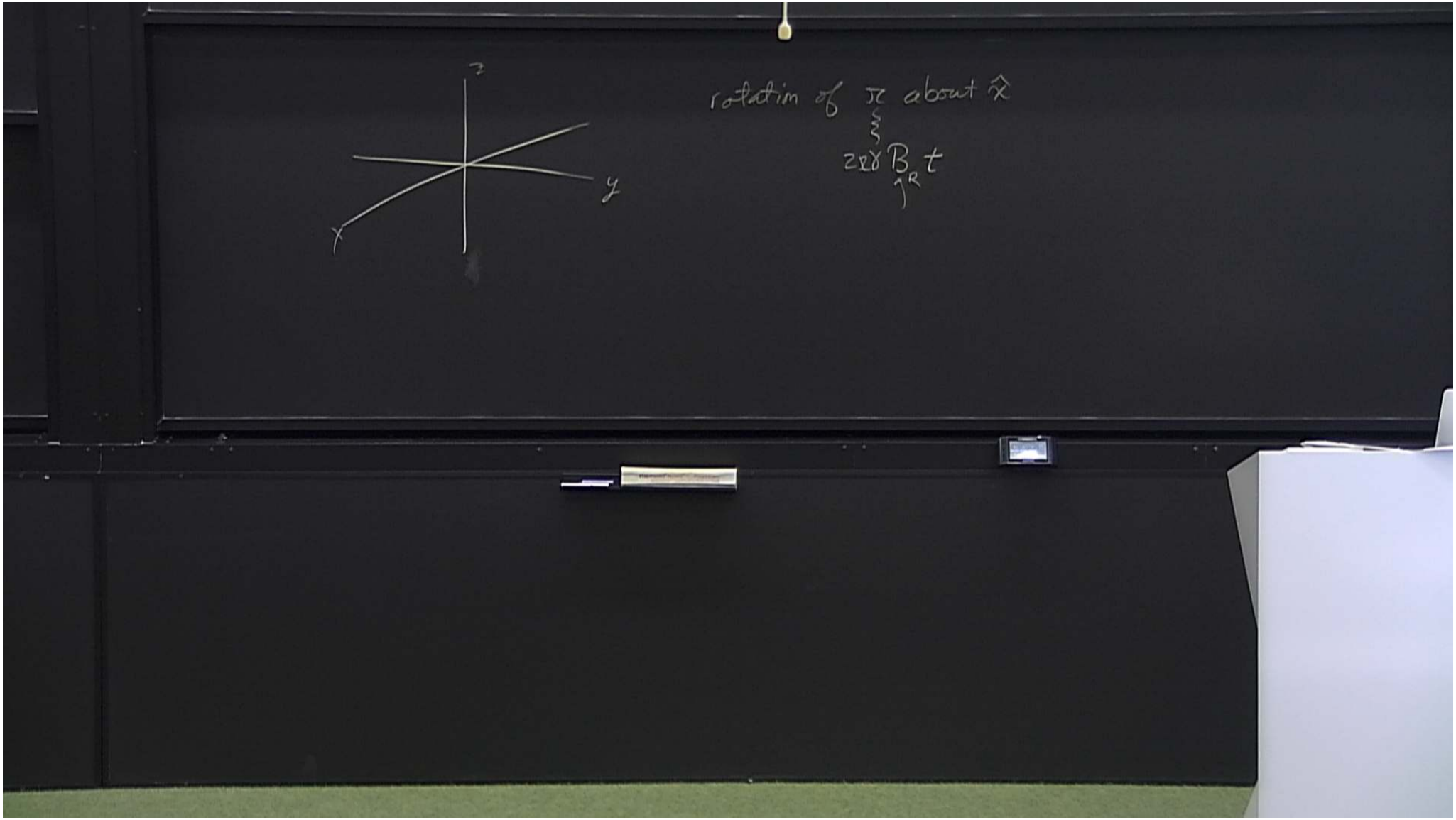


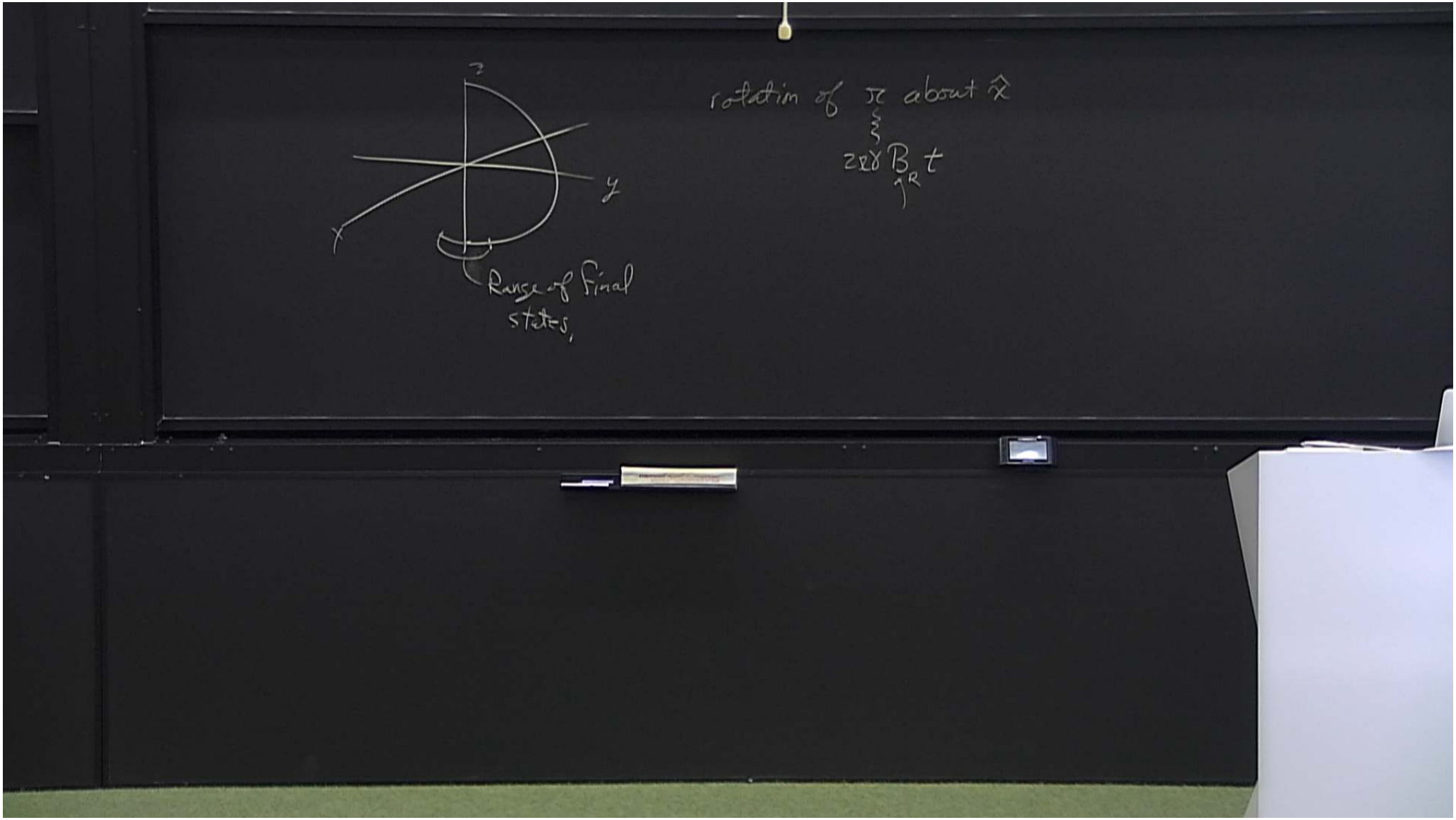
The figure shows the trajectory of the magnetization. Note the thick lines correspond to the motion. The thin lines are just the nutation cones of +z (blue) and -z (red)

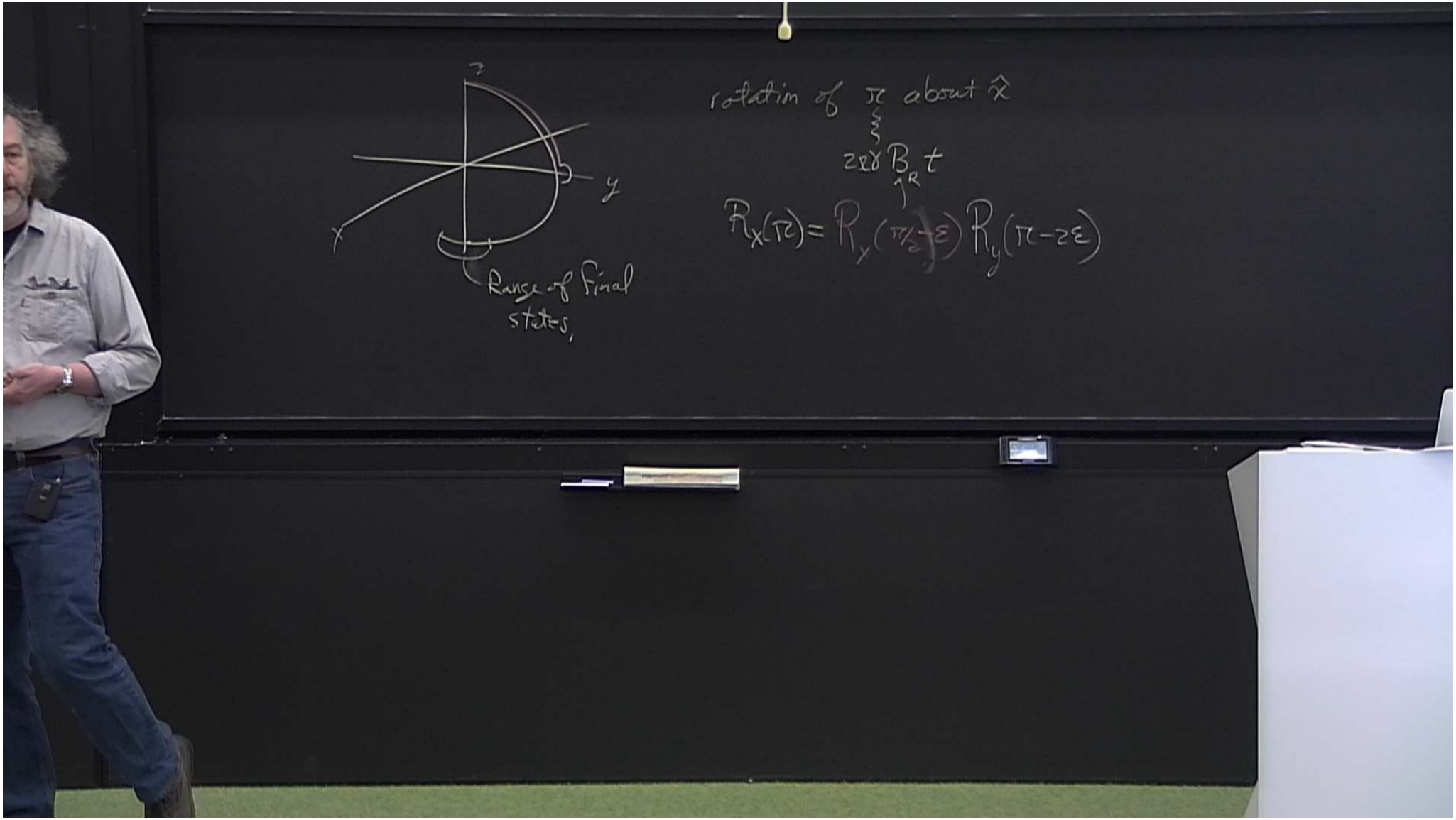
125%

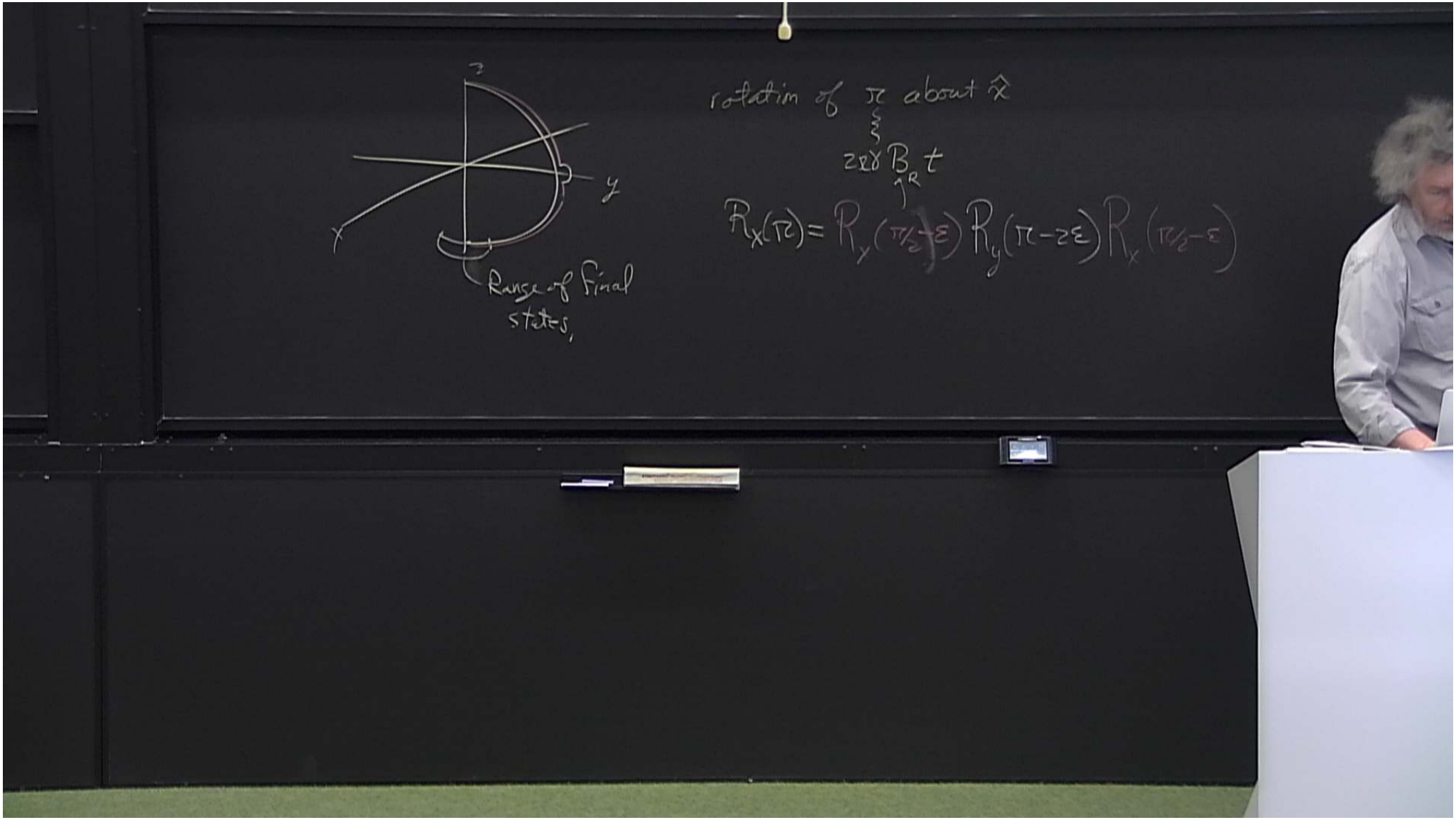

flip the spin from ↑ to ↓
uniform
z
x
y

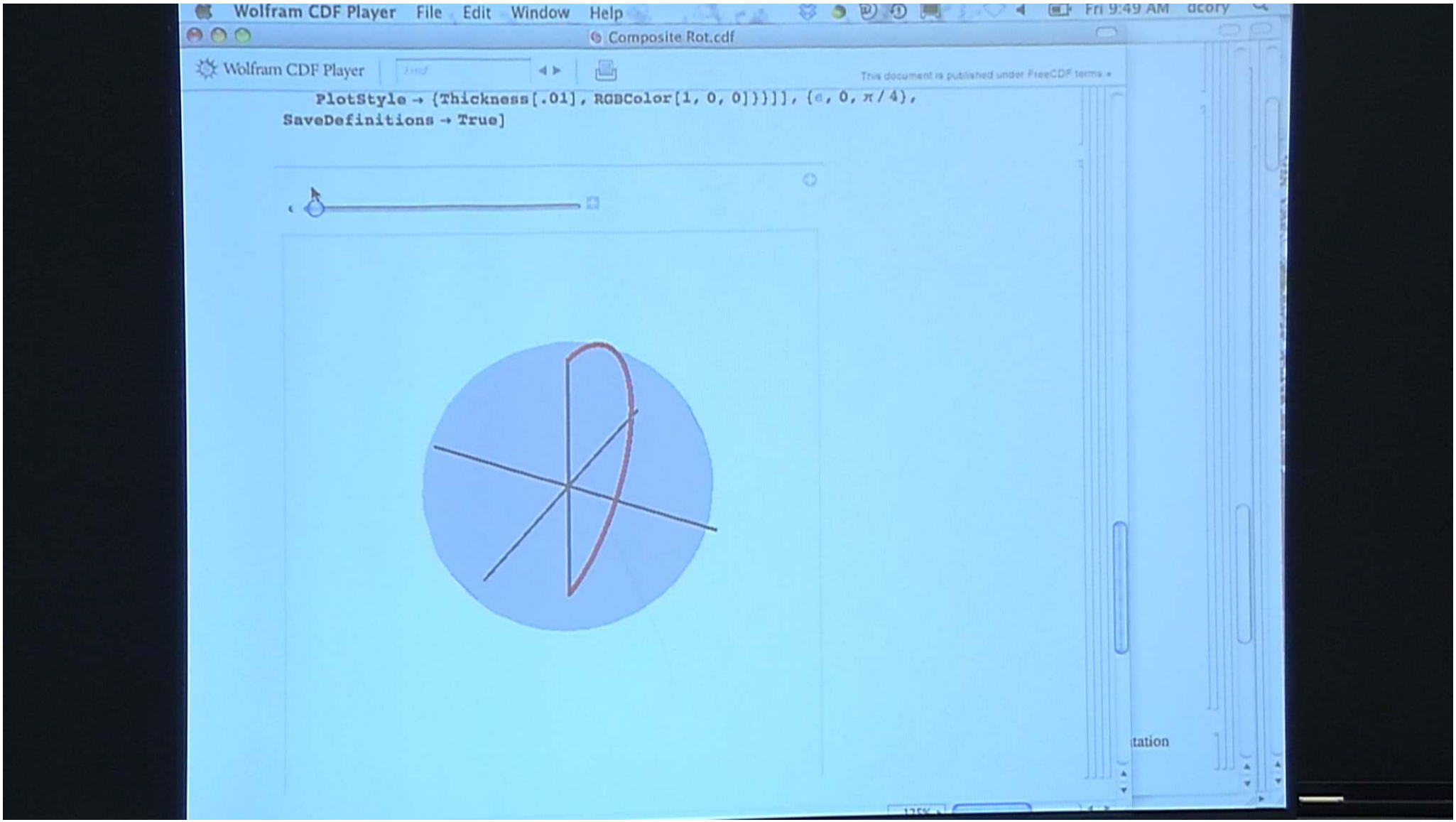

Rotate spin by 180°
$\frac{1}{\sqrt{2}}(|0\downarrow\rangle + |1\uparrow\rangle)$
entangled
$|0\rangle|\uparrow\rangle$
path
$\frac{1}{\sqrt{2}}(|0\uparrow\rangle + |1\uparrow\rangle) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \otimes |\uparrow\rangle$


z
y
x
rotation of π about x̂
2πγ B_R t


z
y
x
Range of final states,
rotation of π about x̂
2πγ B_R t


z
y
x
Range of final states,
rotation of π about x̂
ξ
2εγ B_R t
R_x(π) = R_x(π/2 + ε) R_y(π − 2ε)


z
y
x
Range of final states,
rotation of π about x̂
2πγ B_R t
R_x(π) = R_x(π/2 − ε) R_y(π − 2ε) R_x(π/2 − ε)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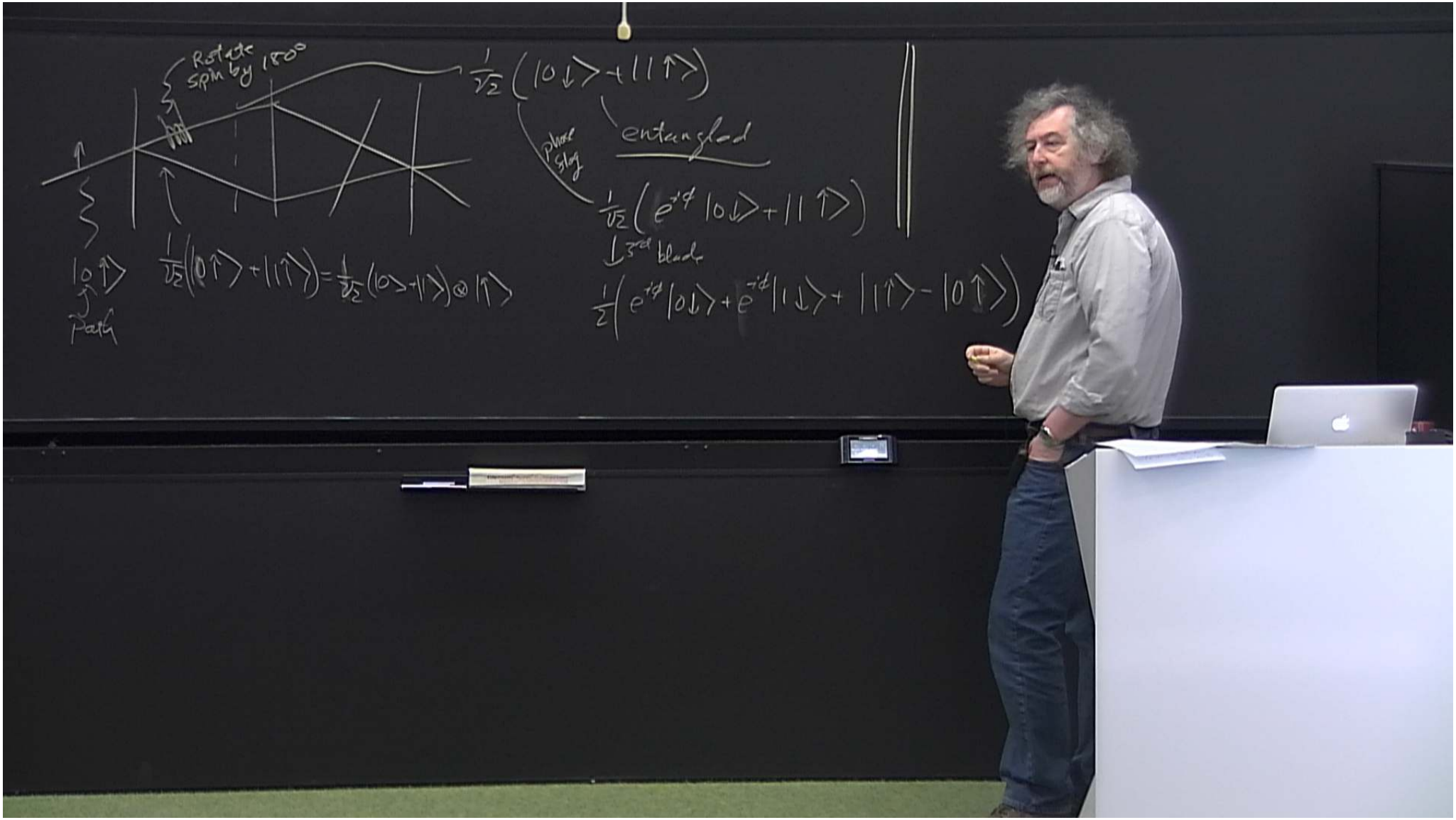
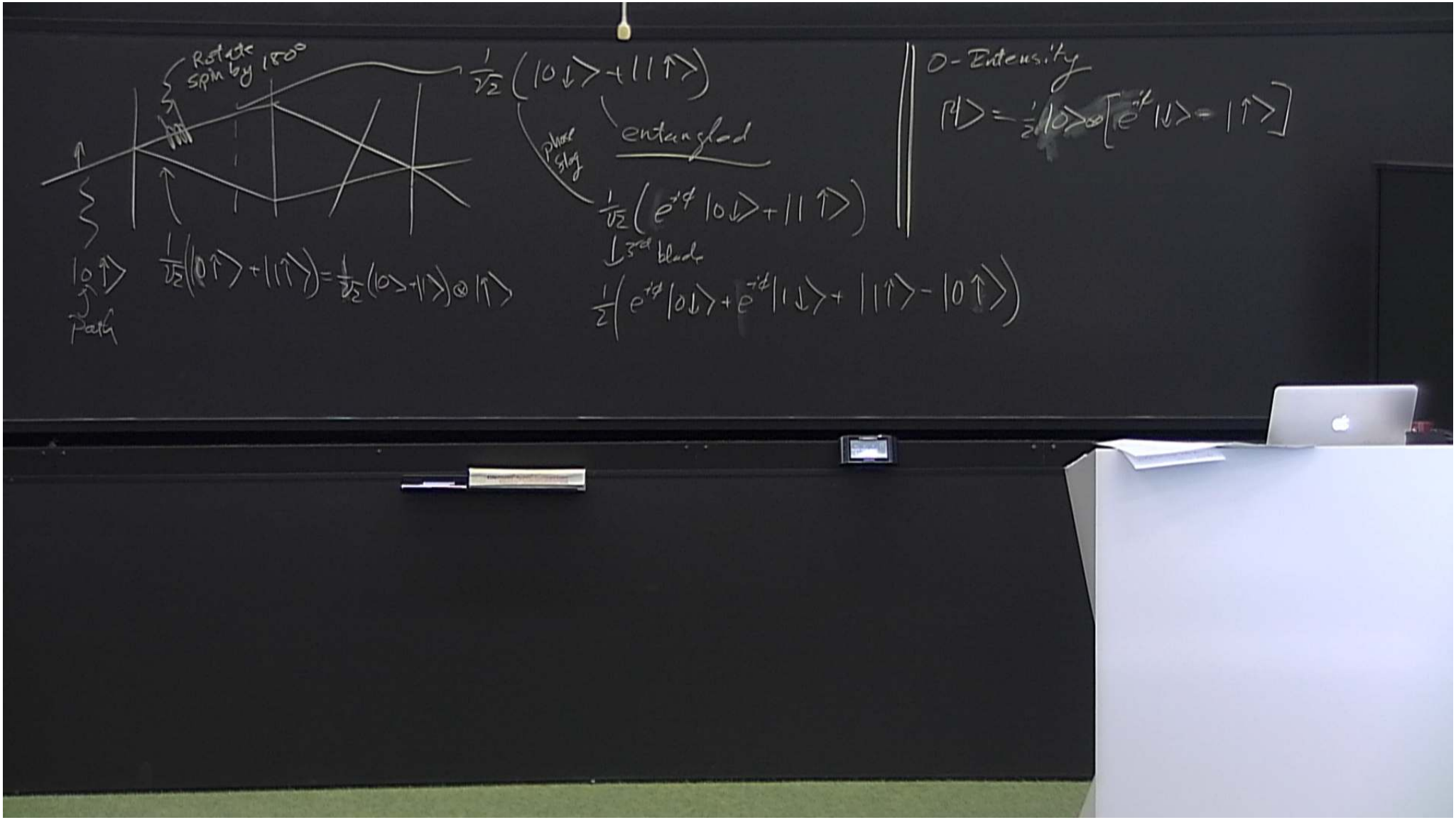
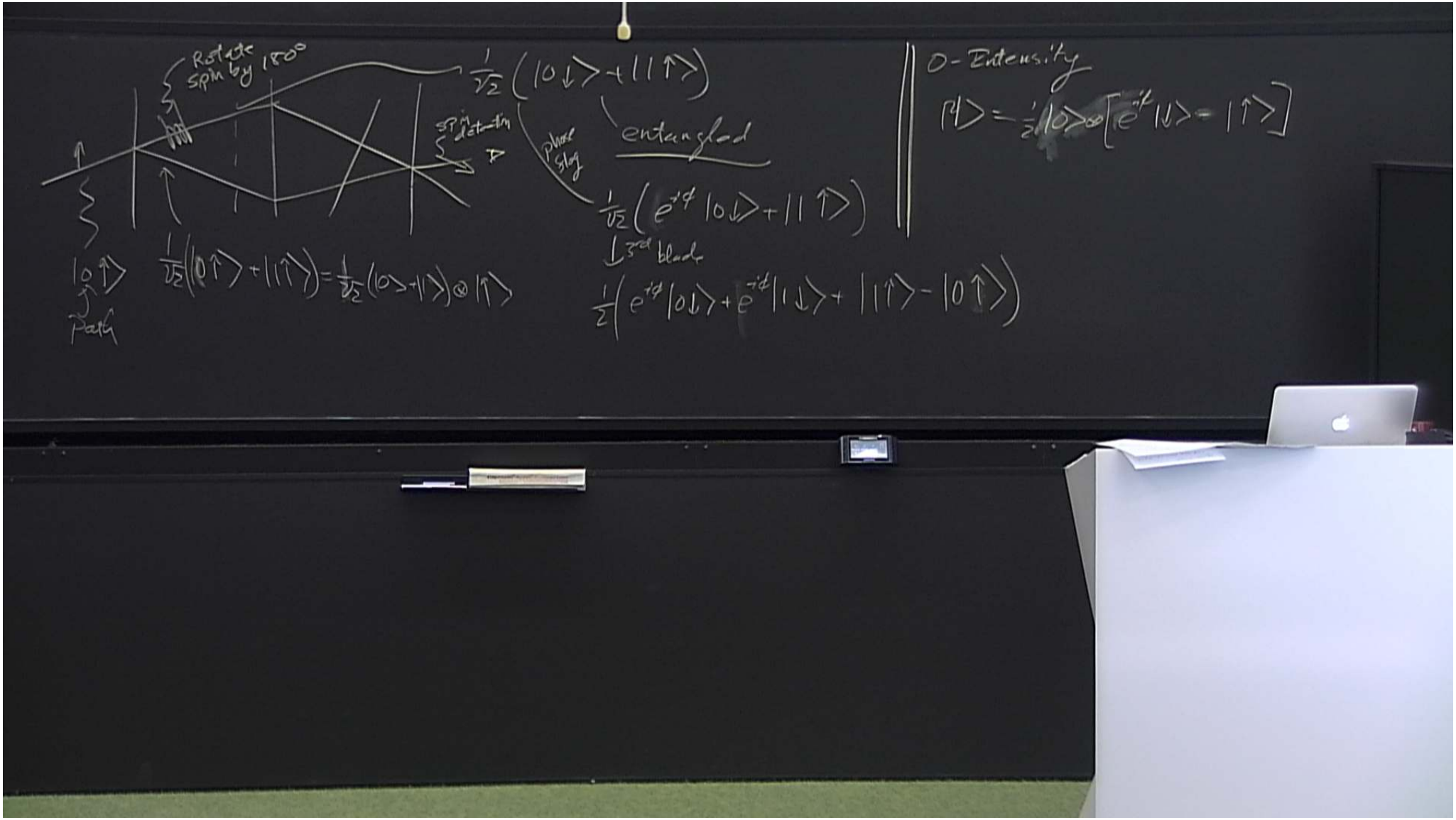
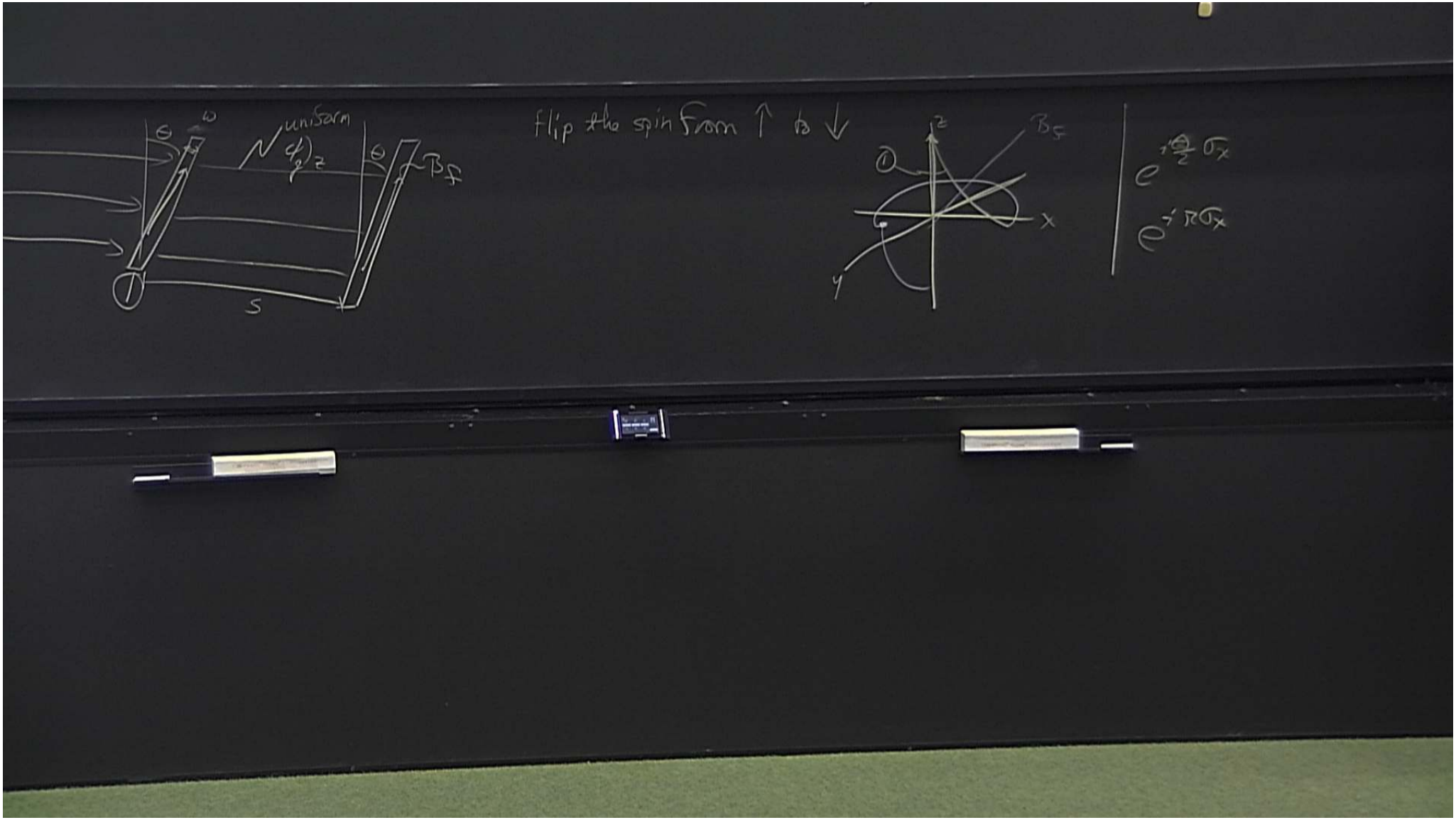
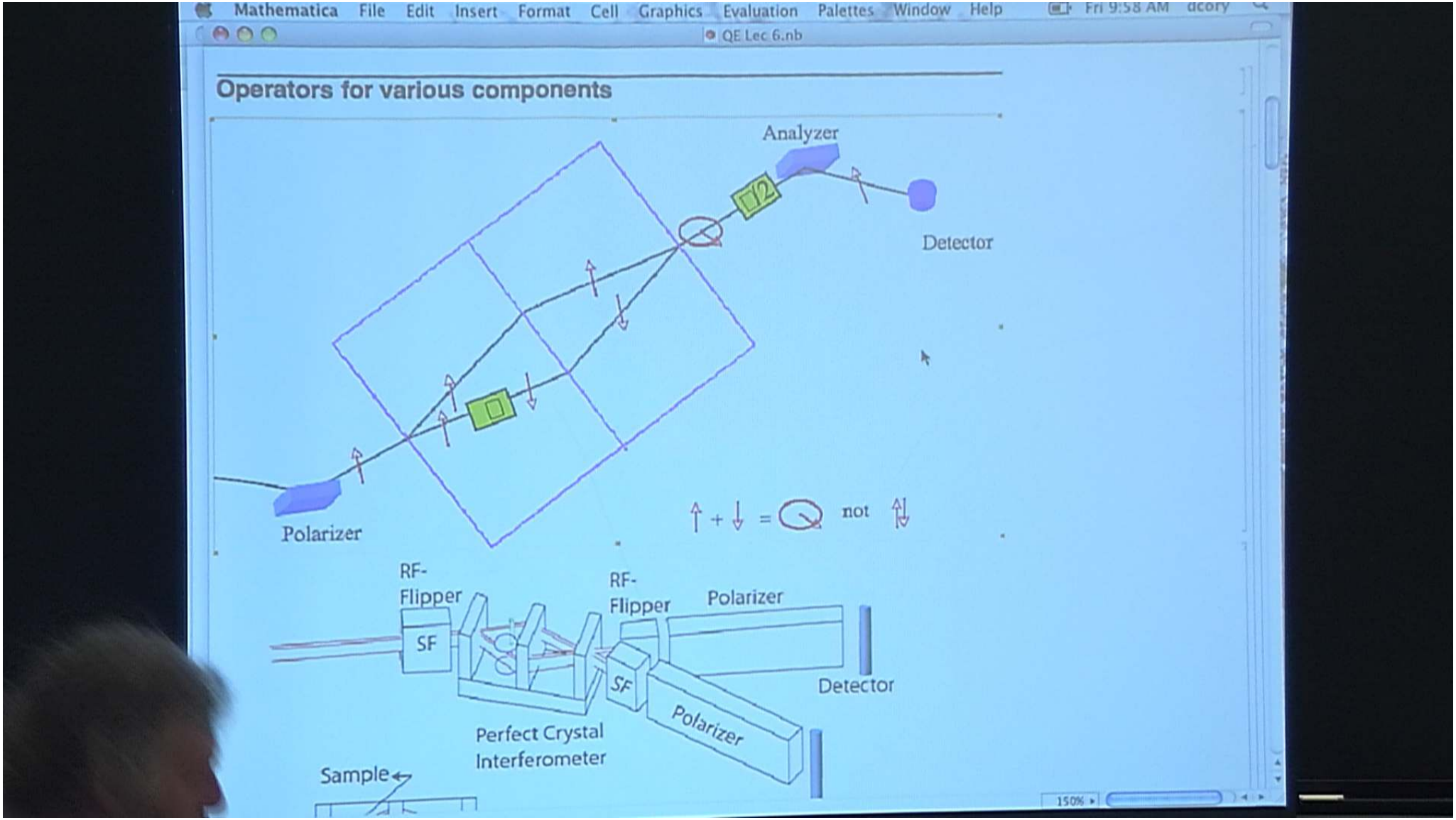
This document is published under FreeCDF terms
PlotStyle → {Thickness[.01], RGBColor[1, 0, 0]}}]], {ϵ, 0, π / 4},
SaveDefinitions → True]


Rotate spin by 180°
$\frac{1}{\sqrt{2}}(|0\downarrow\rangle + |1\uparrow\rangle)$
entangled
phase slip
$\frac{1}{\sqrt{2}}(e^{i\phi}|0\downarrow\rangle + |1\uparrow\rangle)$
3rd blade
$|0\rangle$ Path
$\frac{1}{\sqrt{2}}(|0\uparrow\rangle + |1\uparrow\rangle) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)\otimes|\uparrow\rangle$
$\frac{1}{2}(e^{i\phi}|0\downarrow\rangle + e^{-i\phi}|1\downarrow\rangle + |1\uparrow\rangle - |0\uparrow\rangle)$


Rotate spin by 180°
$\frac{1}{\sqrt{2}}(|0\downarrow\rangle + |1\uparrow\rangle)$
entangled
phase slag
$\frac{1}{\sqrt{2}}(e^{i\phi}|0\downarrow\rangle + |1\uparrow\rangle)$
3rd blade
$\frac{1}{2}(e^{i\phi}|0\downarrow\rangle + e^{-i\phi}|1\downarrow\rangle + |1\uparrow\rangle - |0\uparrow\rangle)$
$|0\uparrow\rangle$
path
$\frac{1}{\sqrt{2}}(|0\uparrow\rangle + |1\uparrow\rangle) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \otimes |\uparrow\rangle$
0-Intensity
$|\psi\rangle = \frac{1}{2}|0\rangle \otimes [e^{i\phi}|1\rangle - |\uparrow\rangle]$


Rotate spin by 180°
spin detection
phase slog
entangled
3rd blade
Path
0-Entensity


uniform
flip the spin from ↑ to ↓
z
x
y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Polarizer
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Detector
Perfect Crystal
Interferometer
Polarizer
Sample

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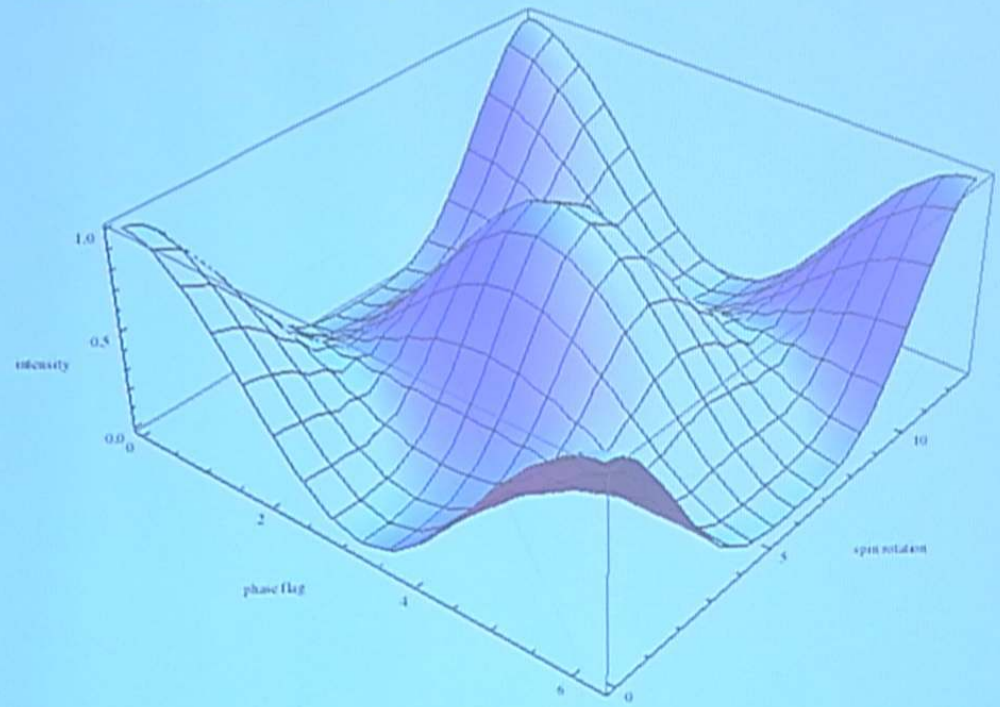
QE Lec 6.nb

■ O-Beam with spin up filter

```
MOup[t_, a_] := Tr[Uspup . resls[t, a]]
MOup[t, a]
```

$$\frac{1}{8}\left(3 + 2\,\text{Cos}\left[a - \frac{t}{2}\right] + 2\,\text{Cos}\left[a + \frac{t}{2}\right] + \text{Cos}[t]\right)$$

```
Plot3D[MOup[t, a], {a, 0, 2 π}, {t, 0, 4 π},
 {AxesLabel → {"phase flag", "spin rotation", "intensity"}}]
```



■ H-Beam with spin up filter

```
MHup[t_, a_] := Tr[Uspdown . resls[t, a]]
MHup[t, a]
```

$$\frac{1}{8}\left(3 - 2\,\text{Cos}\left[a - \frac{t}{2}\right] - 2\,\text{Cos}\left[a + \frac{t}{2}\right] + \text{Cos}[t]\right)$$

150%