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

Date: Mar 22, 2013 09:00 AM

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

Abstract:

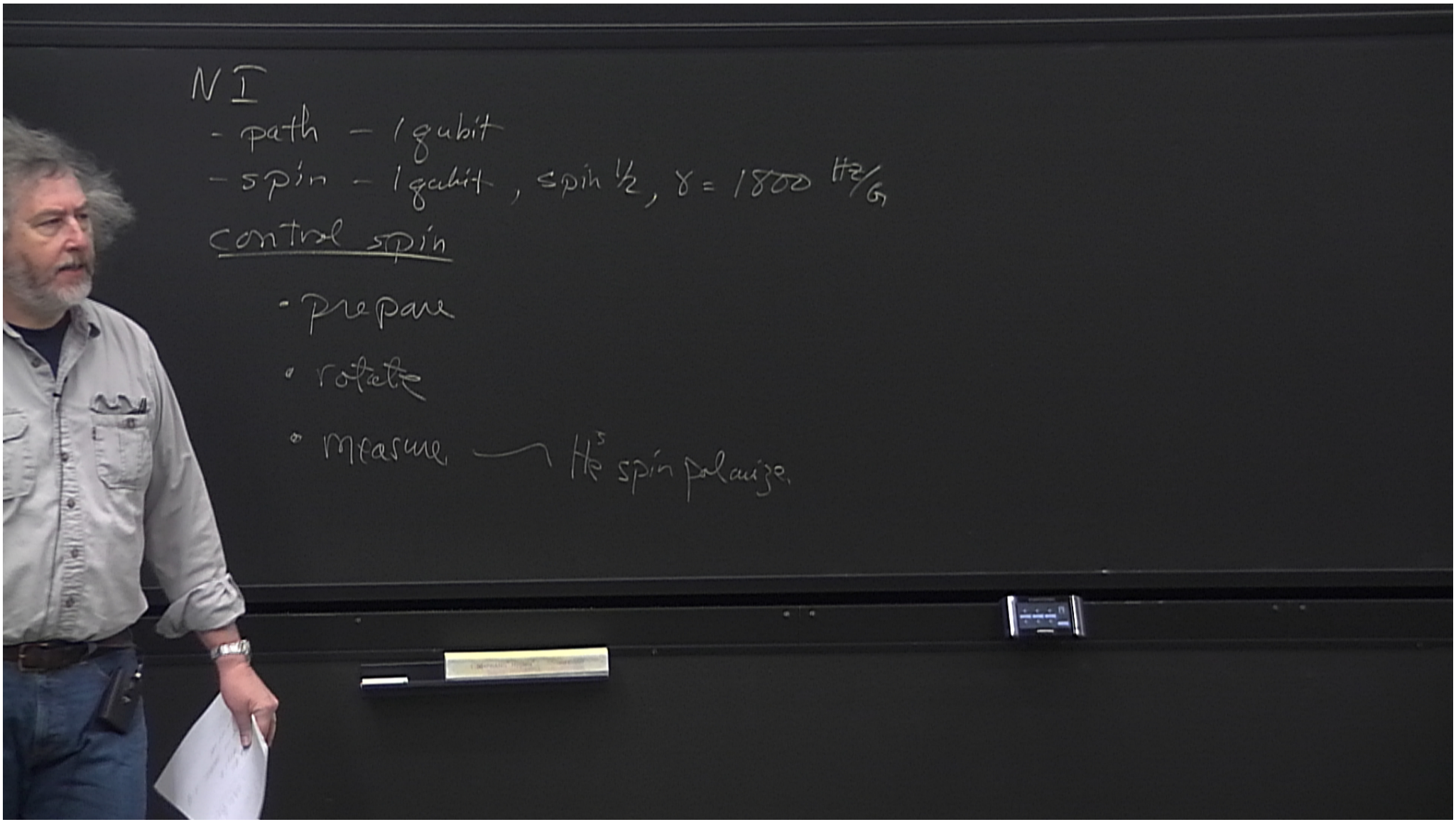
N I

- path – 1 qubit

–

NI

- path – 1 qubit
- spin – 1 qubit, spin 1/2, $\gamma = 1800$ Hz/G

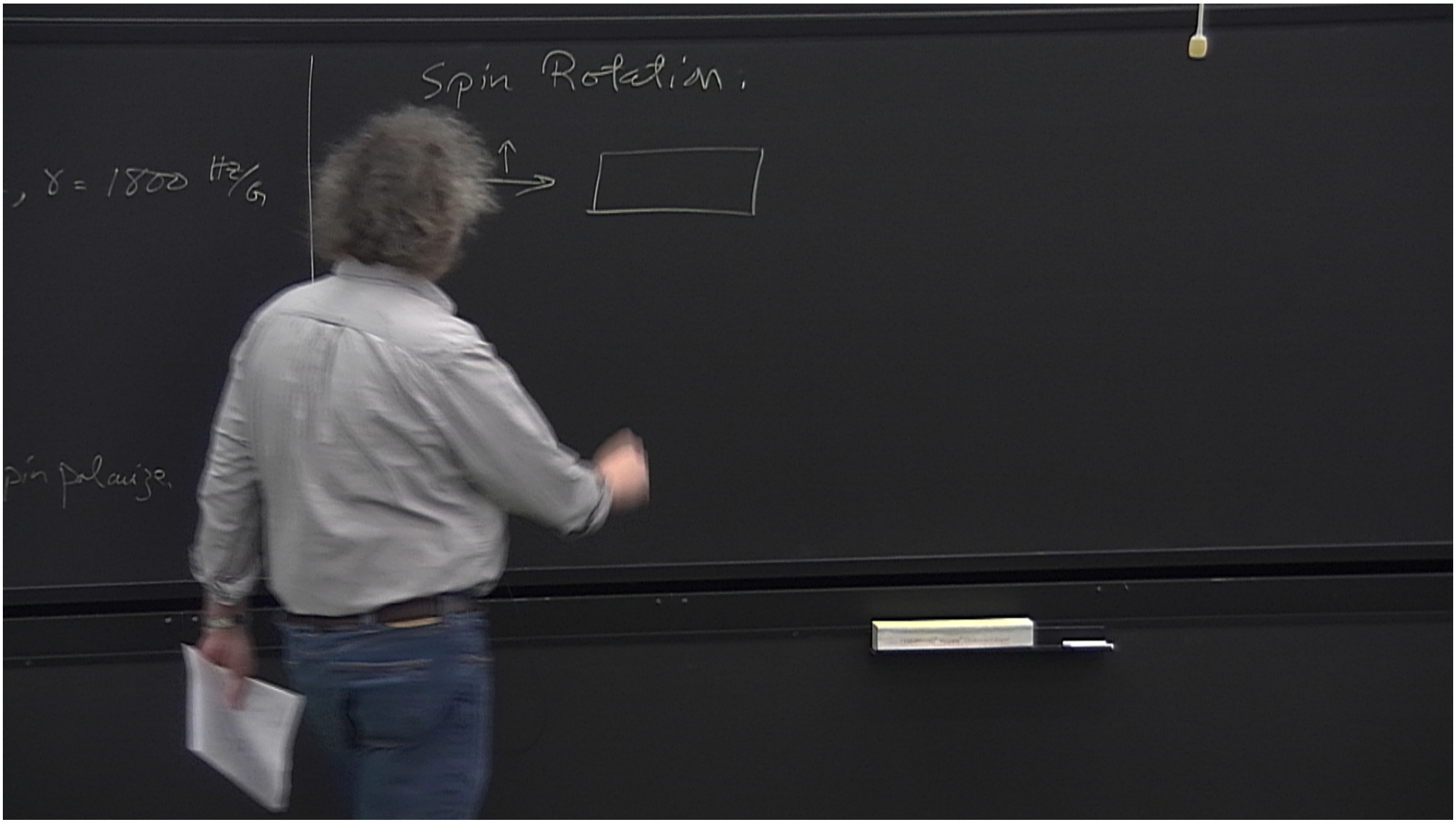

N I
- path - 1 qubit
- spin - 1 qubit, spin 1/2, γ = 1800 Hz/G
control spin
- prepare
- rotate
- measure → He3 spin polarize.

NI

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

control spin

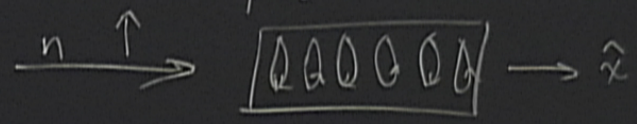
- prepare ✓
- rotate
- measure → He^3 spin polarize.

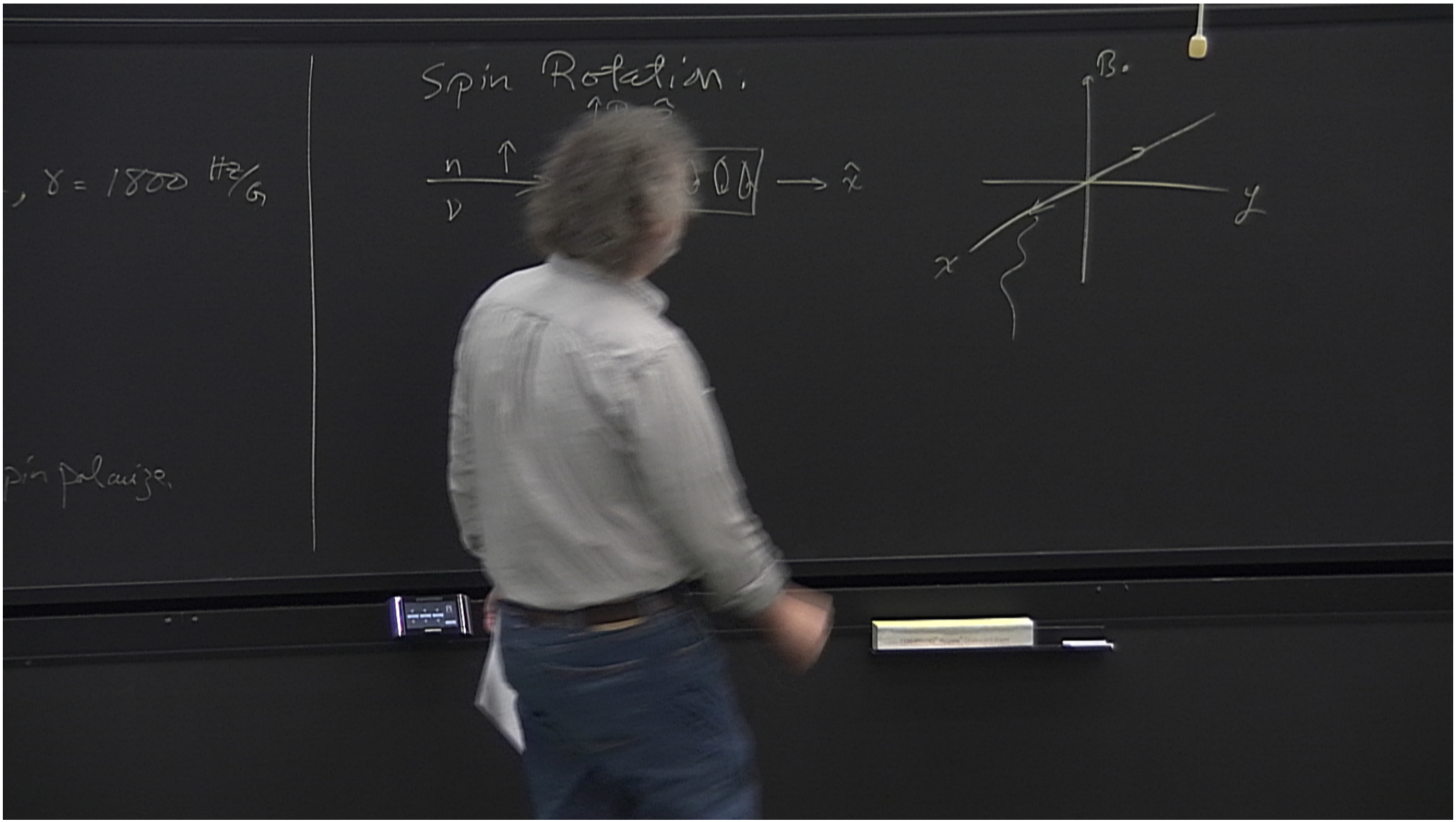

Spin Rotation.
, γ = 1800 Hz/G
pin polarize.

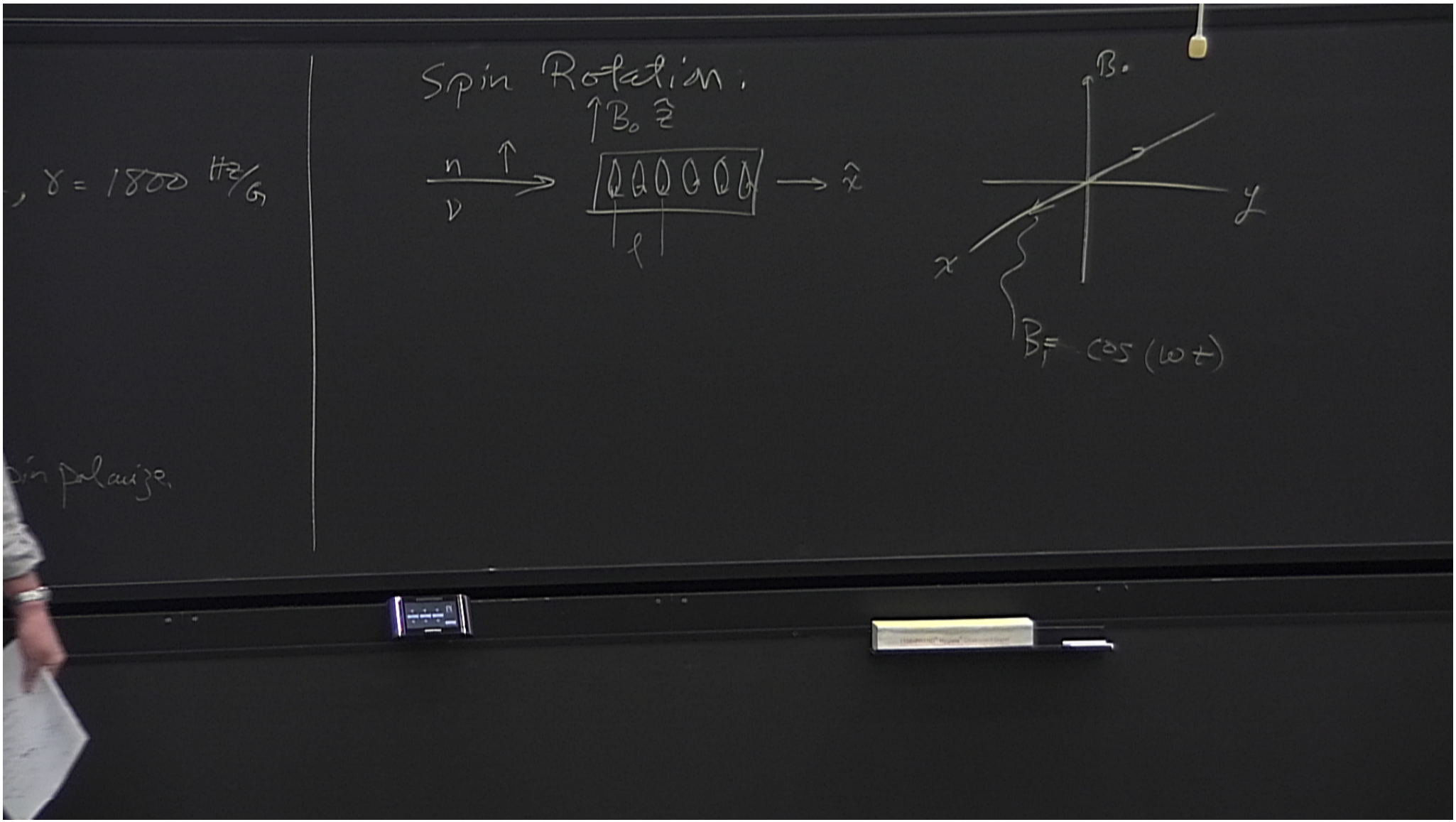
, $\gamma = 1800$ Hz/G

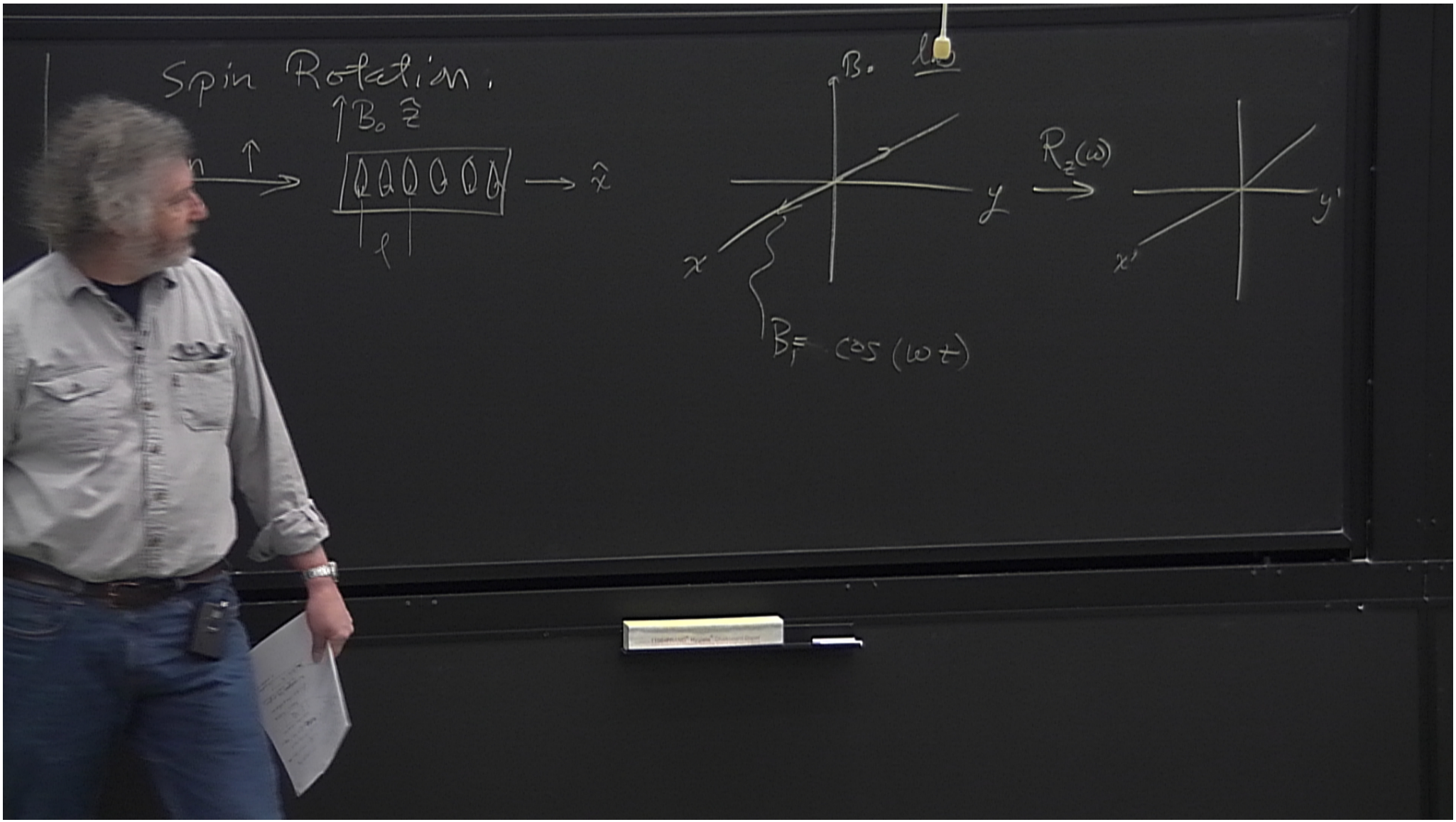
pin polarized.

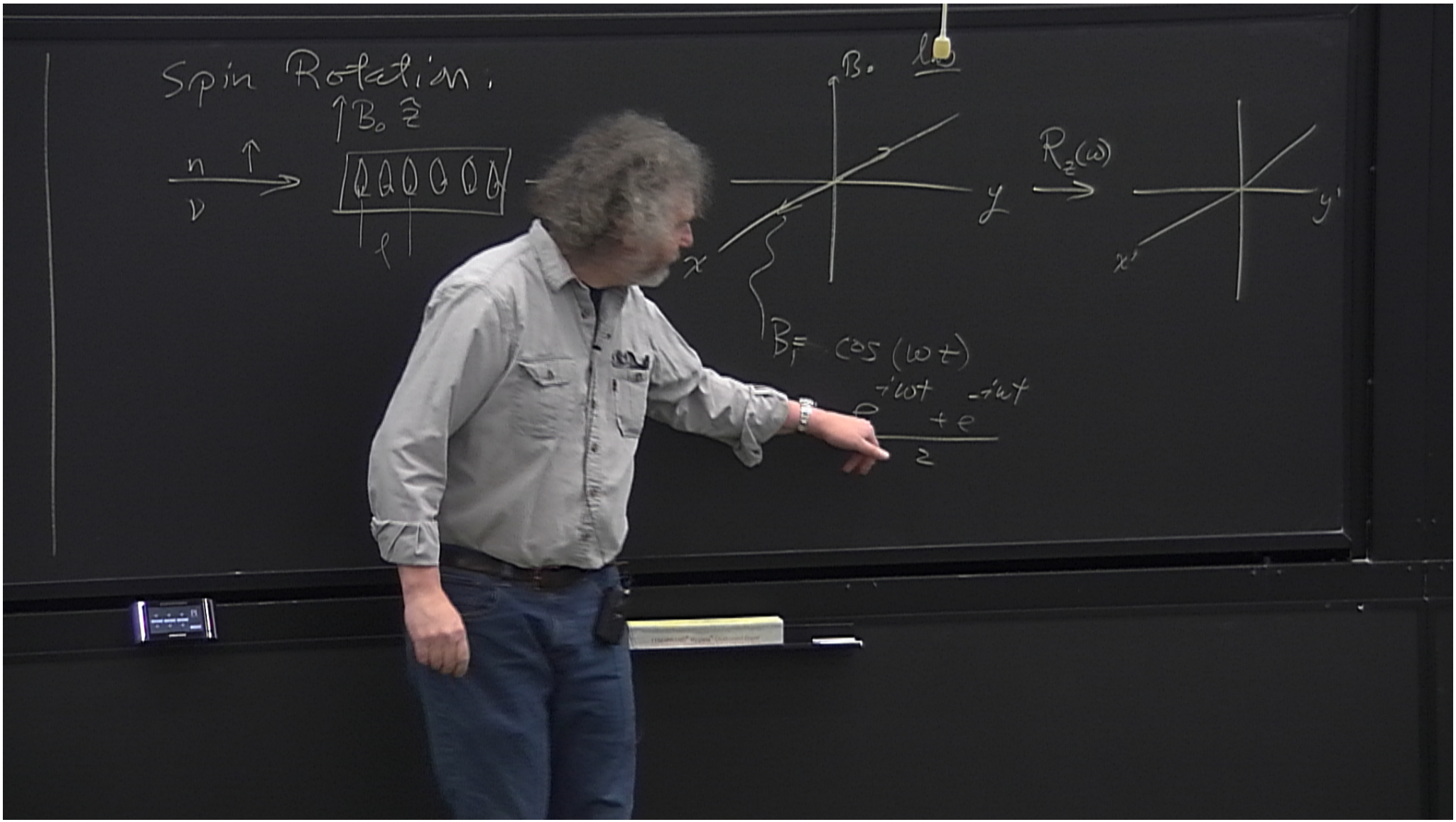
Spin Rotation.



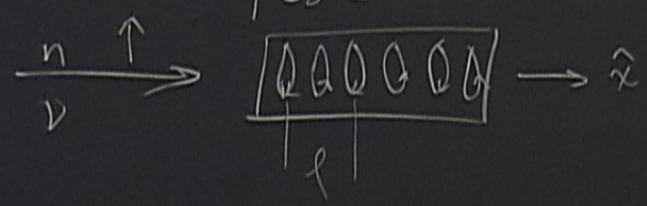

Spin Rotation.
γ = 1800 Hz/G
B.
y
x

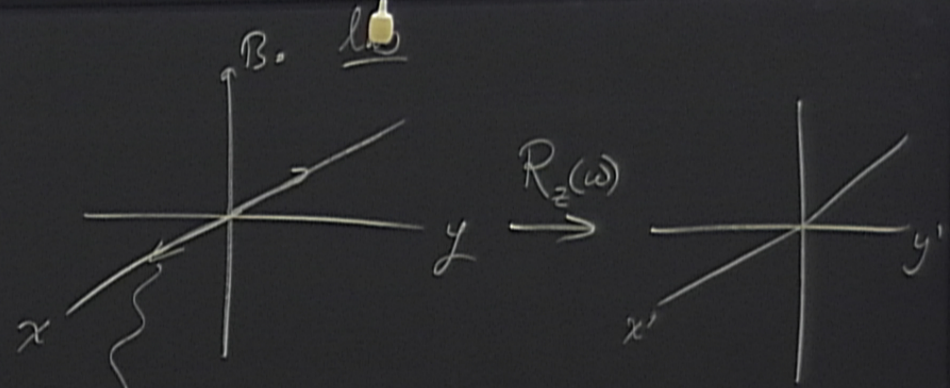

, γ = 1800 Hz/G
pin polarize.
Spin Rotation.
↑B₀ ẑ
n ↑
ν
ℓ
→ x̂
B₀
y
x
B₁ = cos (ωt)


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

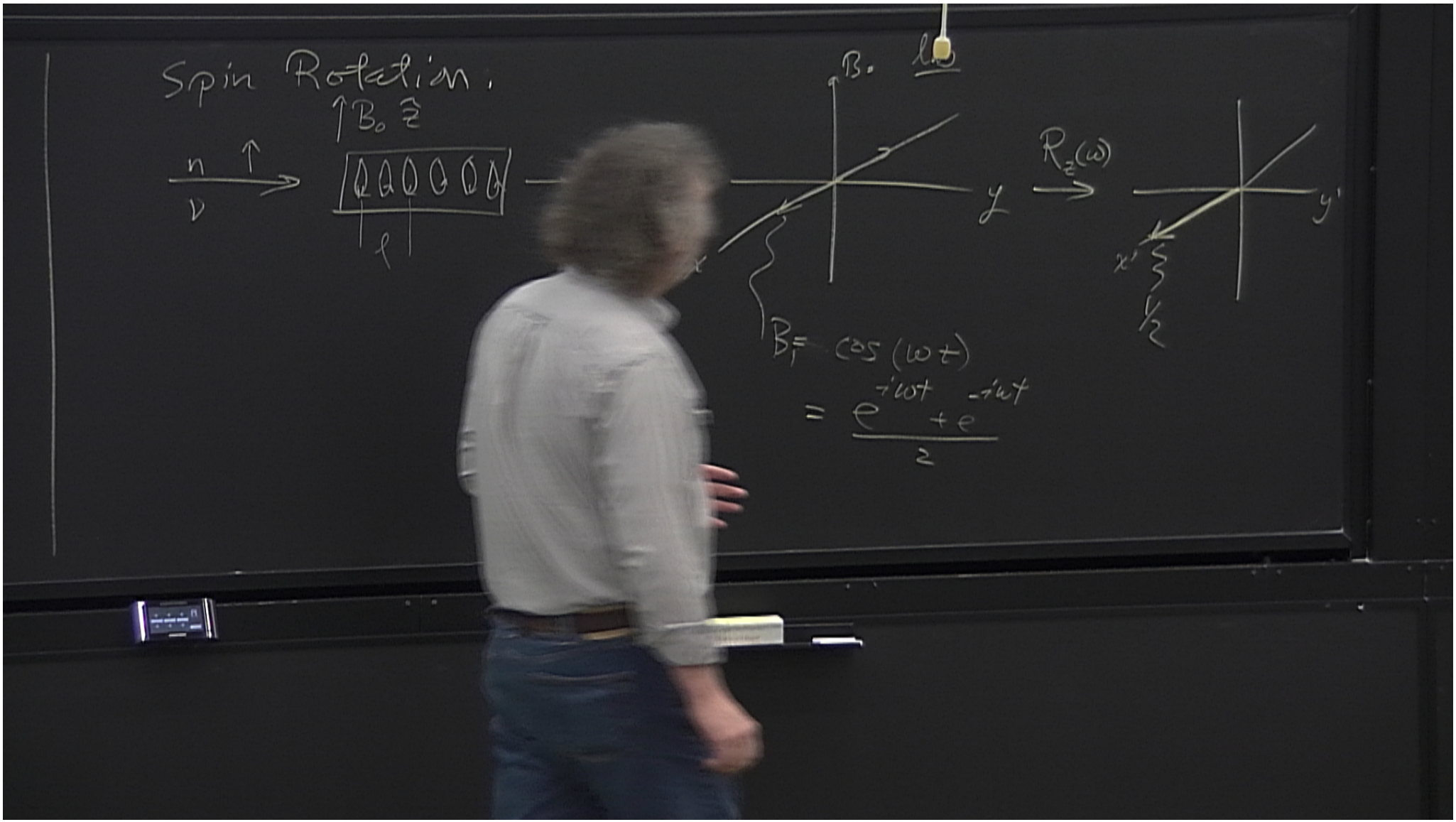

Spin Rotation.
$B_0 \hat{z}$
n
ν
ℓ
B_0
x
y
$R_z(\omega)$
x'
y'
$B_1 = \cos(\omega t)$
$\frac{e^{i\omega t} + e^{-i\omega t}}{2}$

Spin Rotation:

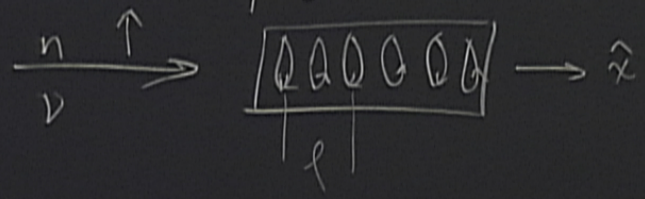


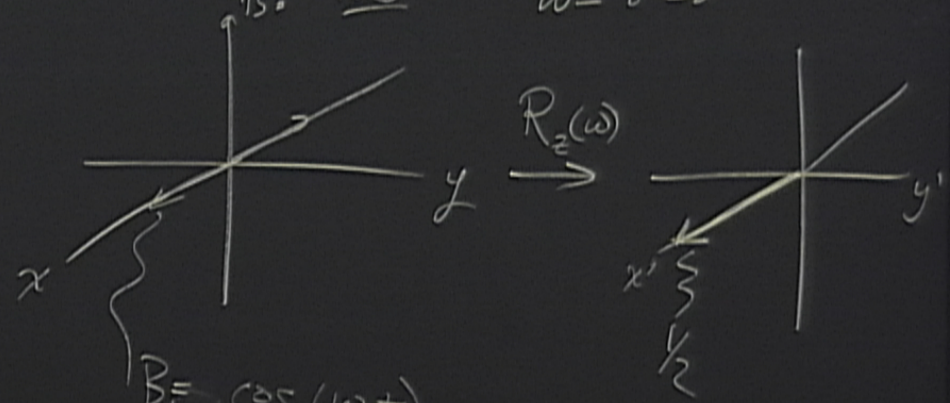


$$B_1 = \cos(\omega t) = \frac{e^{i\omega t} + e^{-i\omega t}}{2}$$


Spin Rotation.
$B_0 \hat{z}$
n
ν
ℓ
B_0
y
$R_z(\omega)$
y'
x'
ξ
1/2
$B_1 = \cos(\omega t)$
$= \frac{e^{i\omega t} + e^{-i\omega t}}{2}$

Spin Rotation.

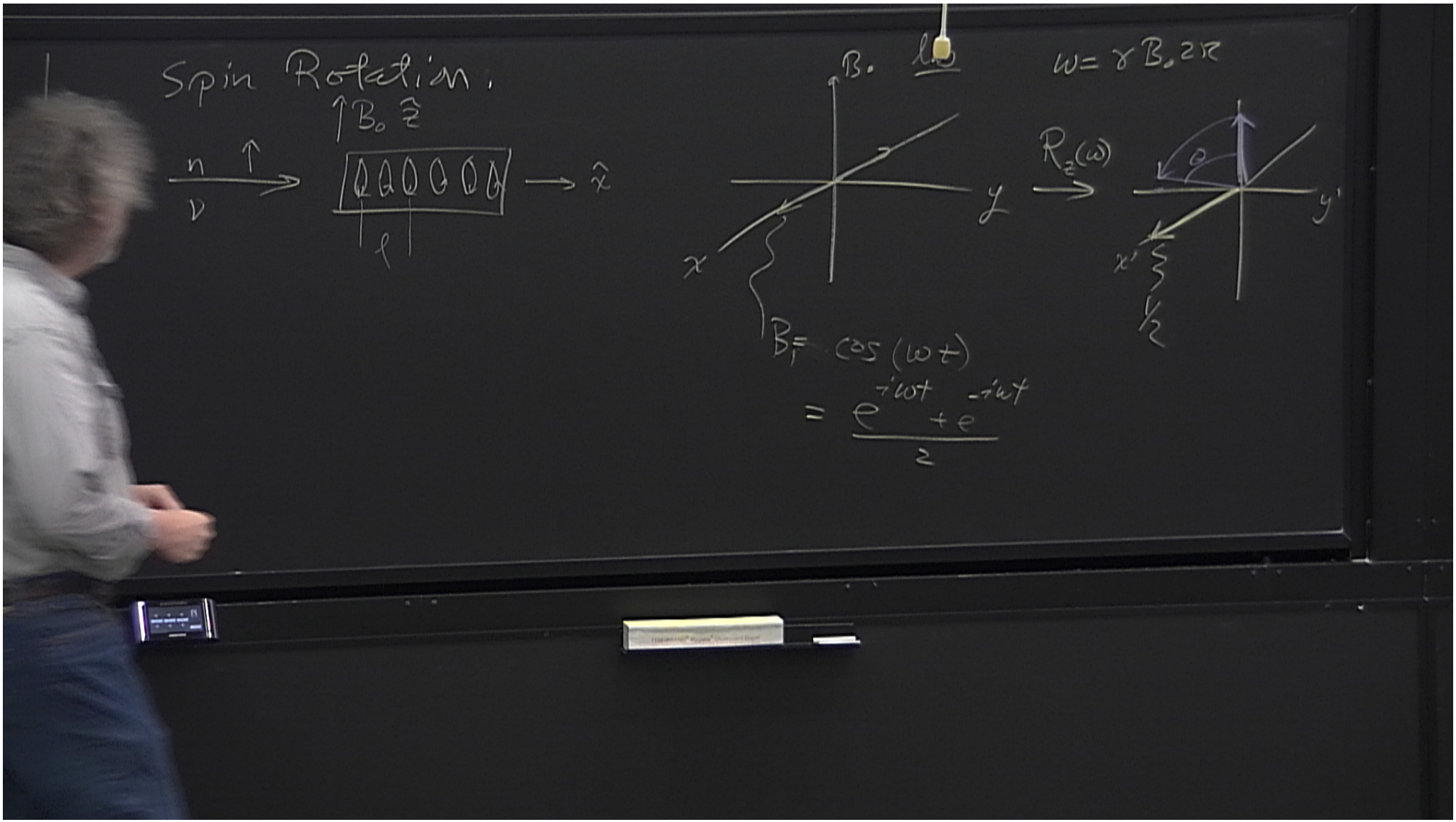


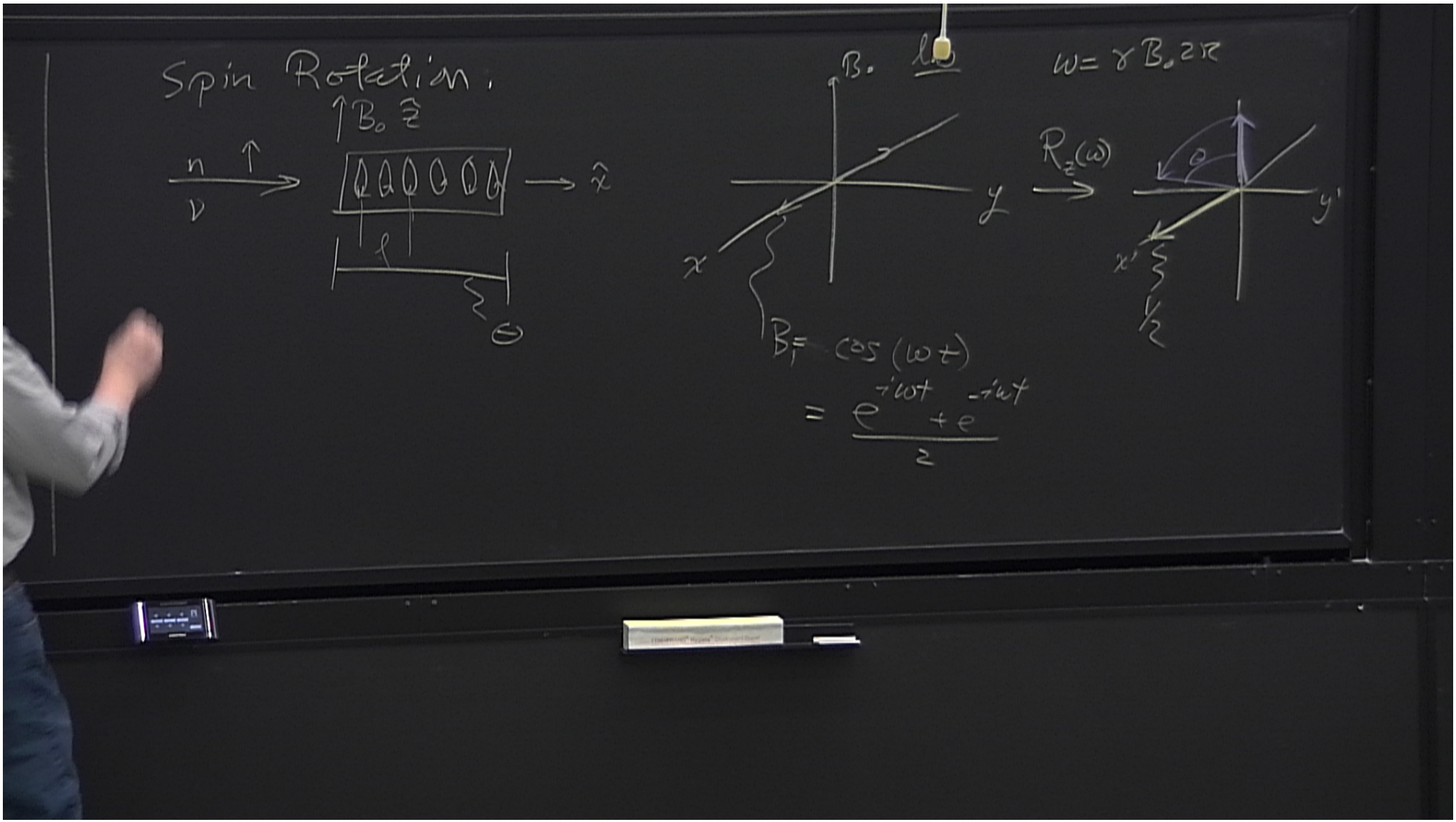


$\omega = \gamma B_0 2\pi$

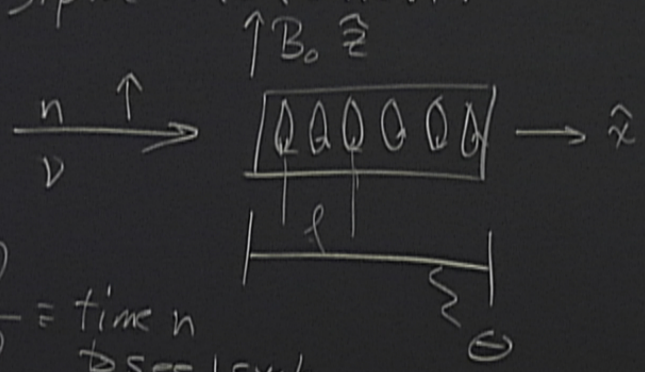
$B_1 = \cos(\omega t)$

$= \dfrac{e^{i\omega t} + e^{-i\omega t}}{2}$

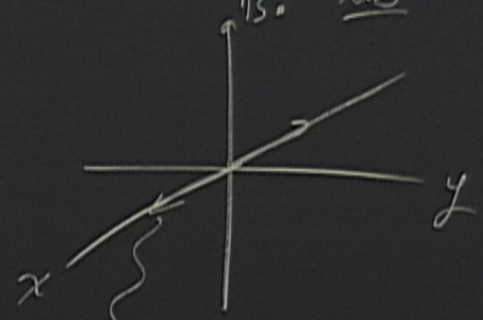

Spin Rotation.
$\uparrow B_0 \hat{z}$
n
ν
$\hat{x}$
ℓ
B_0
$\omega = \gamma B_0 2\pi$
x
y
$R_z(\omega)$
θ
y'
x'
ξ
1/2
$B_1 = \cos(\omega t)$
$= \frac{e^{i\omega t} + e^{-i\omega t}}{2}$


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

Spin Rotation.



$\frac{l}{\nu}$ = time n to see 1 cycle of the field

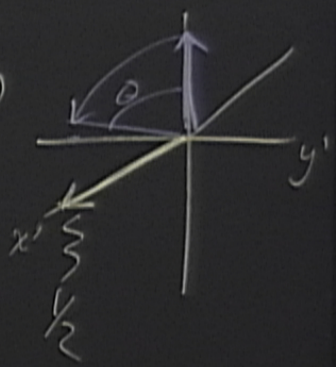


$B_1 = \cos(\omega t)$

$= \frac{e^{i\omega t} + e^{-i\omega t}}{2}$

$\omega = \gamma B_0 2\pi$

$R_z(\omega)$



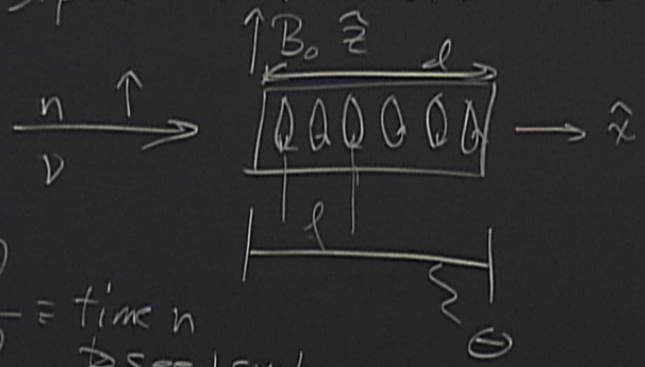
Spin Rotation.

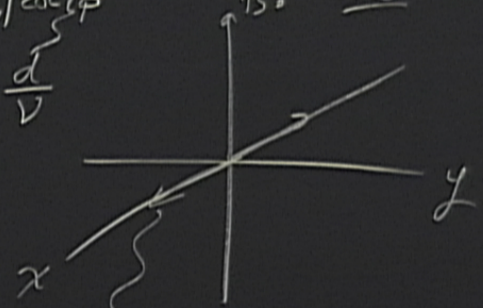
Spin Rotation.

$\theta = \gamma |B_1| \cos\omega t$

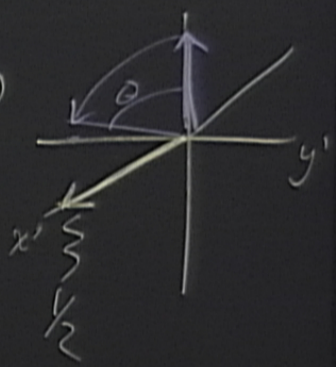
$\frac{d}{v}$

$\omega = \gamma B_0 2\pi$





$R_z(\omega)$



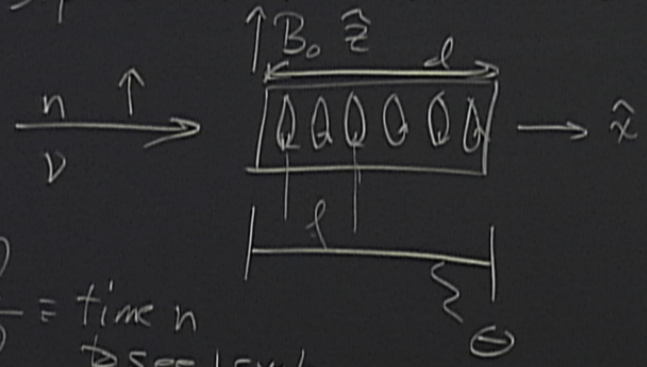
$\frac{l}{v}$ = time in to see 1 cycle of the field

$\omega = 2\pi \frac{v}{l}$

$B_1 = |B_1| \cos(\omega t)$

$= \frac{e^{i\omega t} + e^{-i\omega t}}{2}$

Spin Rotation.

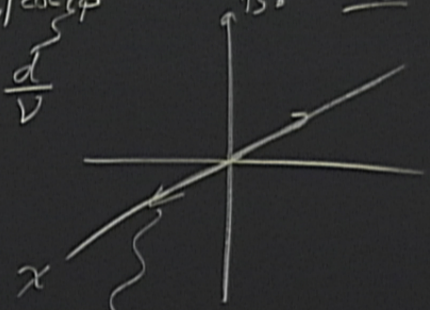


$\frac{l}{v}$ = time n to see 1 cycle of the field

$\omega = 2\pi \frac{v}{l}$

$\theta = \gamma |B_1| \cos \omega t \, \tau_p$

$\tau_p = \frac{d}{v}$

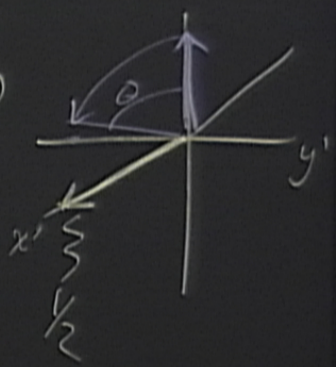


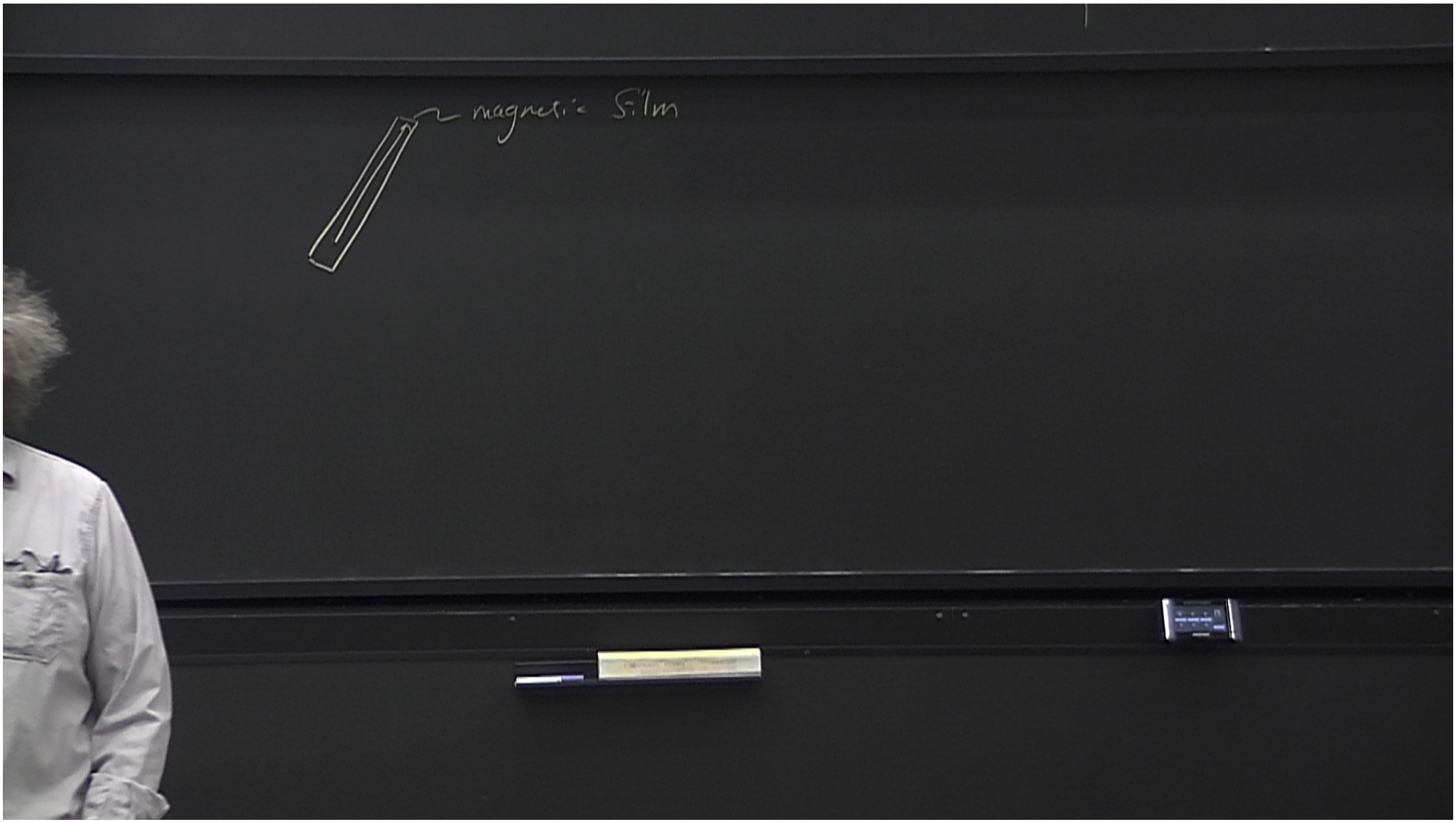
$B_1 = |B_1| \cos(\omega t)$

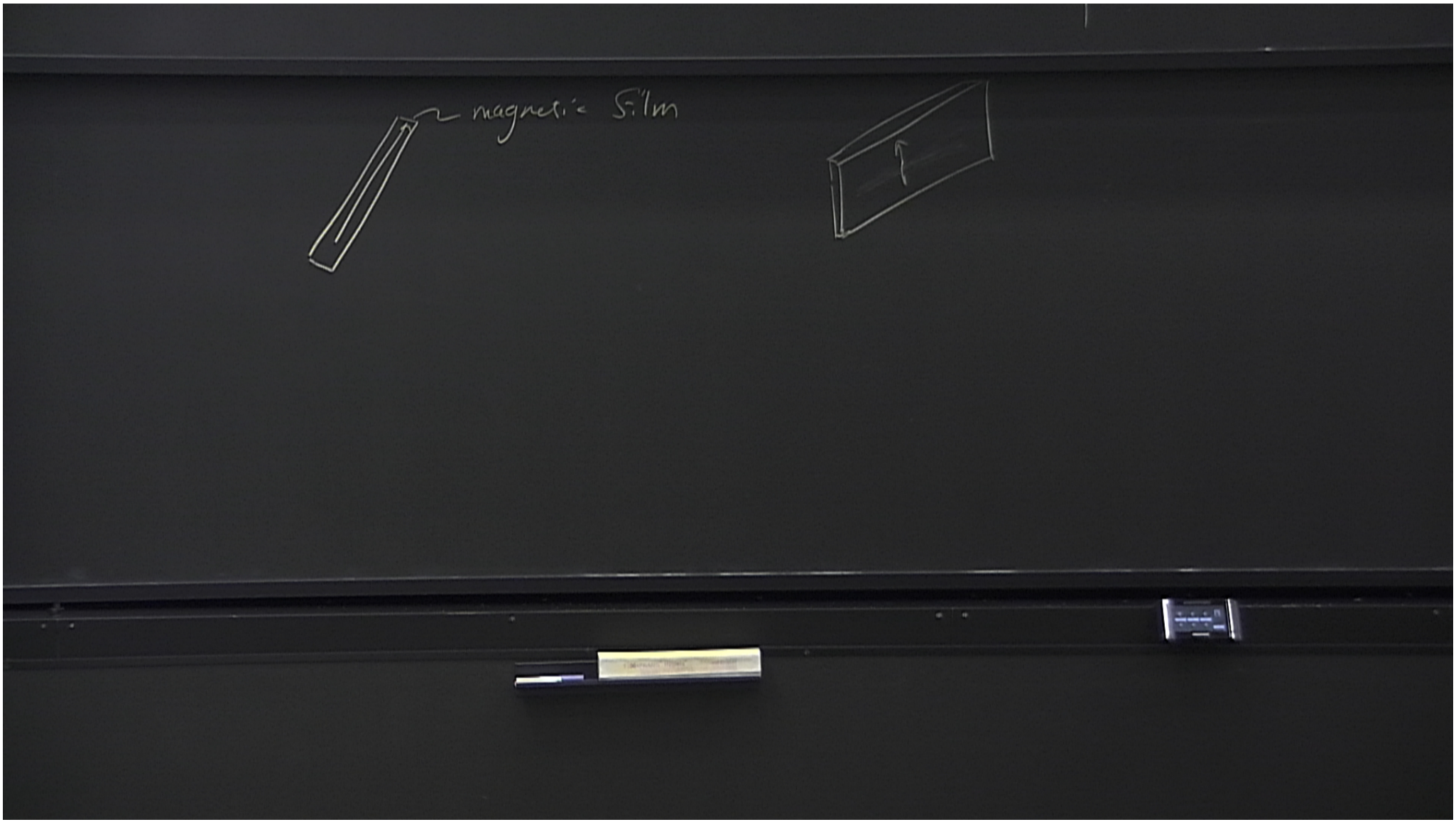
$= \frac{e^{i\omega t} + e^{-i\omega t}}{2}$

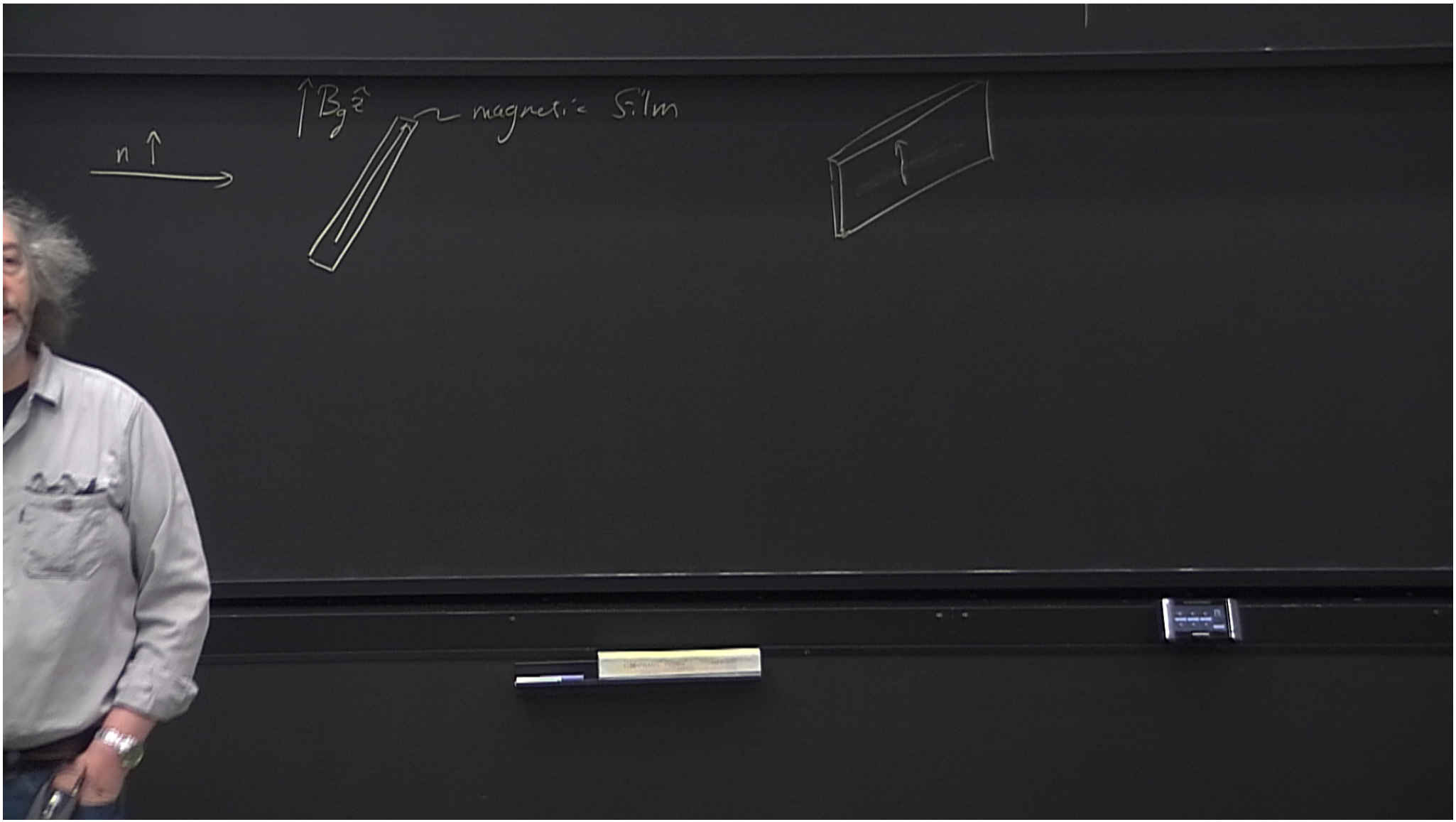
$\omega = \gamma B_0 2\pi$

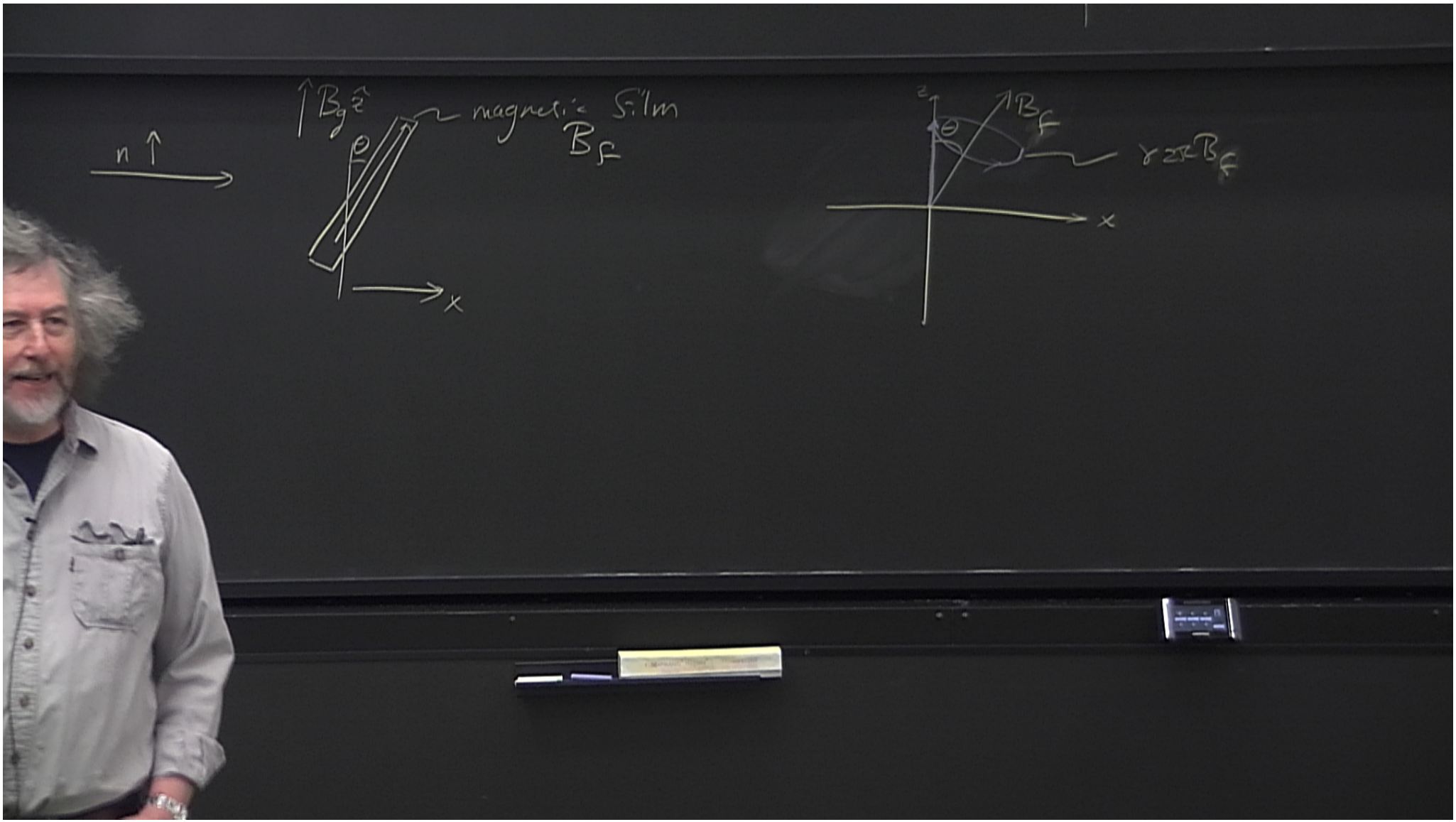
$R_z(\omega)$

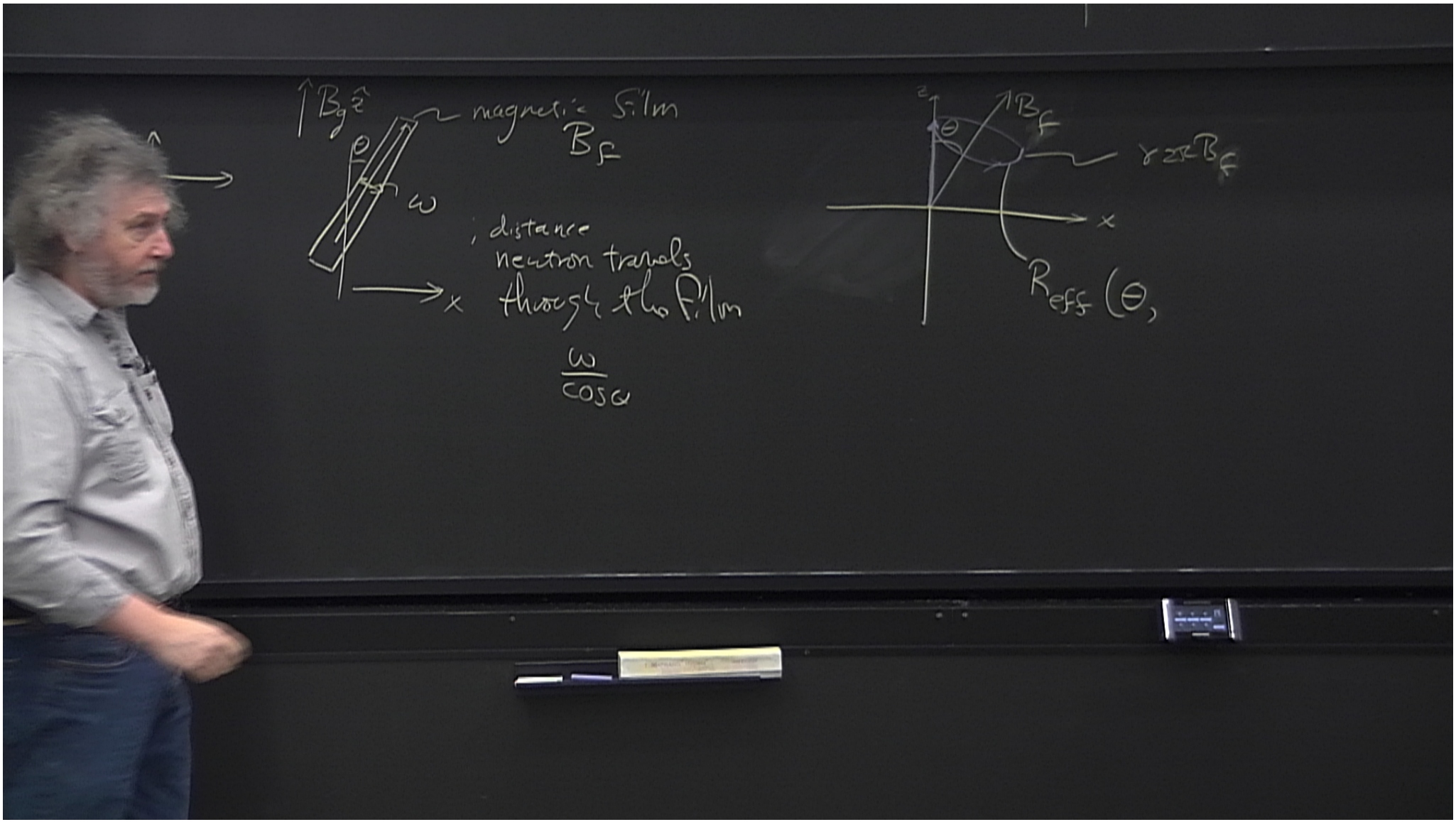


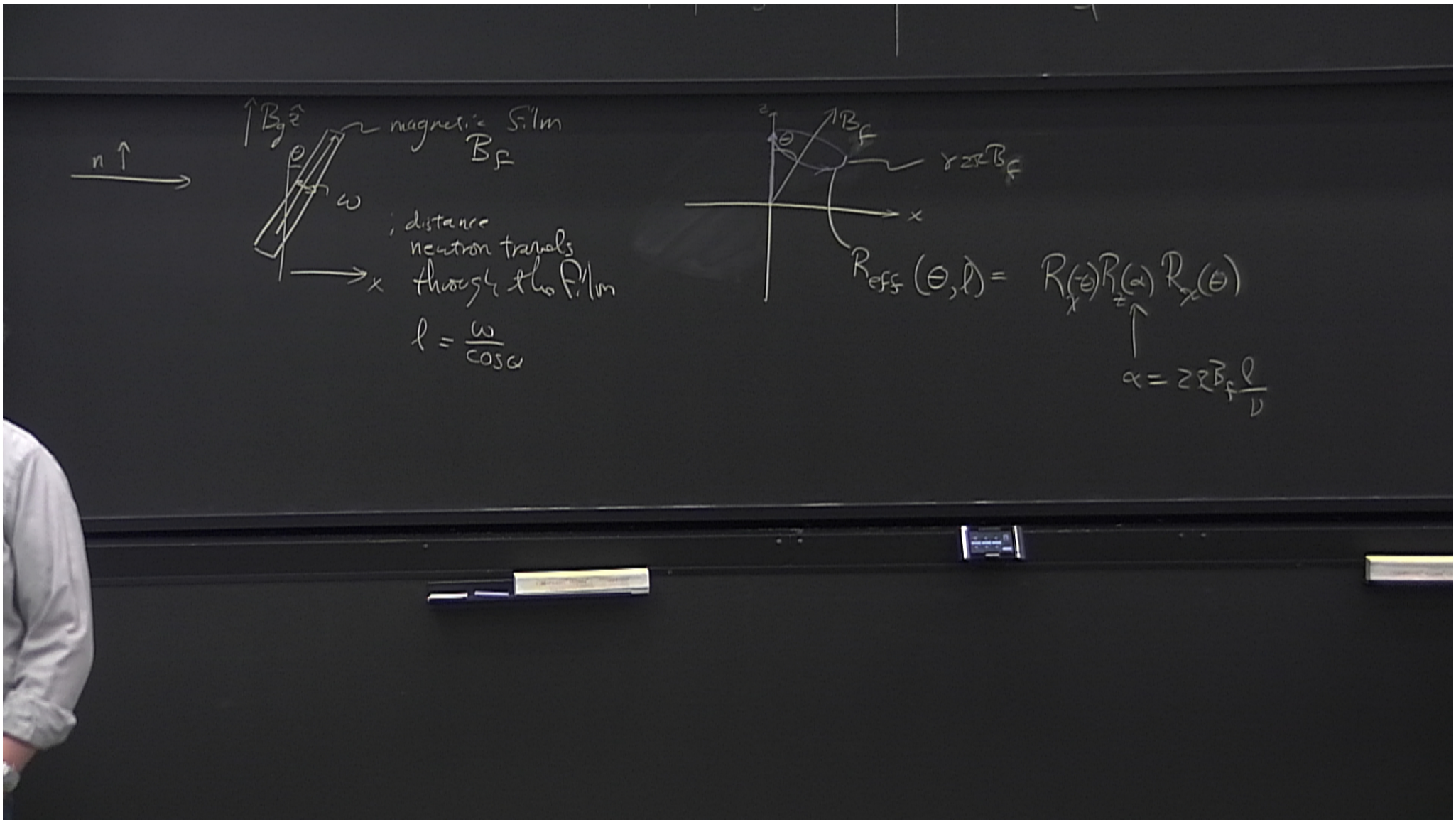

magnetic film

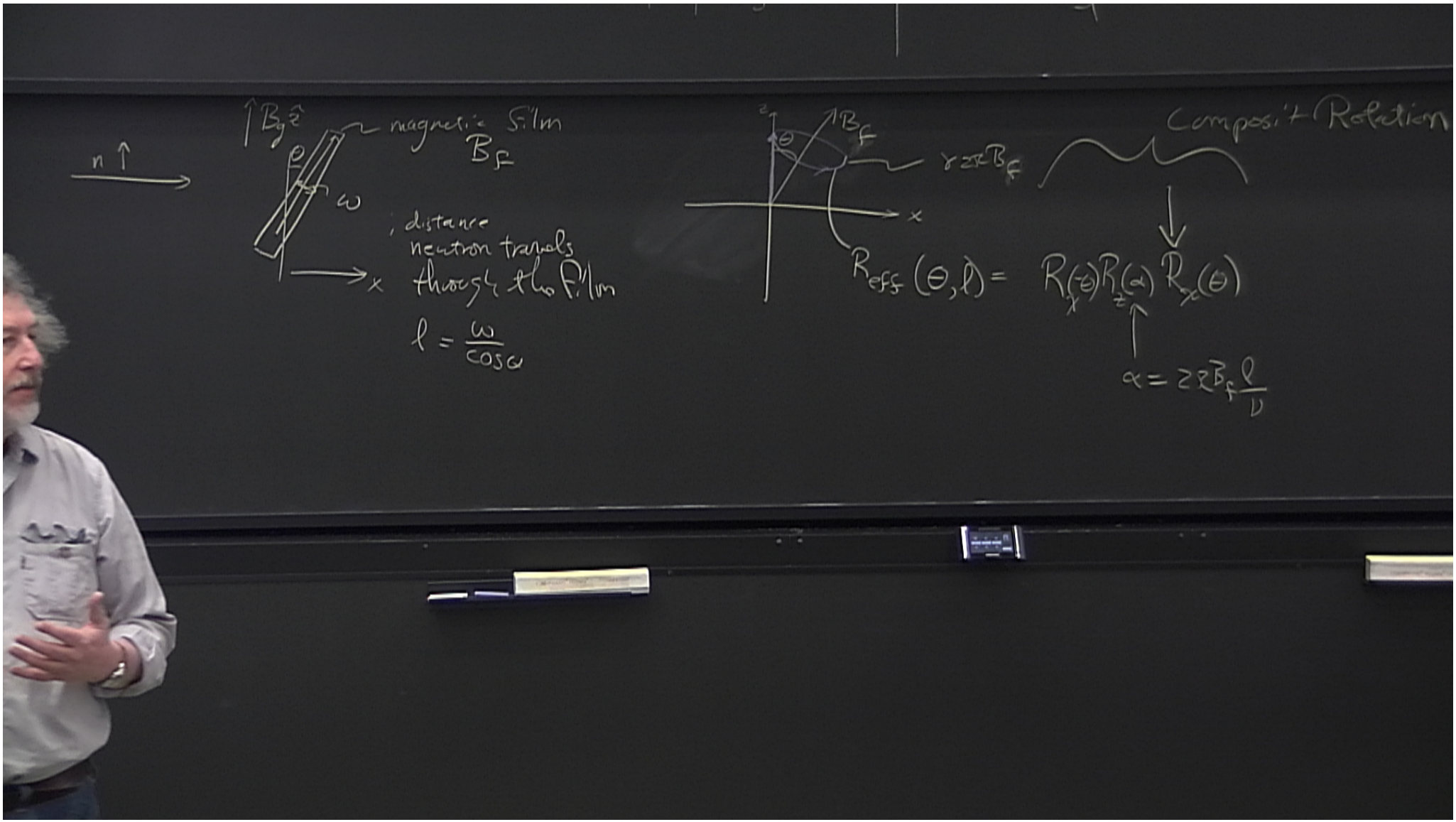

magnetic film

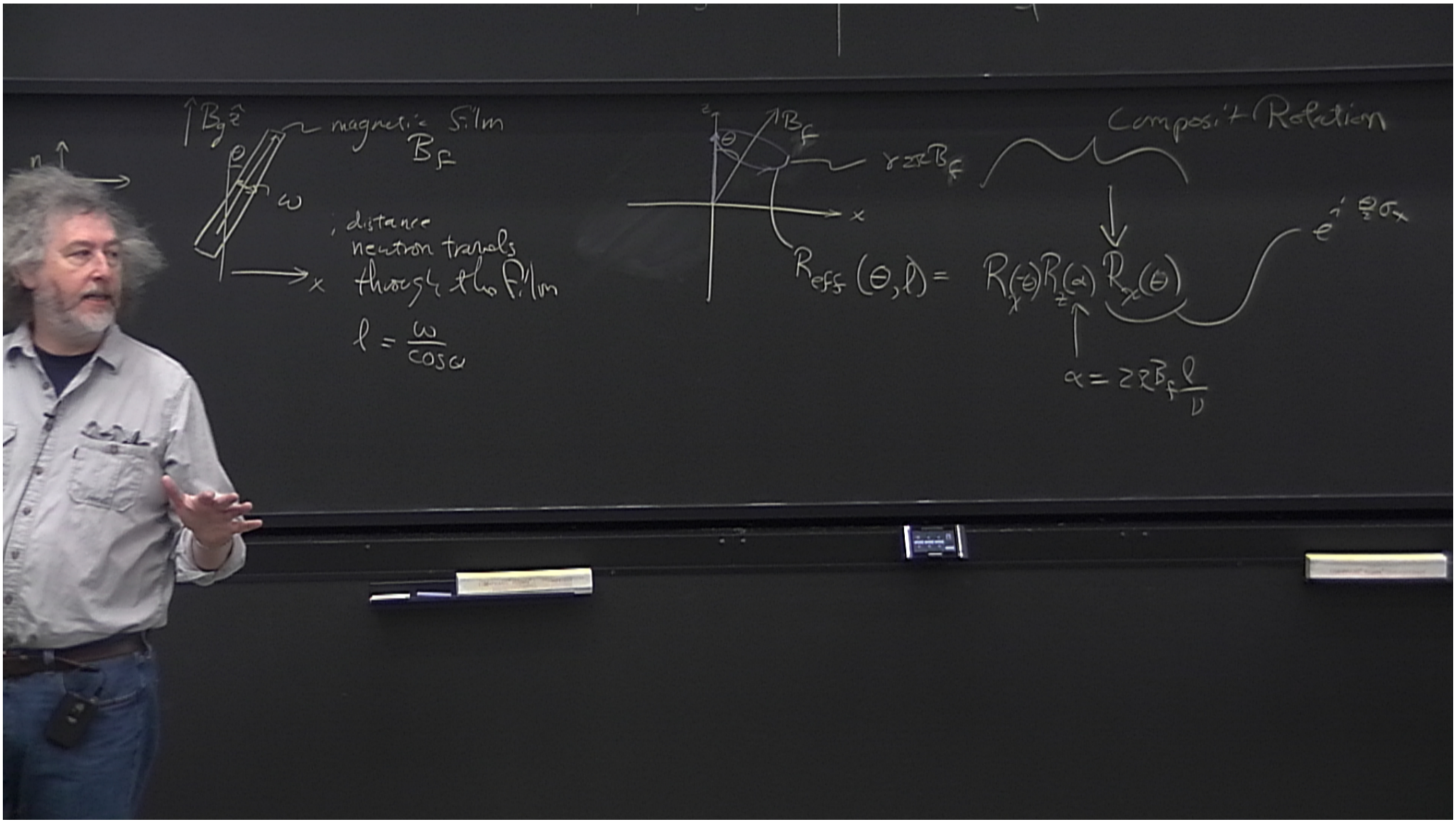

$B_g \hat{z}$
magnetic film
n

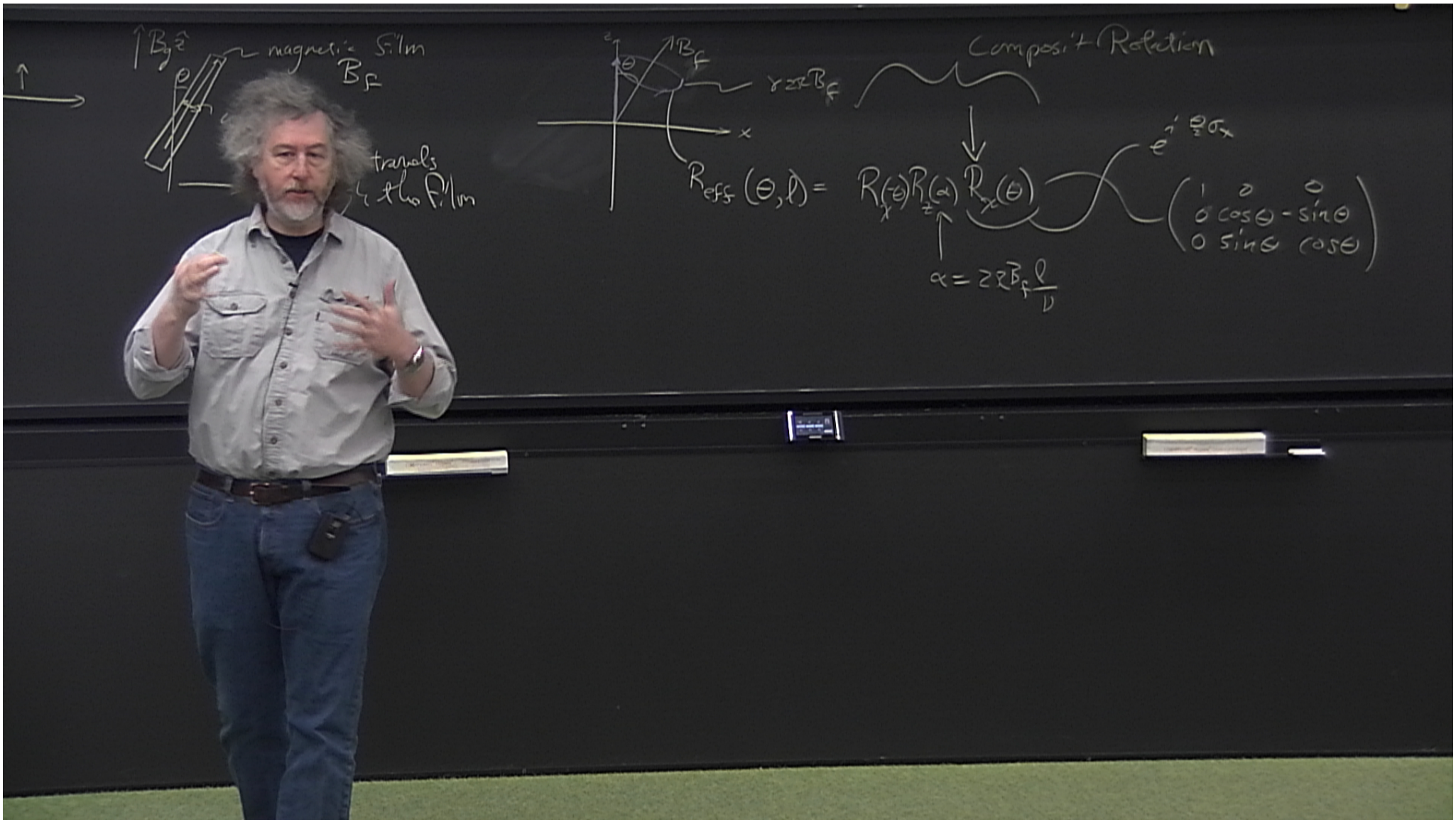

n
$B_g \hat{z}$
θ
magnetic film
B_f
x
z
θ
B_f
$\gamma \propto B_f$
x

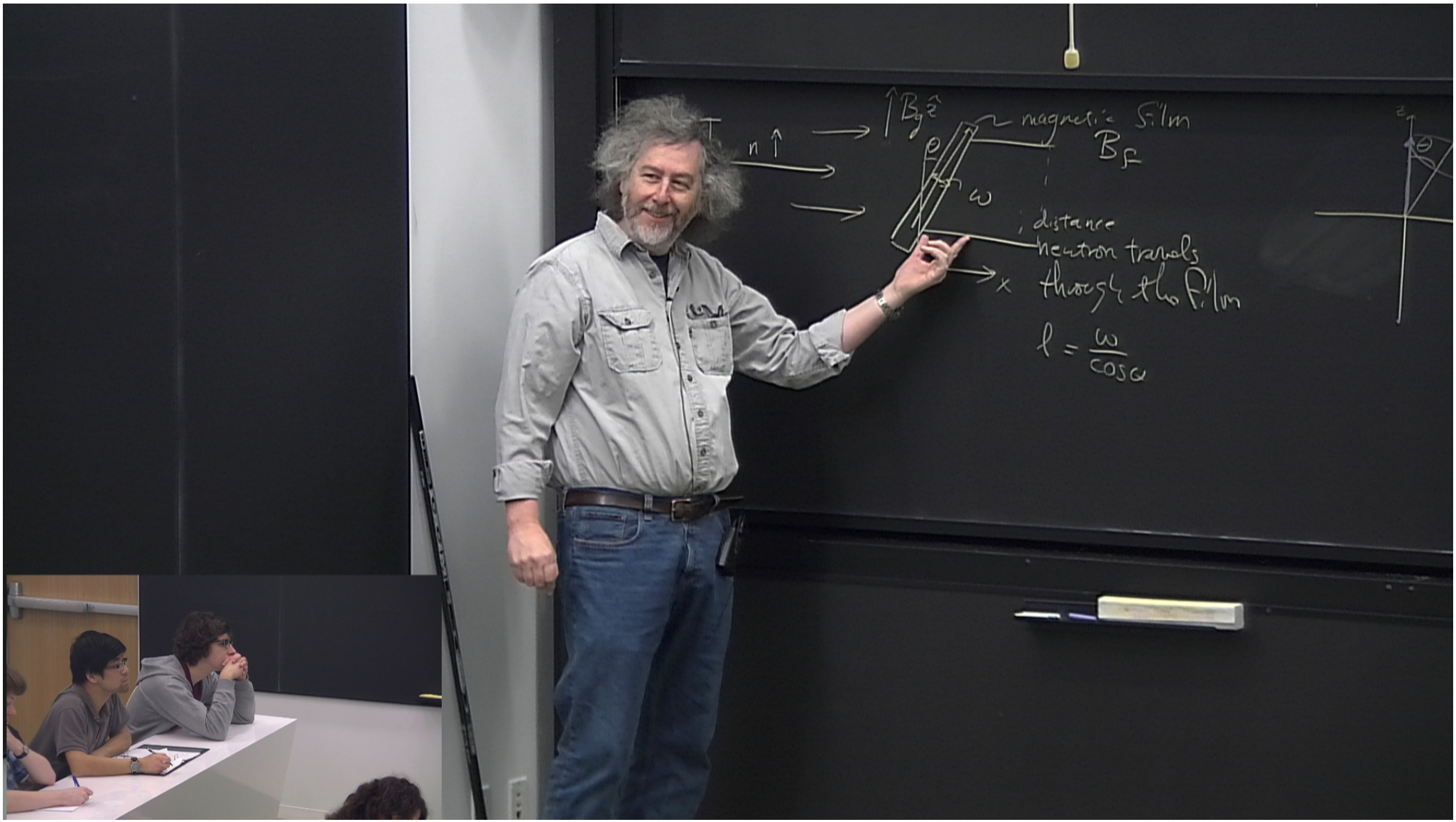

$B_g \hat{z}$
magnetic film
B_f
θ
ω
; distance
neutron travels
through the film
$\frac{\omega}{\cos\alpha}$
x
z
B_f
θ
$\gamma \propto B_f$
x
$R_{eff}(\theta,$

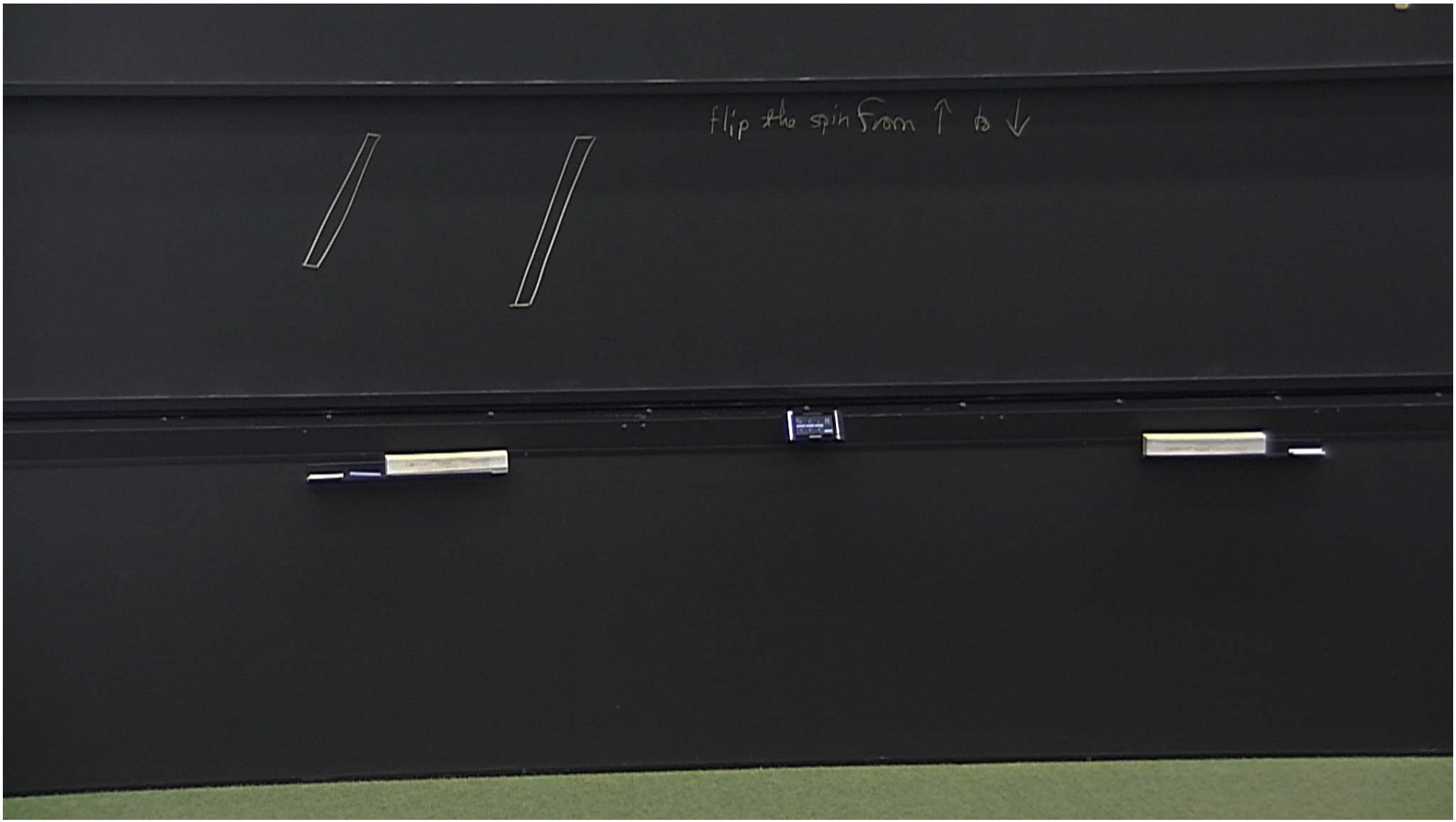

$B_g \hat{z}$
n
magnetic film
B_f
θ
ω
x
; distance neutron travels through the film
$l = \frac{\omega}{\cos\theta}$
z
θ
B_f
$\gamma 2\pi B_f$
x
$R_{eff}(\theta, l) = R_x(-\theta) R_z(\alpha) R_x(\theta)$
$\alpha = 2\pi B_f \frac{l}{v}$


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

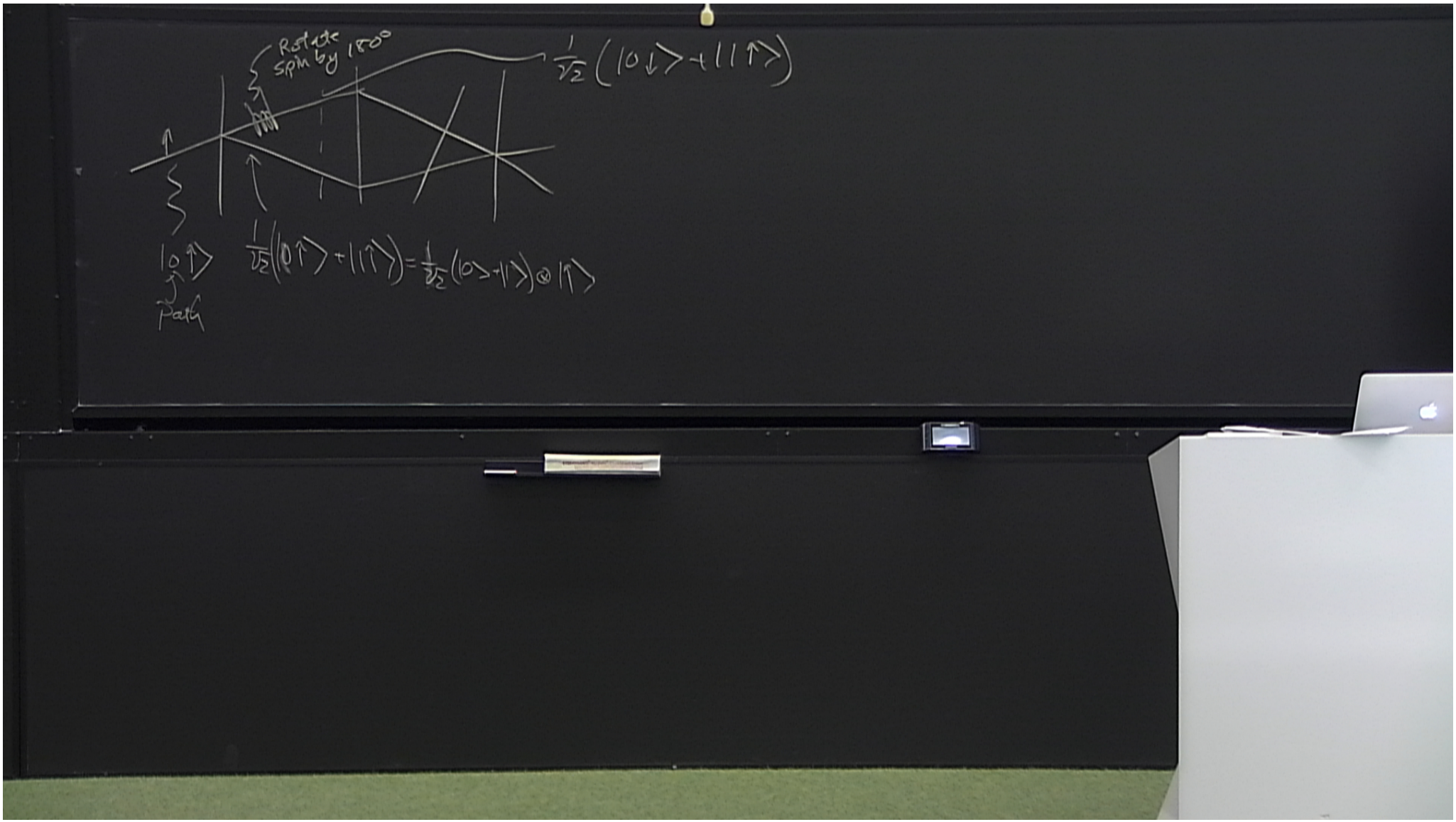

$B_g \hat{z}$
magnetic film
B_f
ω
x
; distance
neutron travels
through the film
$l = \frac{\omega}{\cos\alpha}$
B_f
$\gamma 2\pi B_f$
θ
x
Composit Rotation
$R_{eff}(\theta, l) = R_x(-\theta) R_z(\alpha) R_x(\theta)$
$\alpha = 2\pi B_f \frac{l}{v}$
$e^{-i\frac{\theta}{2}\sigma_x}$

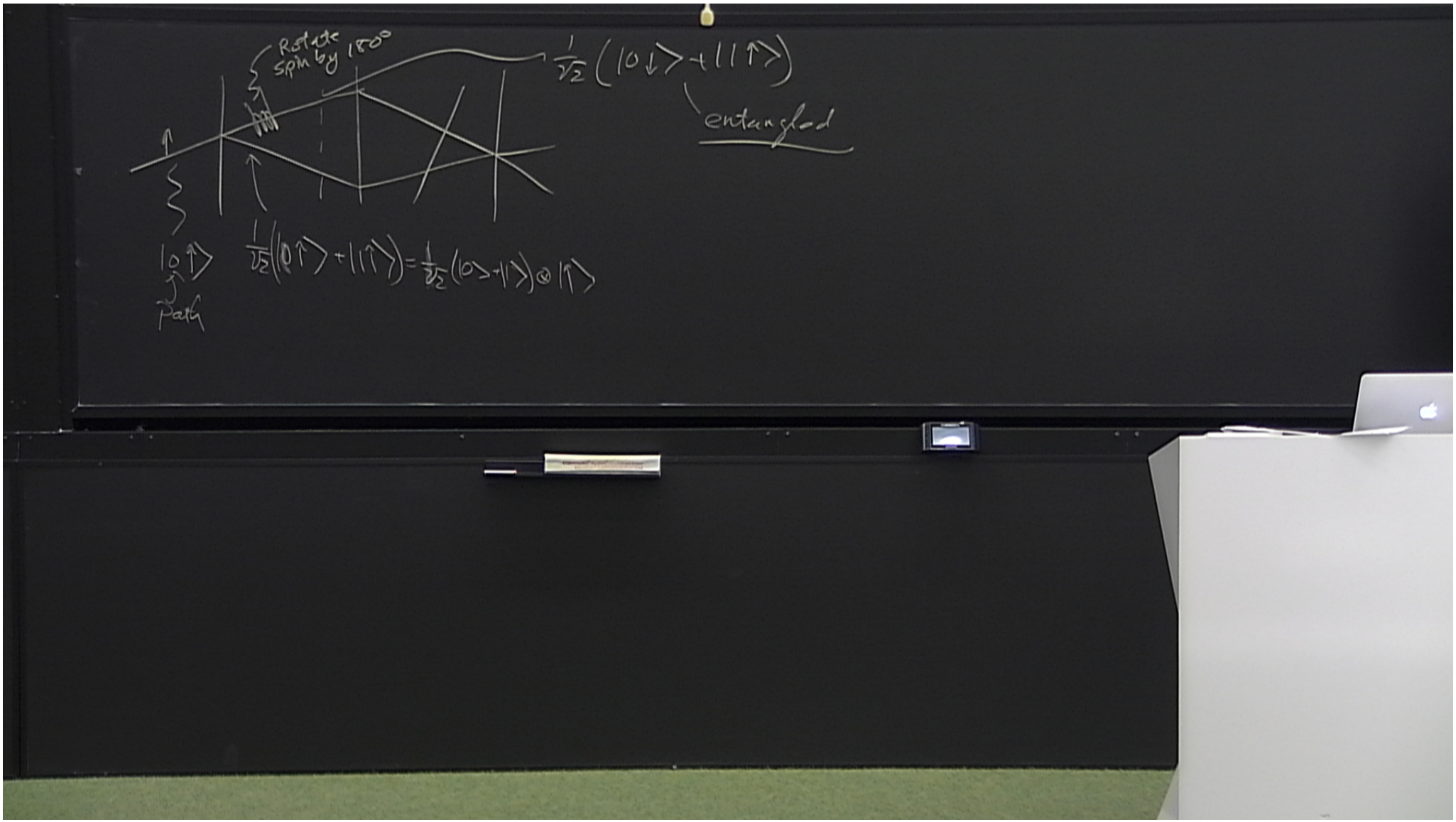

magnetic film
B_F
travels
the film
$\gamma \propto B_F$
Composit Rotation
$R_{eff}(\theta, l) = R_x(-\theta) R_z(\alpha) R_x(\theta)$
$\alpha = 2\gamma B_F \frac{l}{v}$
$e^{i \frac{\theta}{2} \sigma_x}$
$\begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix}$

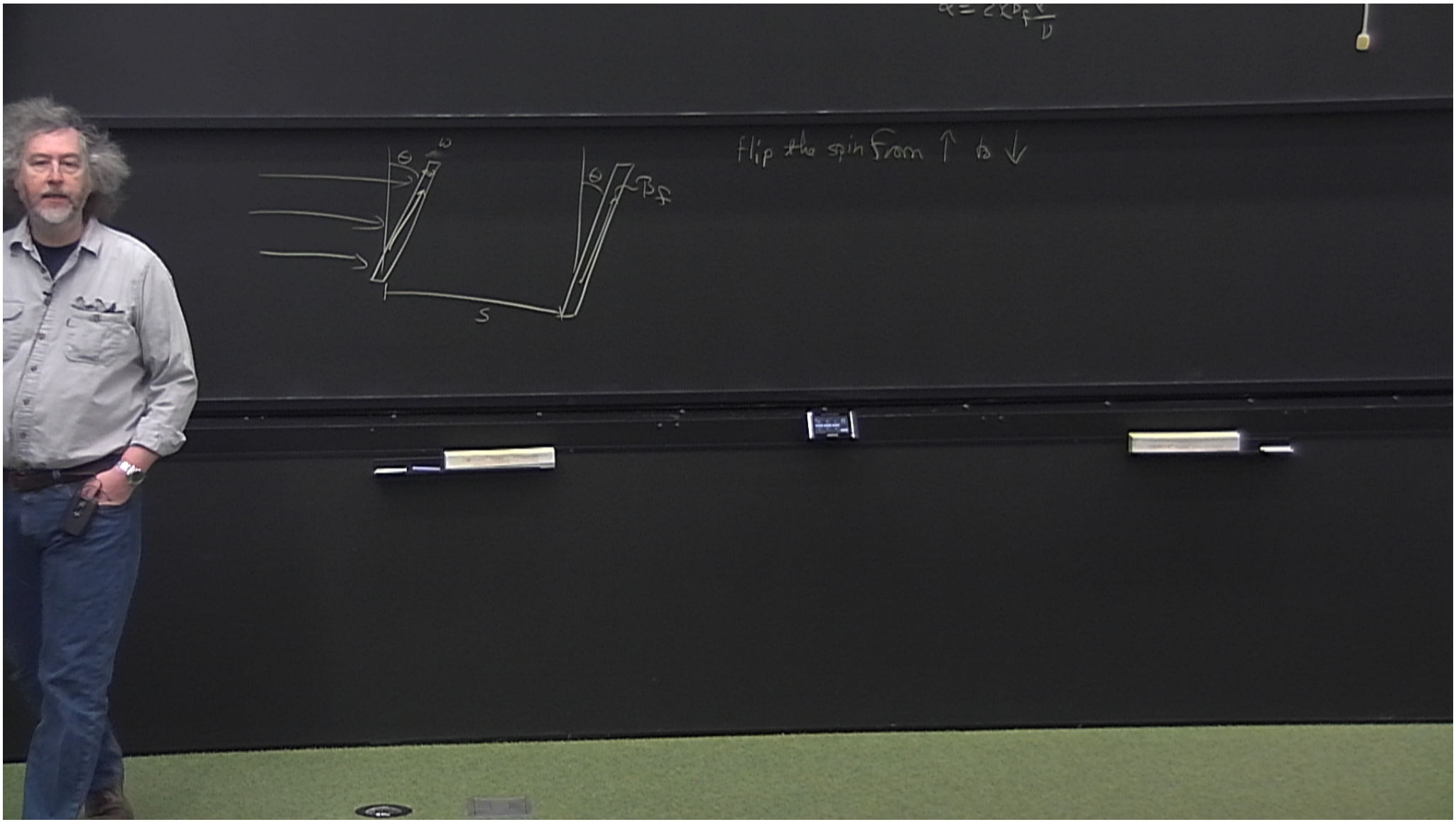

magnetic film
B_f
distance
neutron travels
through the film
$l = \frac{w}{\cos\alpha}$

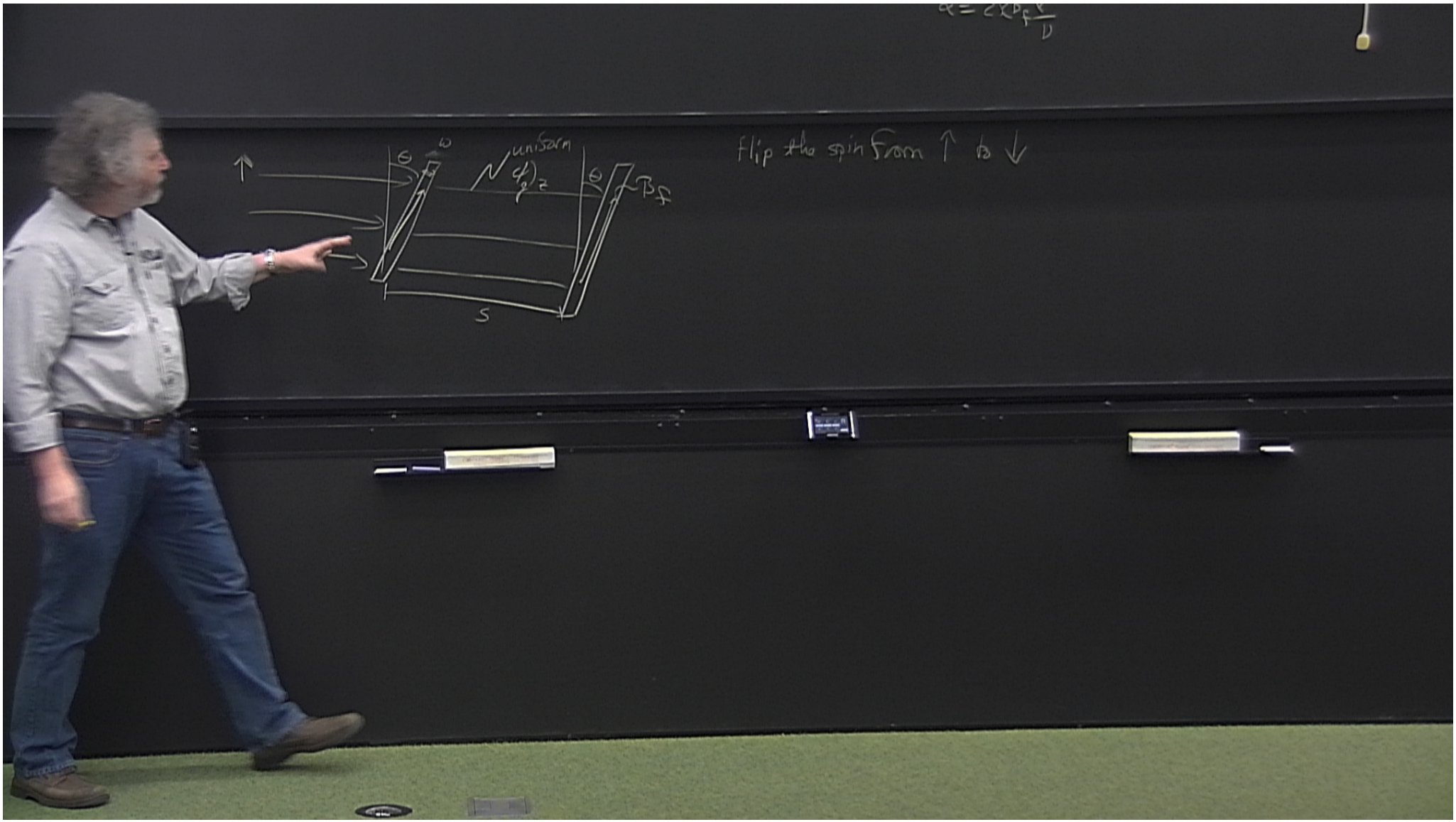

flip the spin from ↑ to ↓

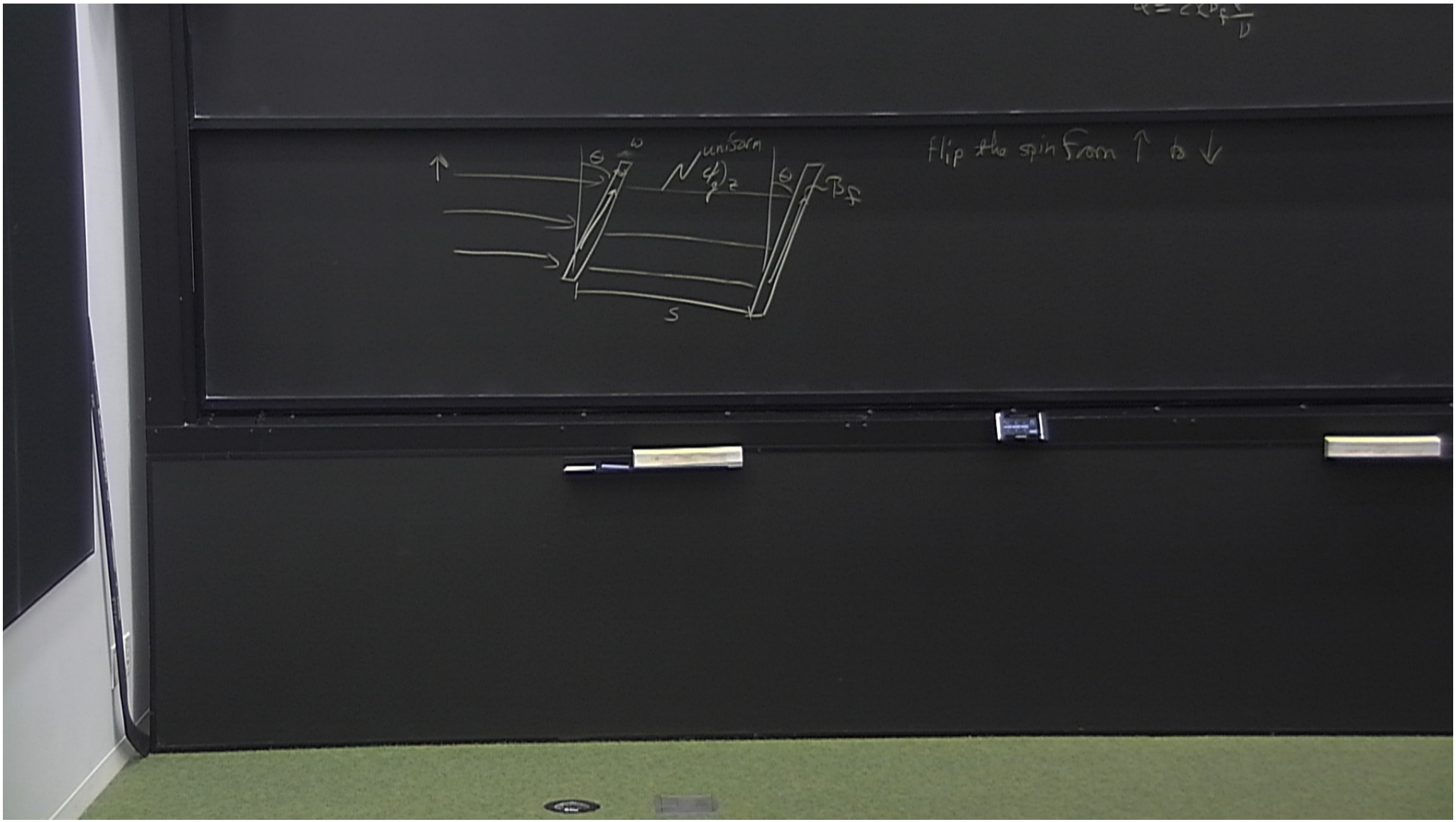
$|0\uparrow\rangle$
Path
$\frac{1}{\sqrt{2}}(|0\uparrow\rangle + |1\uparrow\rangle) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \otimes |\uparrow\rangle$


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


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

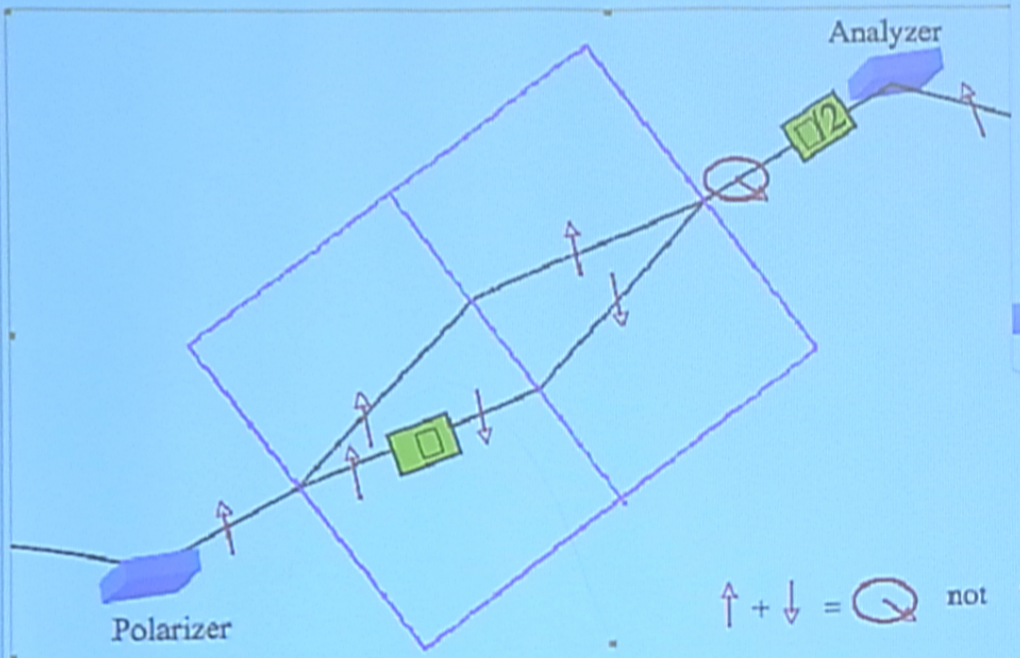

flip the spin from ↑ to ↓
θ
ω
θ
β_f
s


flip the spin from ↑ to ↓
uniform
S

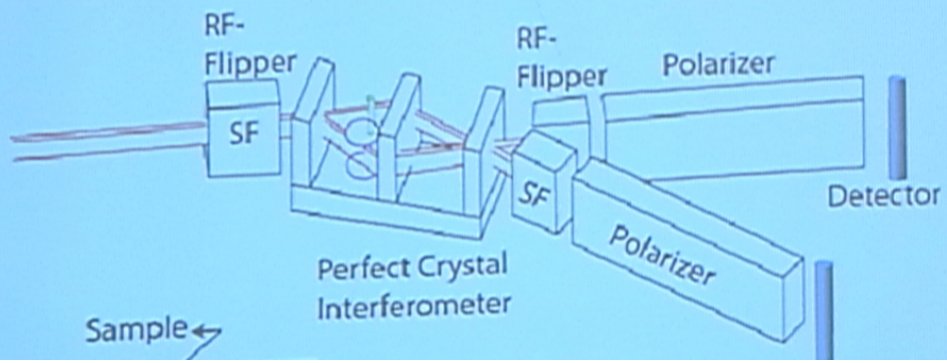

uniform
flip the spin from ↑ to ↓

QE Lec 6.nb

Operators for various components



$\uparrow + \downarrow = \bigcirc$ not $\updownarrow$



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

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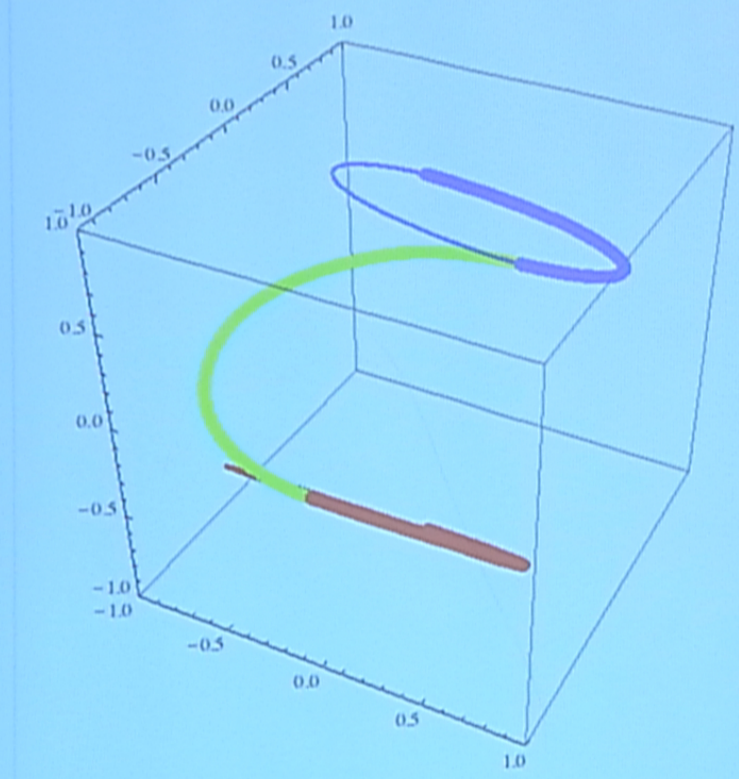
composite films.cdf

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

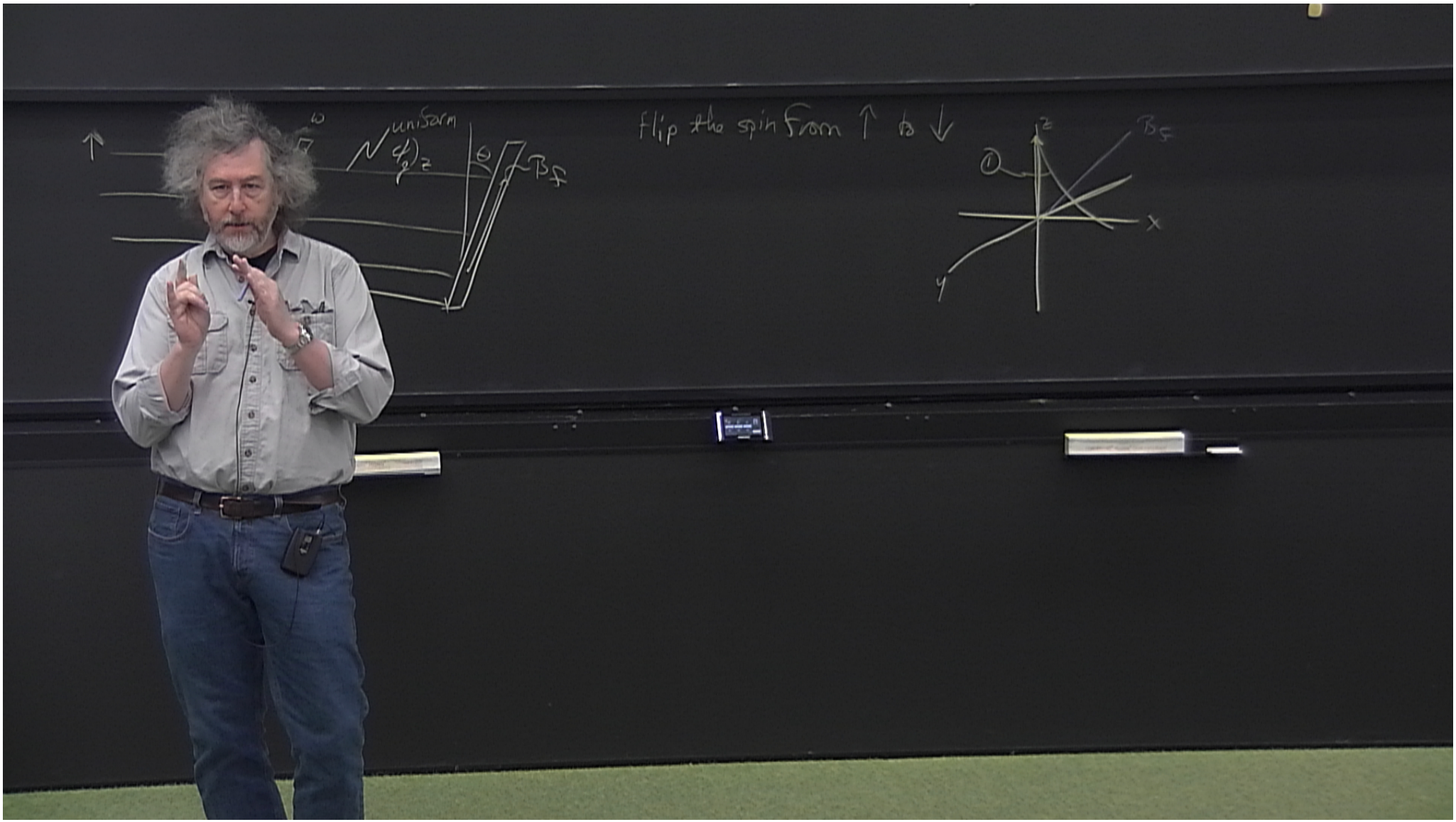
α

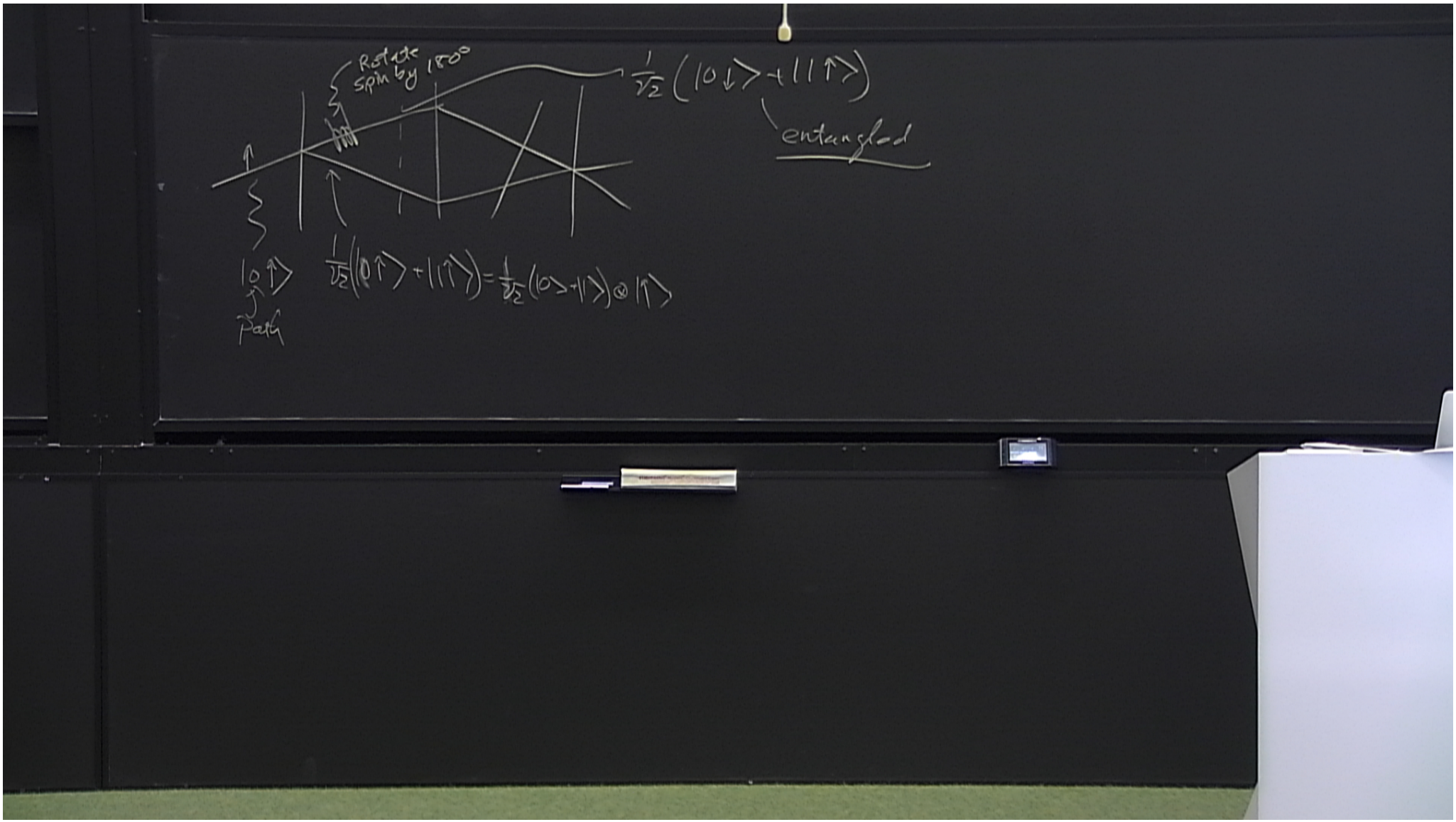
Out[14]=

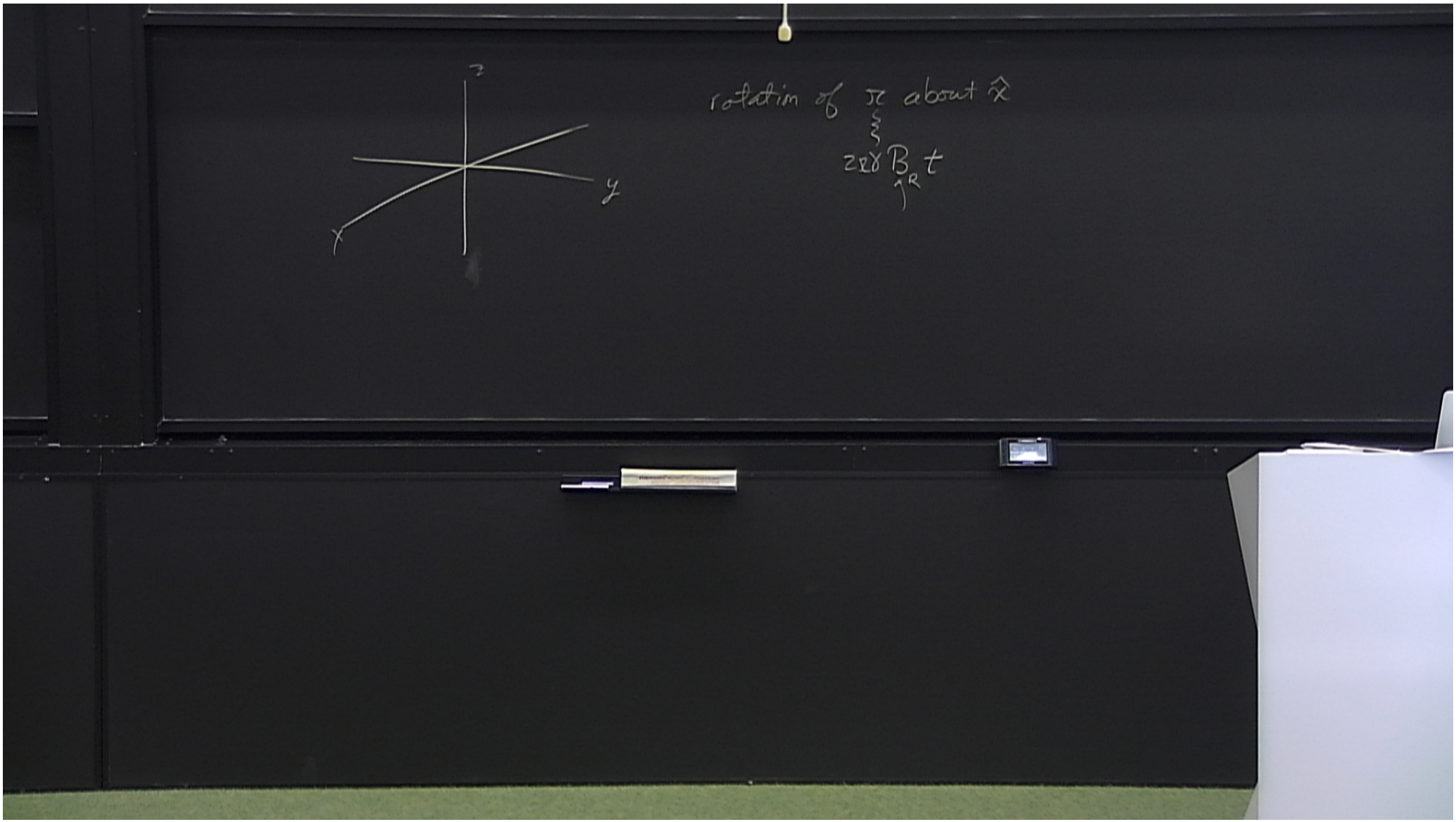


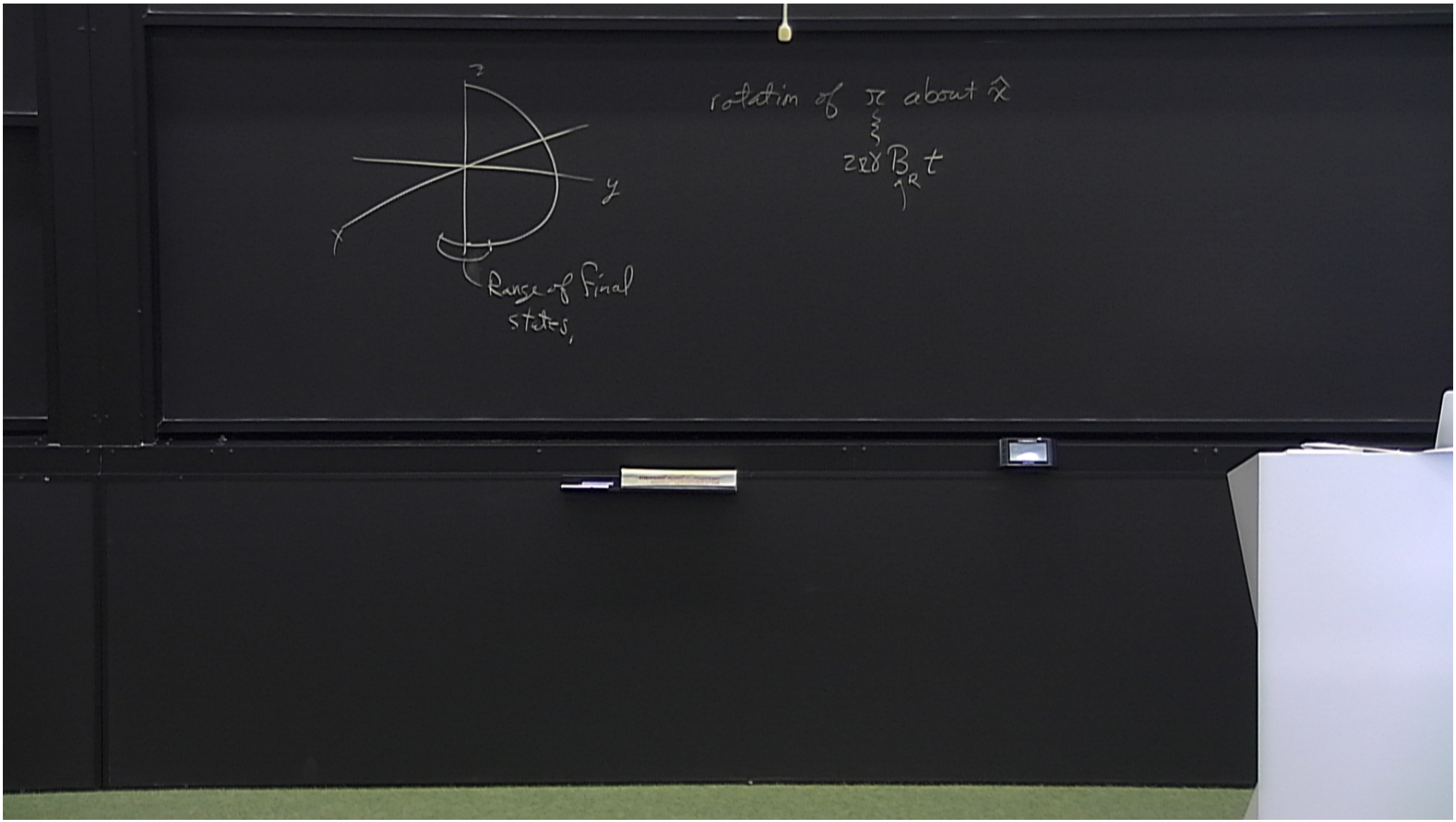
The figure shows the trajectory of the magnetization. Note the thick lines correspond to the motion. The thin lines are just the nutation cones of +z (blue) and -z (red)

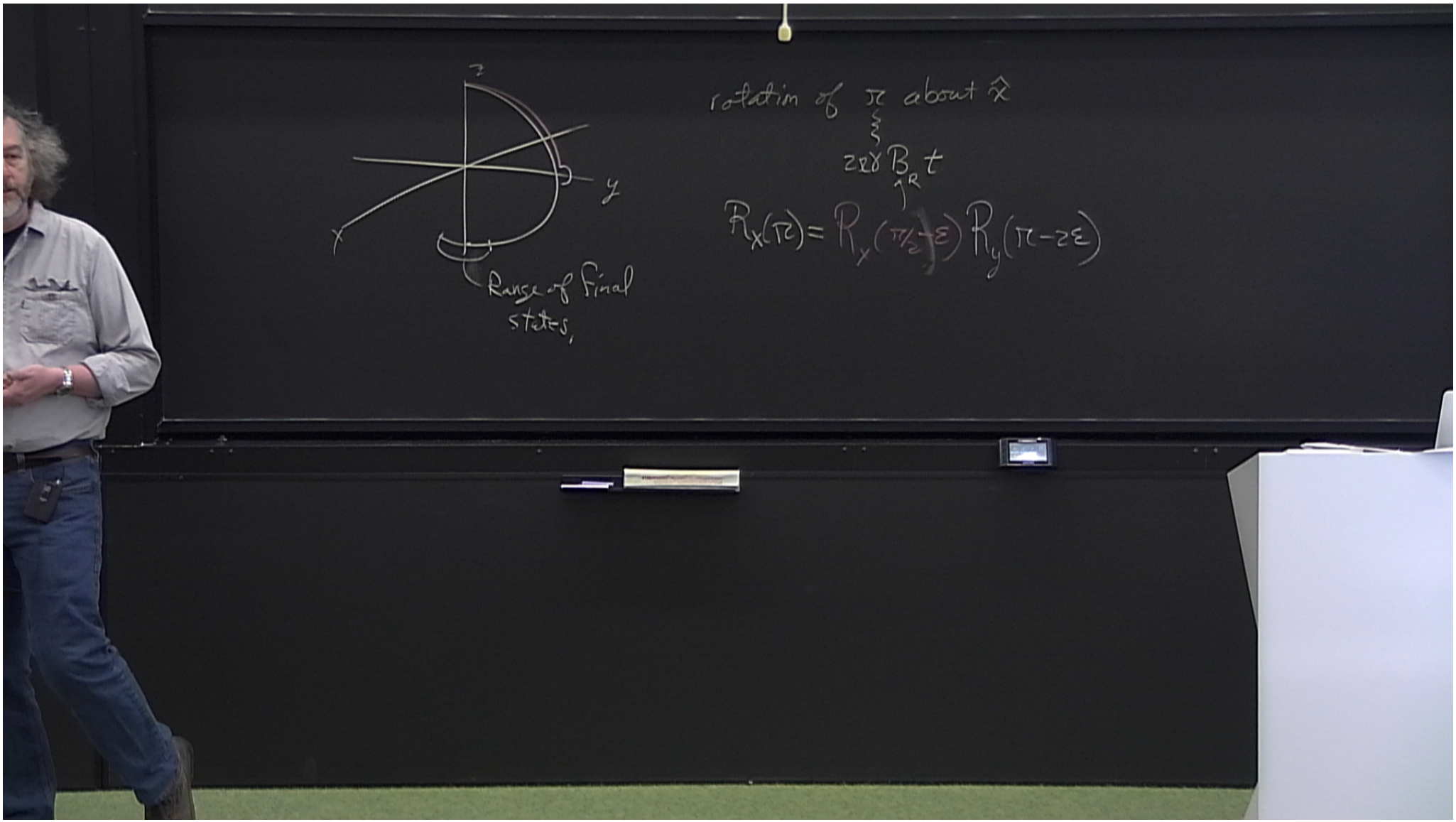
125%

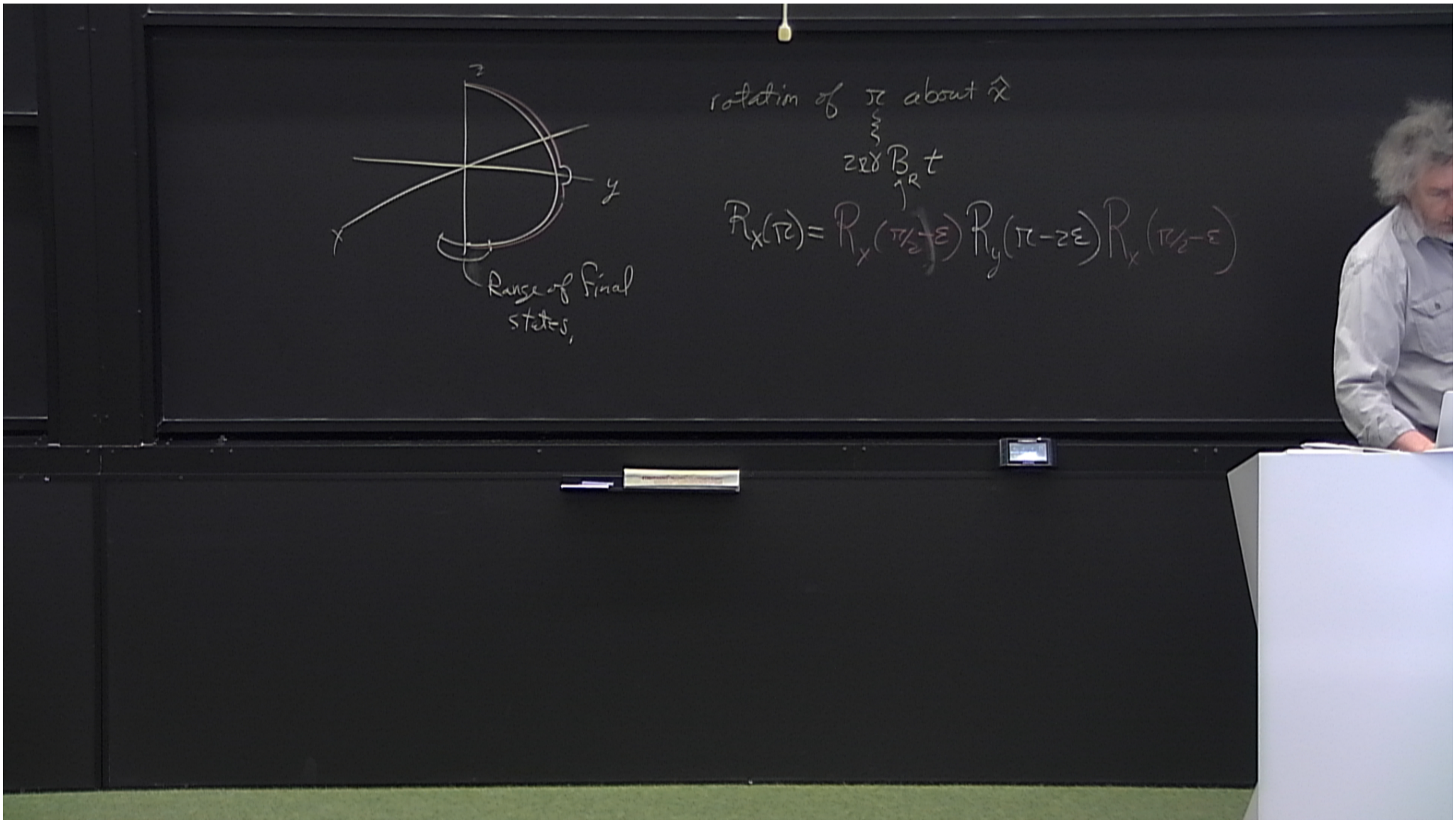

uniform
flip the spin from ↑ to ↓

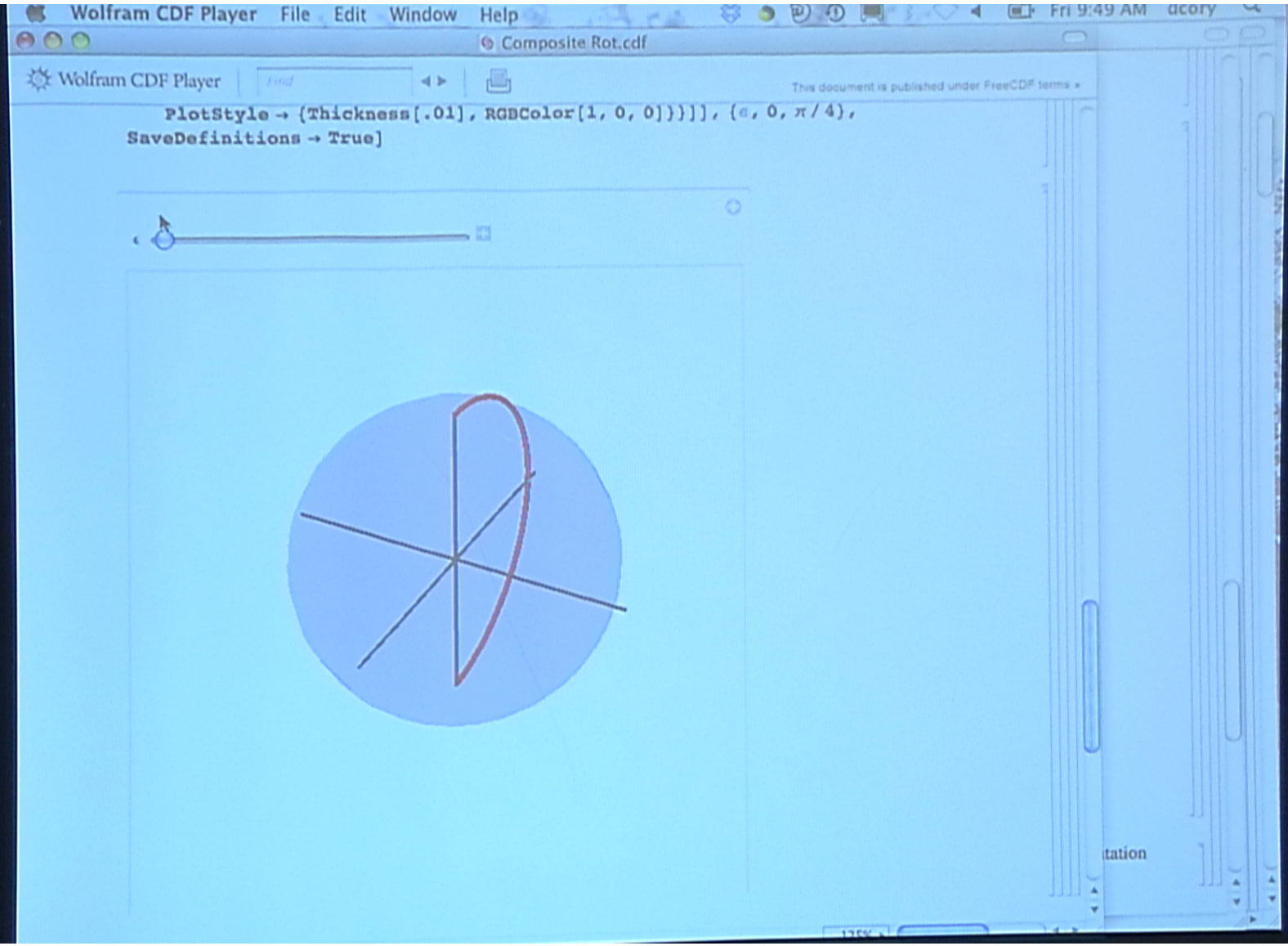

Rotate spin by 180°
$\frac{1}{\sqrt{2}}(|0\downarrow\rangle + |1\uparrow\rangle)$
entangled
$|0\uparrow\rangle$
path
$\frac{1}{\sqrt{2}}(|0\uparrow\rangle + |1\uparrow\rangle) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \otimes |\uparrow\rangle$

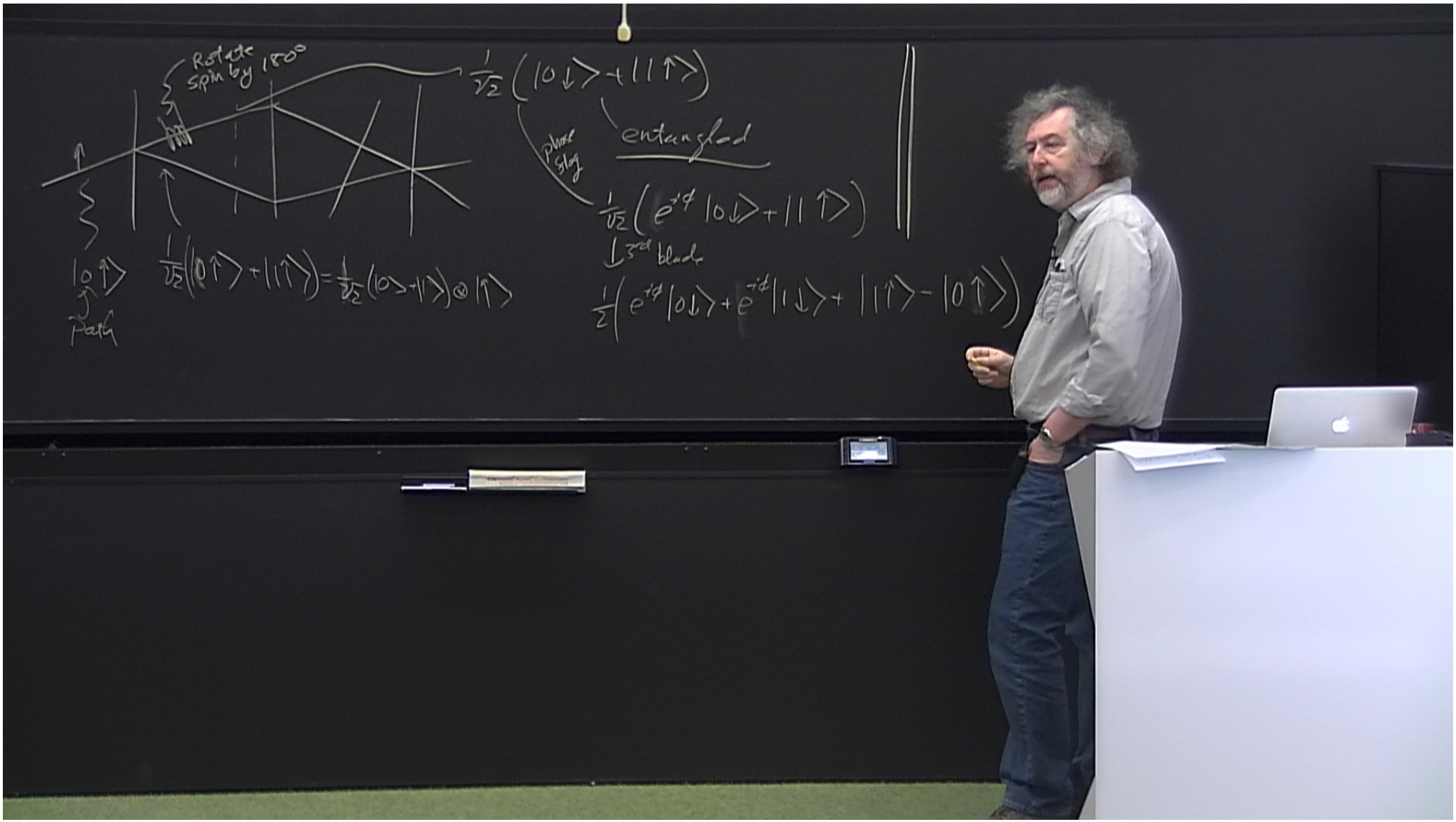

z
y
x
rotation of π about $\hat{x}$
$2\xi\gamma B_R t$

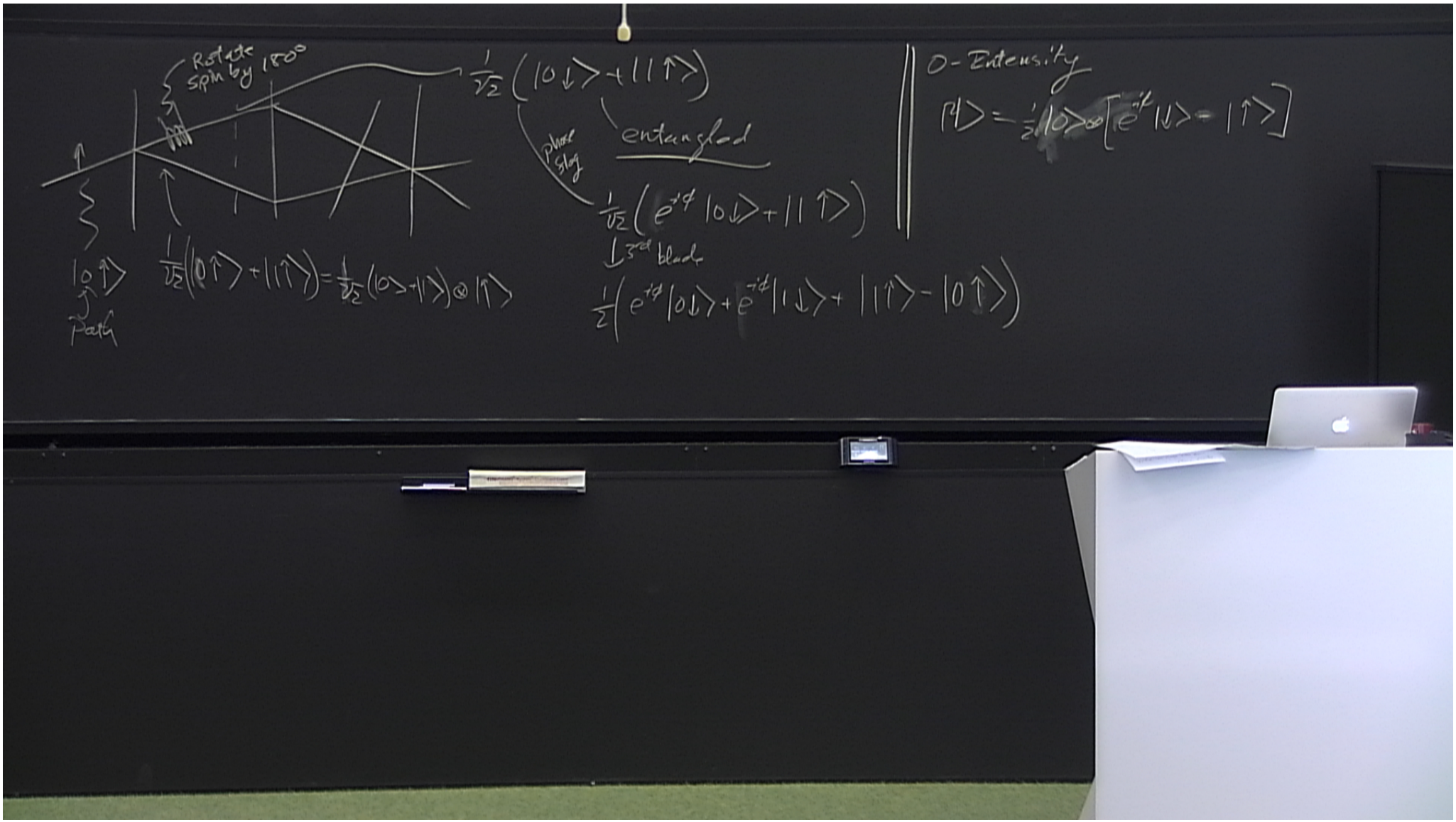

z
y
x
Range of final states,
rotation of π about x̂
2εγ B_R t

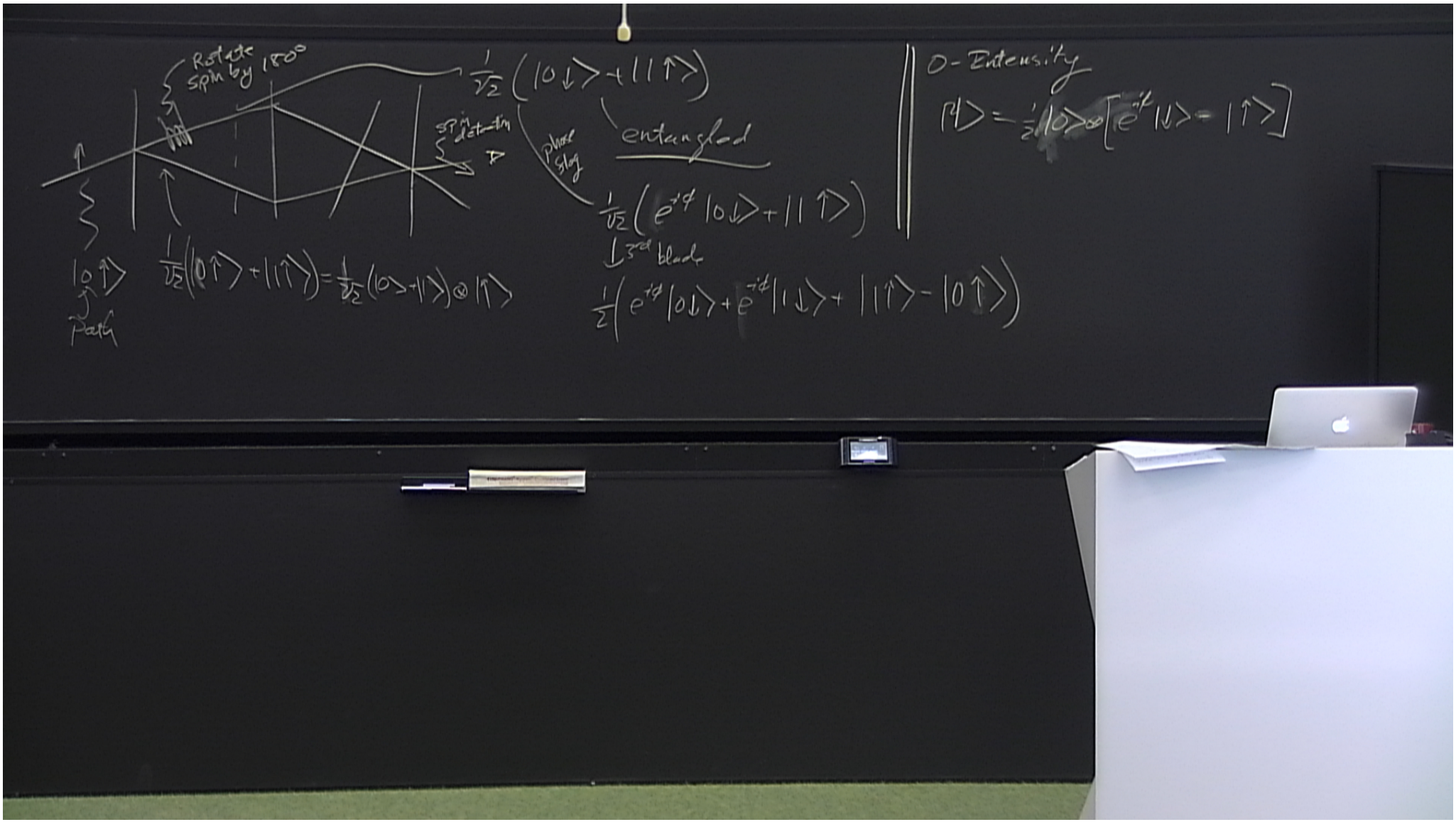

z
y
x
Range of final states,
rotation of π about x̂
2εγ B_R t
R_x(π) = R_y(π/2 + ε) R_y(π − 2ε)

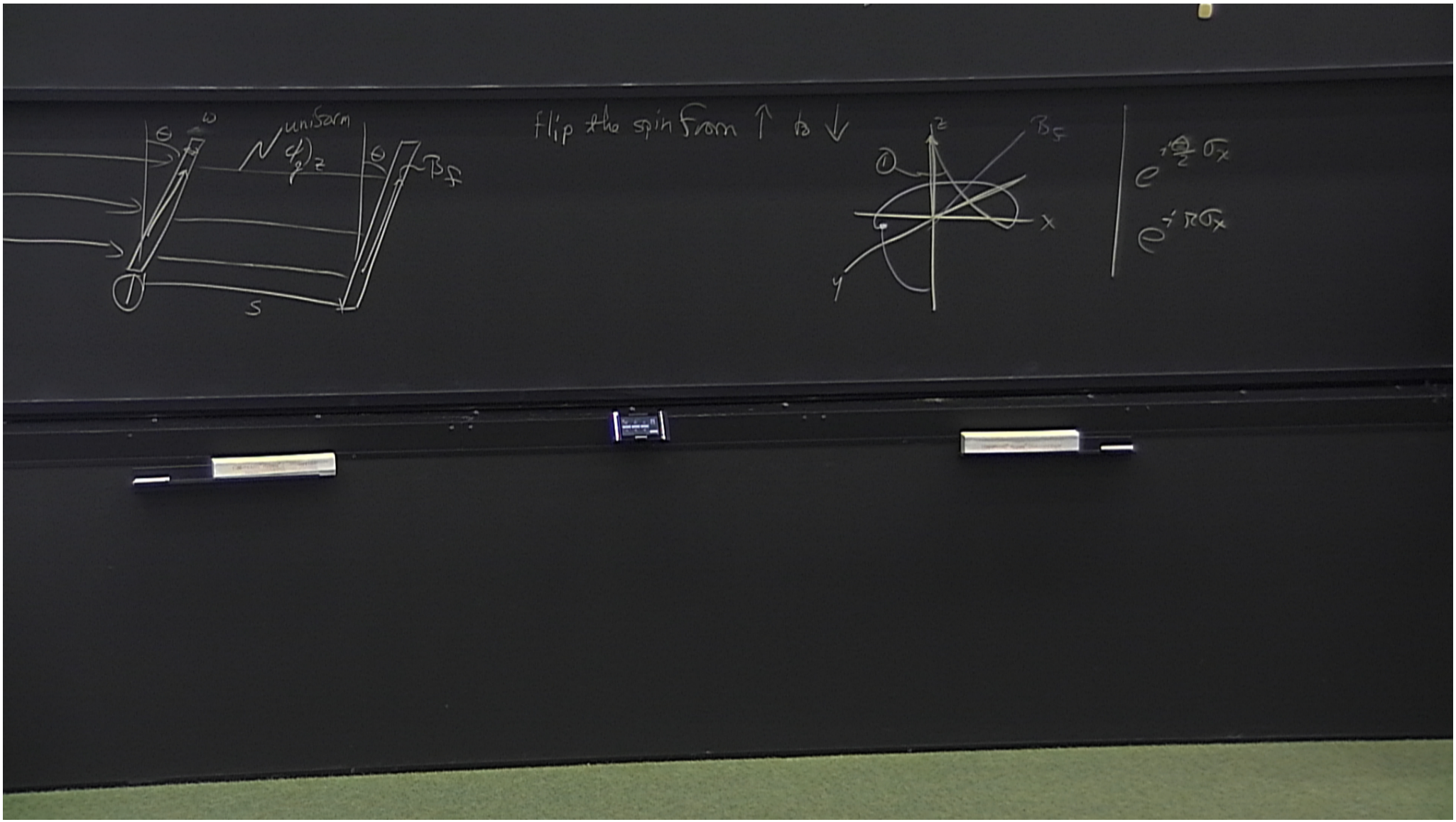

z
y
x
Range of final states,
rotation of π about x̂
2εγB_R t
R_x(π) = R_y(π/2 + ε) R_y(π − 2ε) R_x(π/2 − ε)


Wolfram CDF Player File Edit Window Help
Fri 9:49 AM
Composite Rot.cdf
Wolfram CDF Player
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
$\frac{1}{2}(e^{i\phi}|0\downarrow\rangle + e^{-i\phi}|1\downarrow\rangle + |1\uparrow\rangle - |0\uparrow\rangle)$
$|0\rangle\uparrow\rangle$
path
$\frac{1}{\sqrt{2}}(|0\uparrow\rangle + |1\uparrow\rangle) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)\otimes|\uparrow\rangle$


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


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


θ
ω
uniform
ϕ_z
θ
B_f
S
flip the spin from ↑ to ↓
z
B_f
x
y
$e^{i\frac{\theta}{2}\sigma_x}$
$e^{i\pi\sigma_x}$

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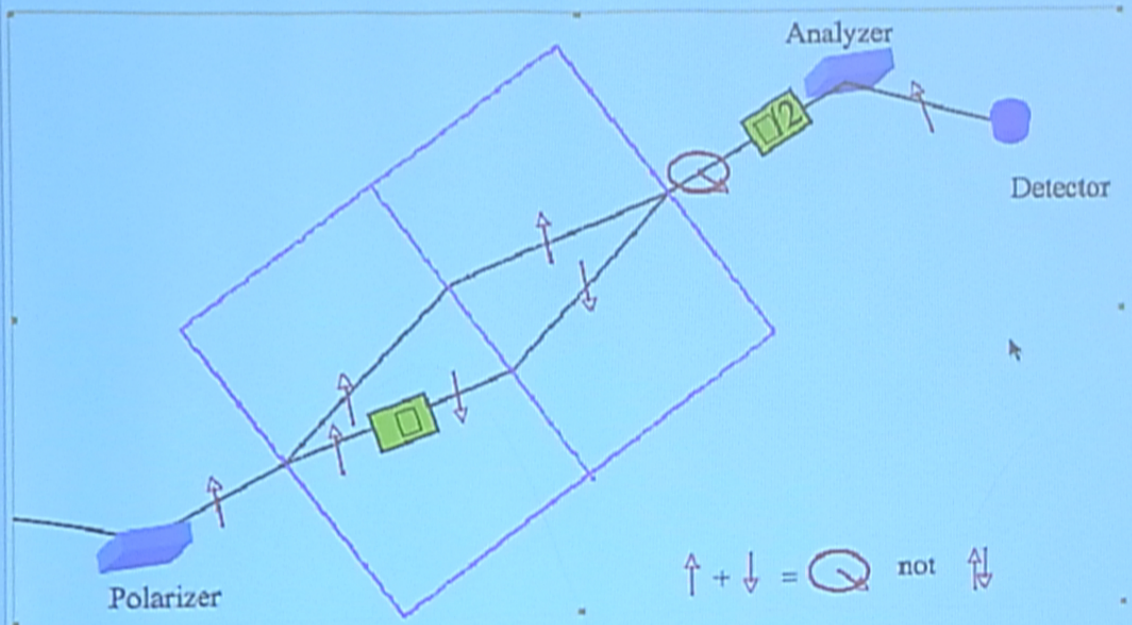
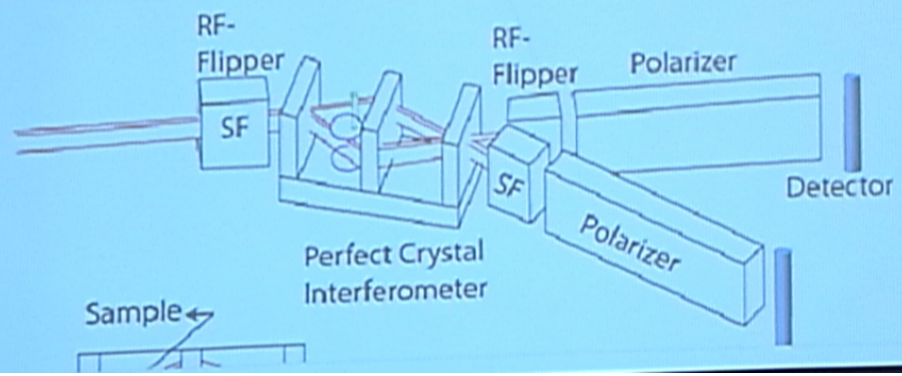
Operators for various components





150%

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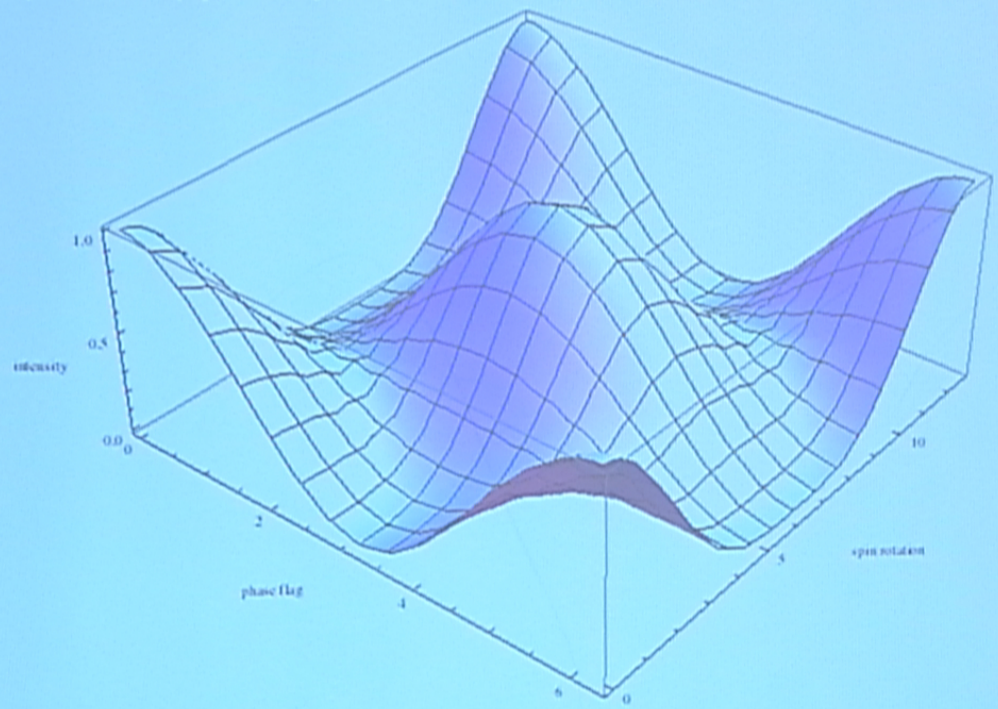
QE Lec 6.nb

■ O-Beam with spin up filter

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

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

```
PlotJD[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[Uzpdown . resls[t, a]]
MHup[t, a]
```

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

150%