

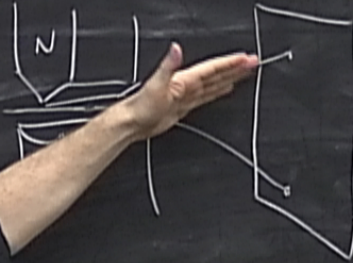
Title: Interpretations of Quantum Mechanics

Date: Jul 25, 2012 10:30 AM

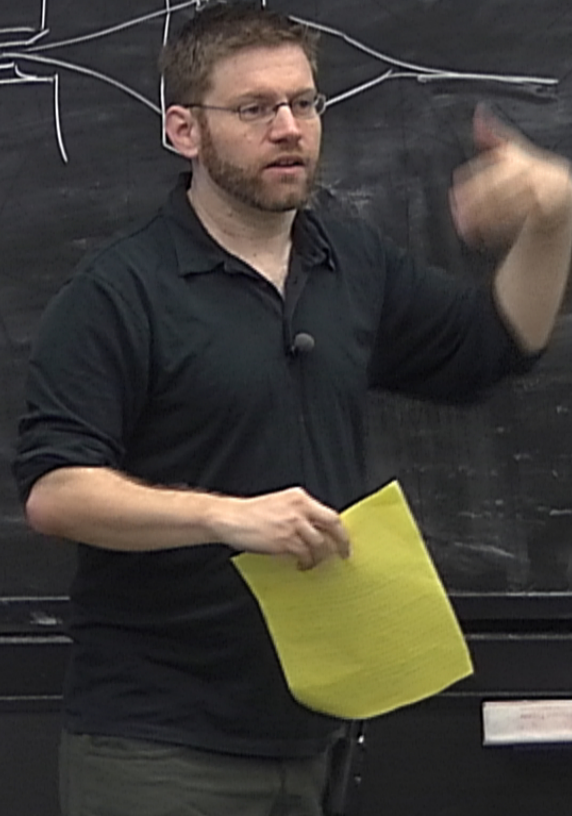
URL: <http://pirsa.org/12070006>

Abstract: Just as there is a difference between knowing how to *drive* a car and understanding its functioning well enough to fix it when it breaks down, so too is there a difference between knowing how to *use* quantum theory to make predictions and understanding what it says about the world well enough to see how it might fail or how it might be usefully generalized. The field of quantum foundations seeks to achieve such a deeper understanding. In particular, it seeks to determine the correct interpretation of quantum theory and to find the principles underlying it, questions for which there is still no consensus among researchers. In this talk, I'll discuss some of the interpretational problems of quantum theory and several of the most prominent proposals for how to overcome these problems. The list includes introducing hidden variables that we must necessarily remain uncertain of, changing the rules of logic, and positing the existence of an infinite number of parallel worlds.

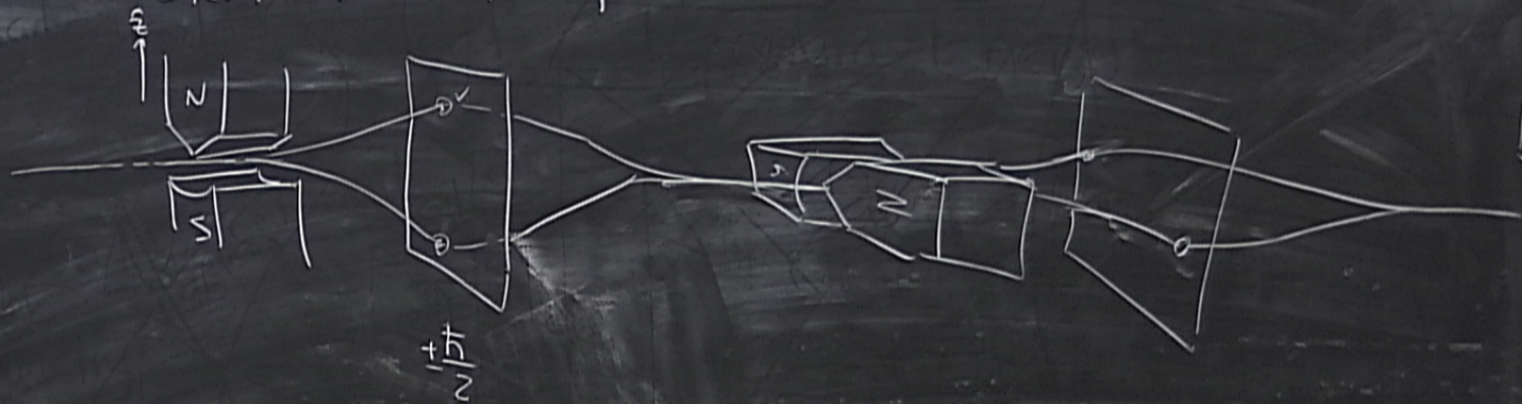
Stern-Gerlach expt.



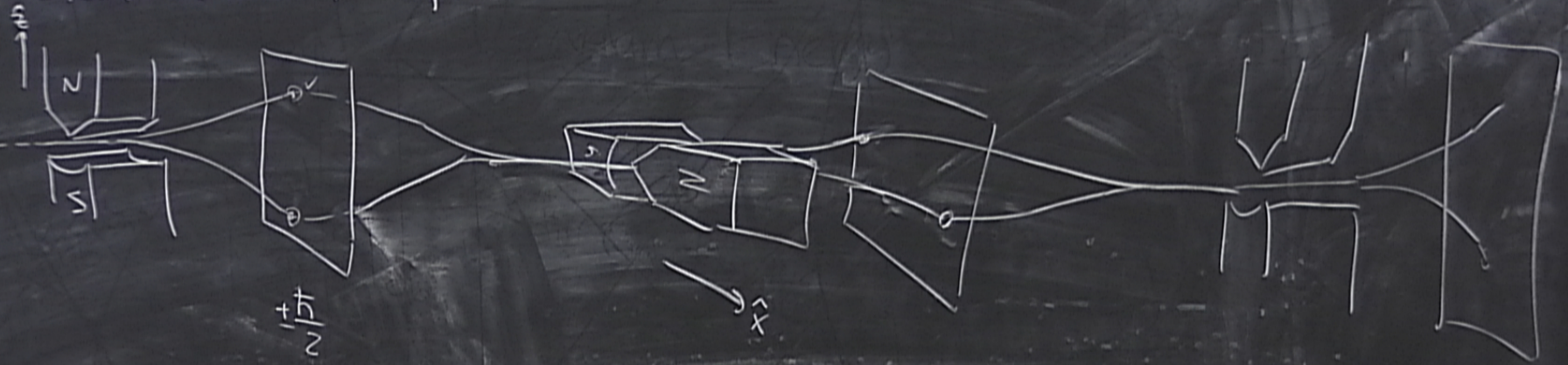
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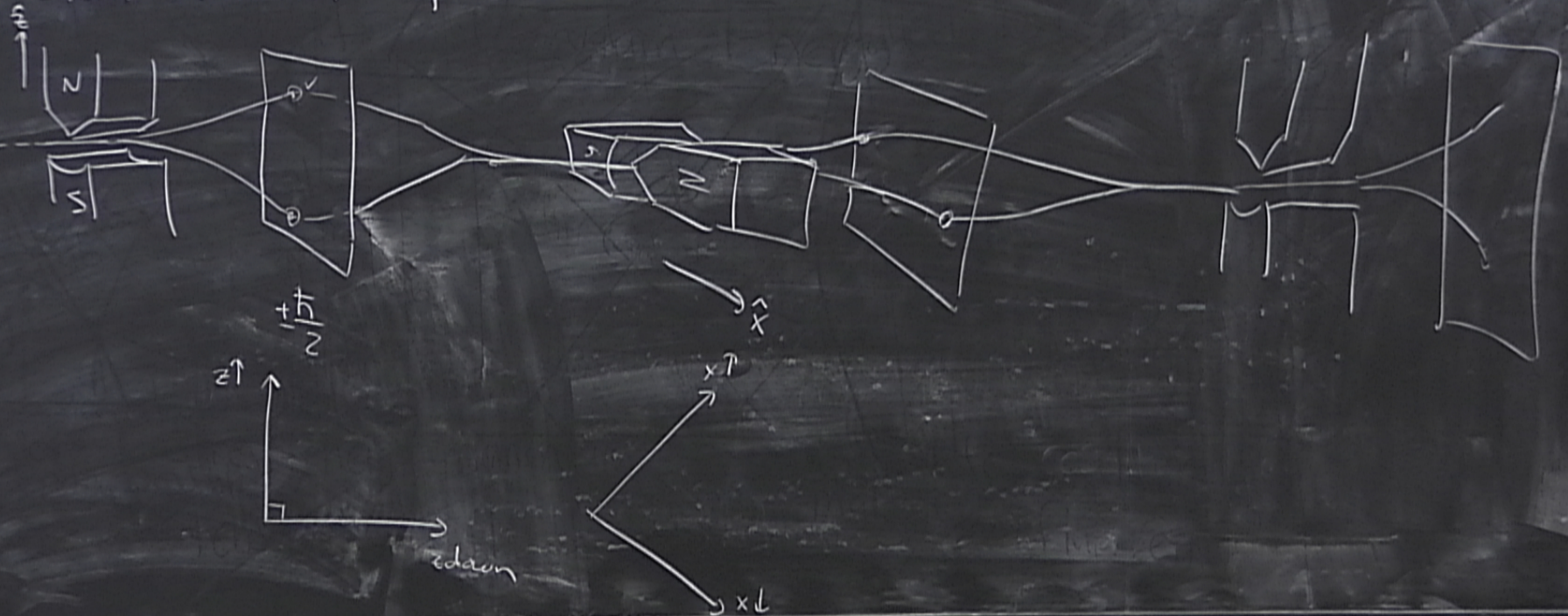
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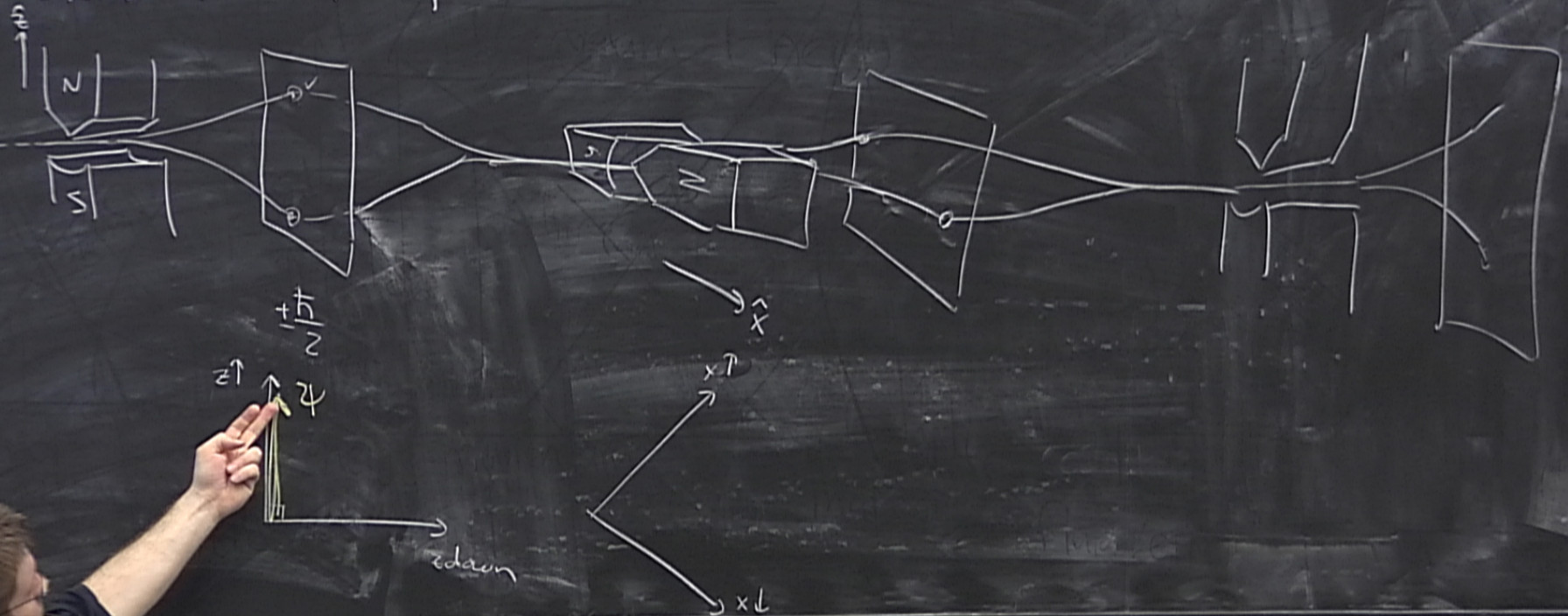
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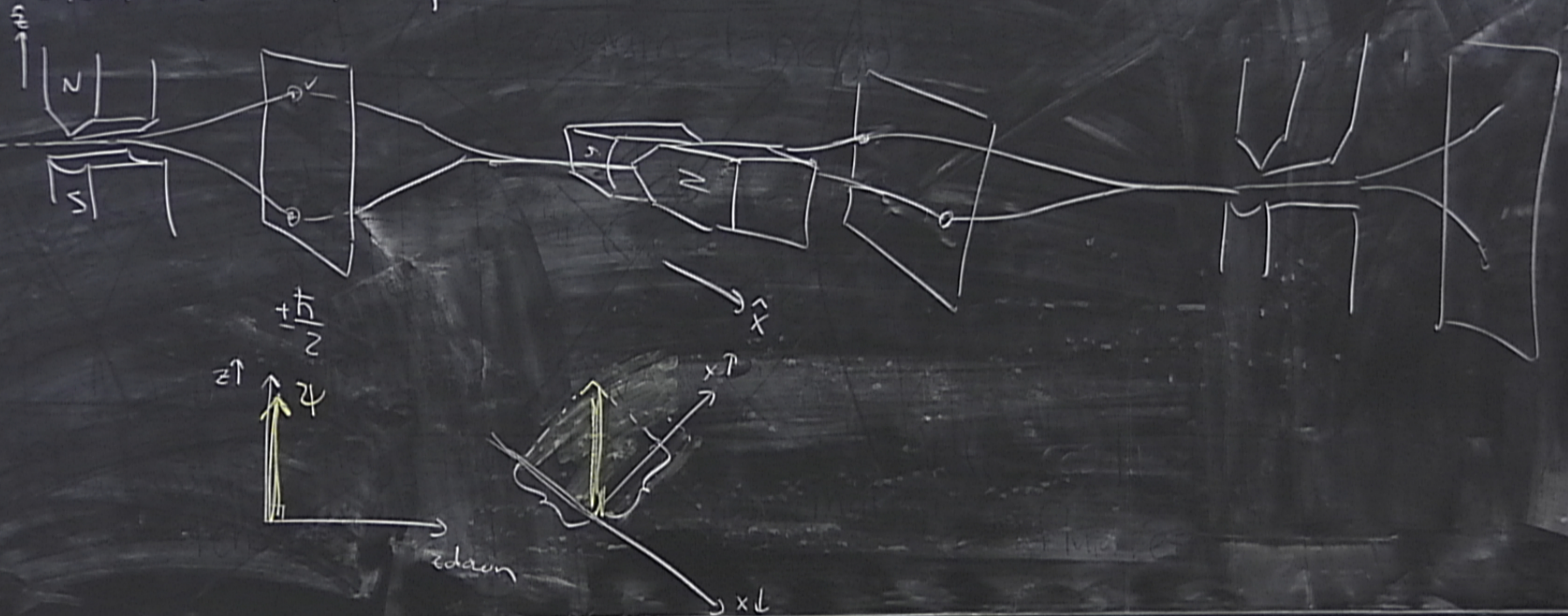
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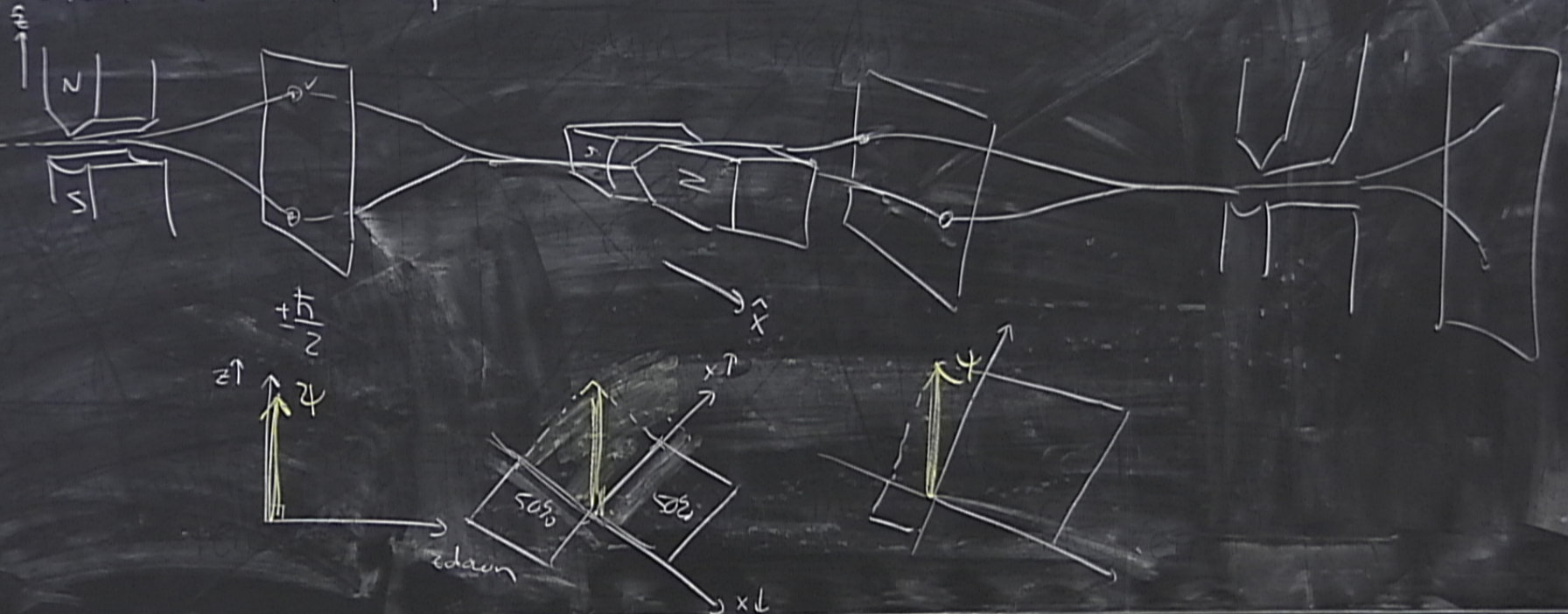
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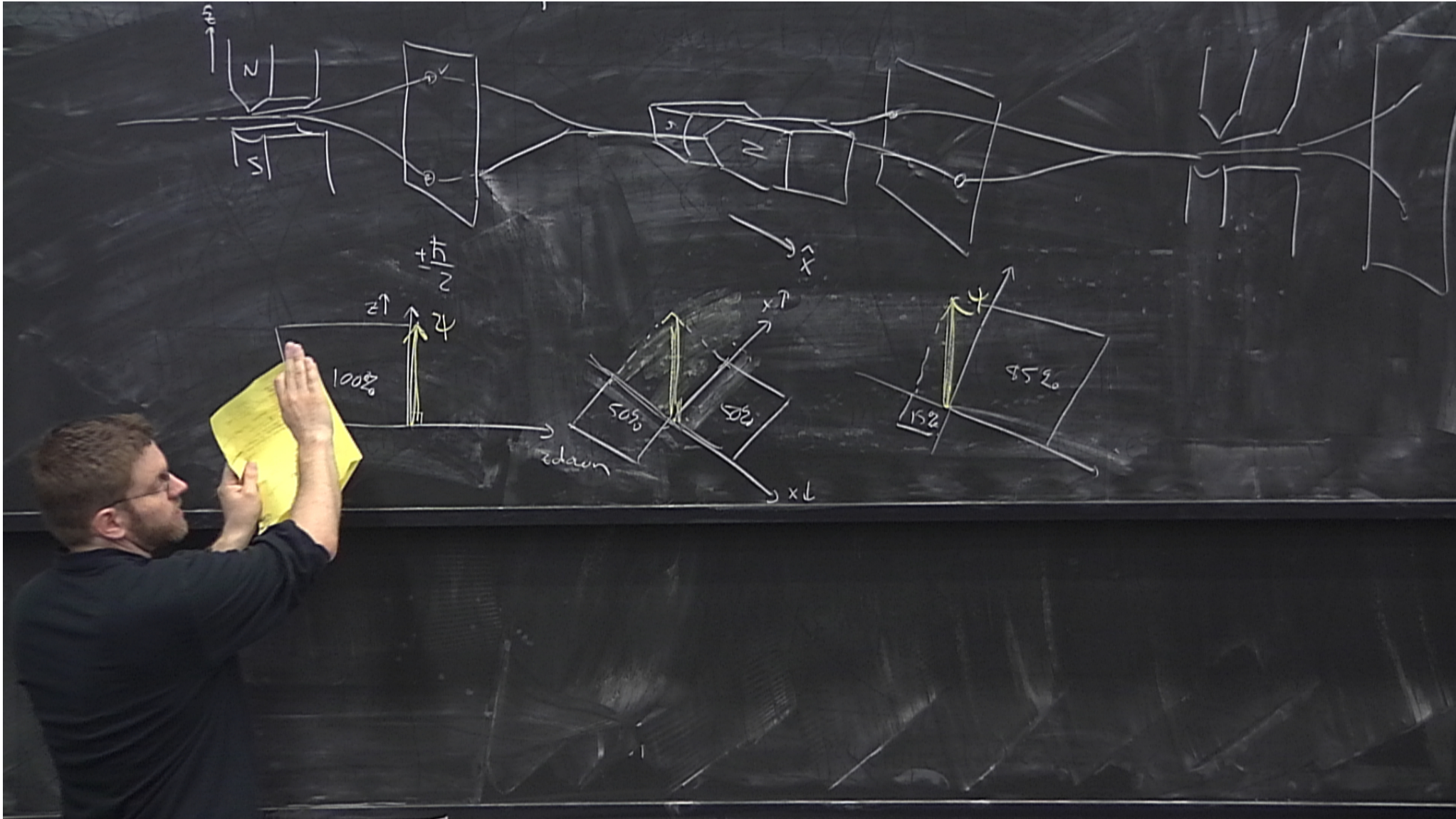


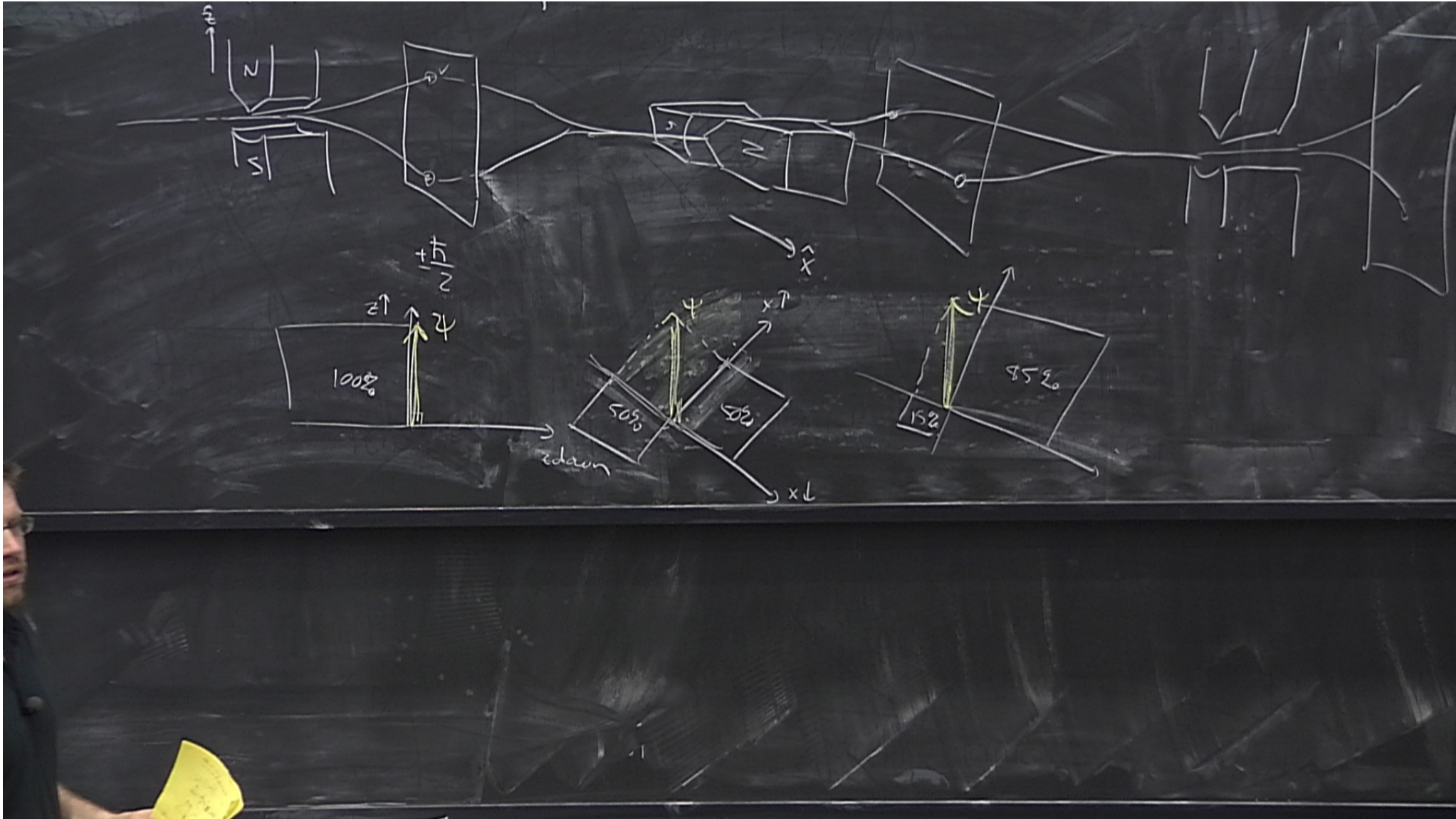
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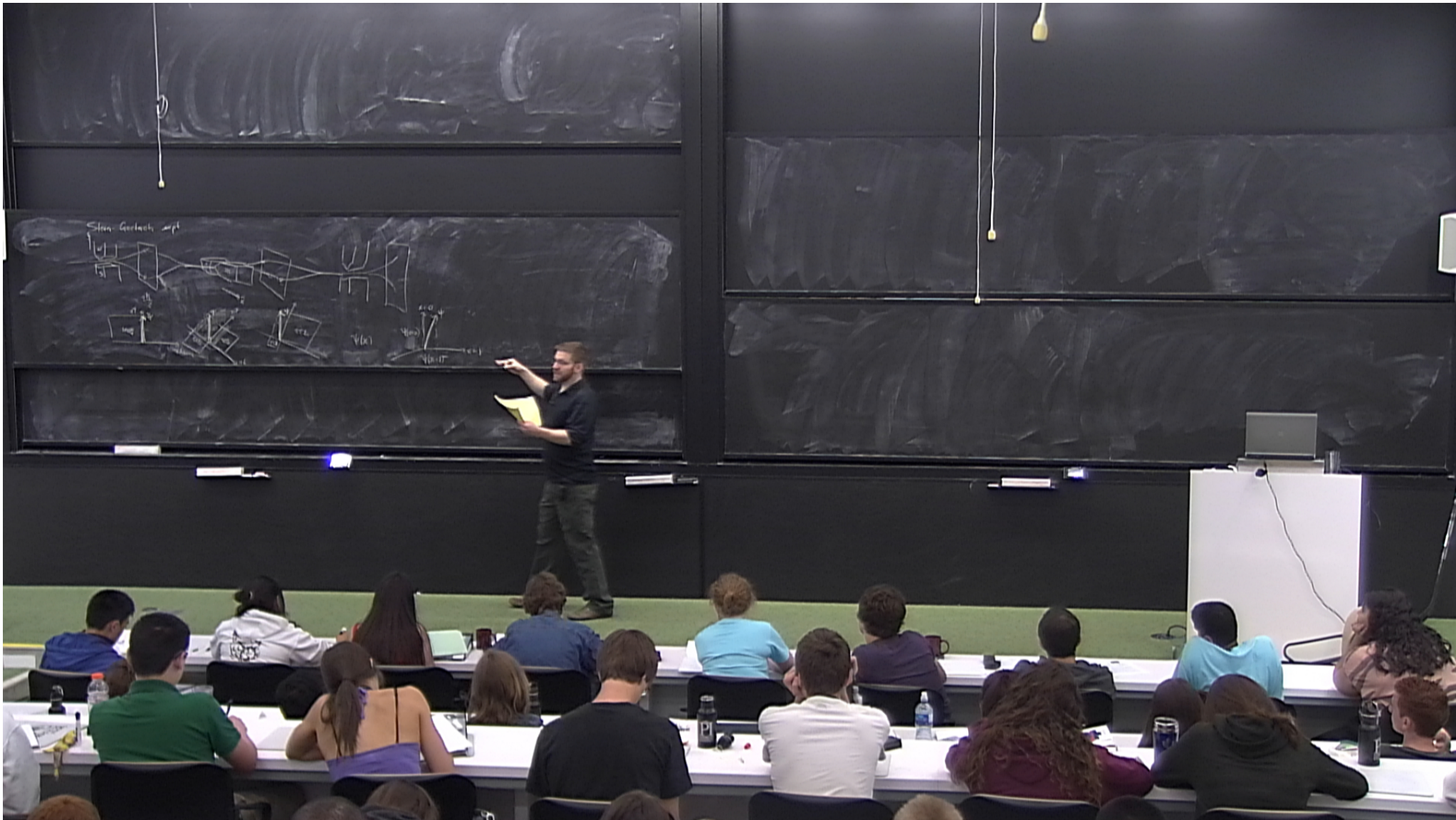
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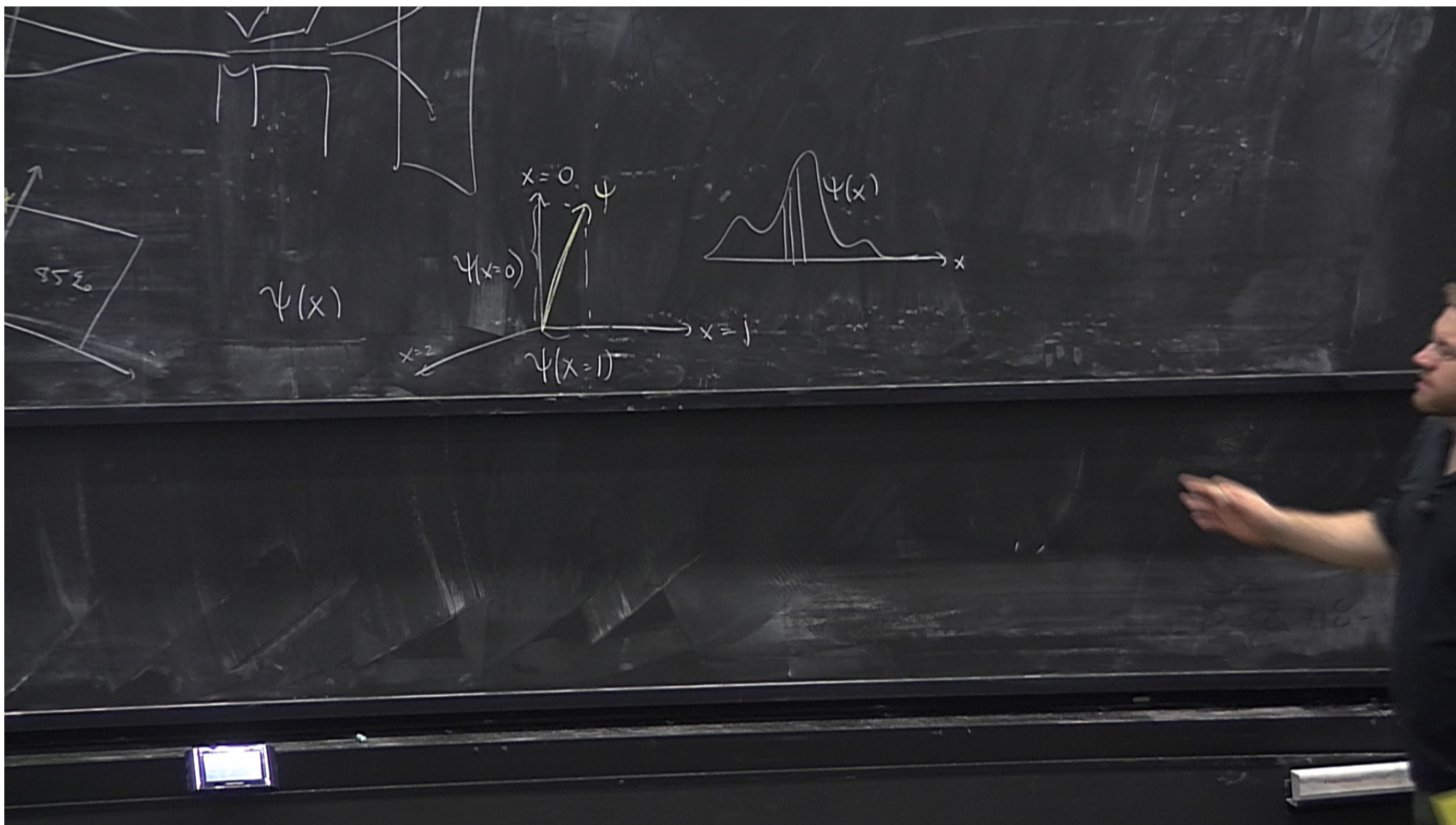












Orthodox postulates

①

Orthodox postulates

① ψ is in 1-to-1 correspondence with the physical state of the system

Orthodox postulates

- ① Ψ is in 1-to-1 correspondence with the physical state
- ② Evolution of Ψ (when system is isolated) is deterministic

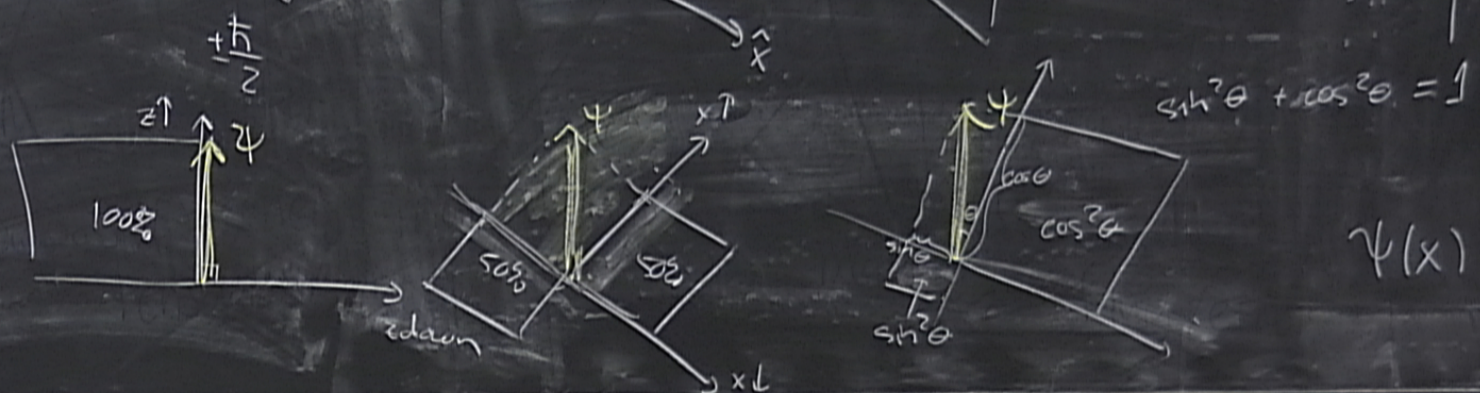
postulates

is in 1-to-1 correspondence with the physical state of the system
evolution of Ψ (when system is isolated) is deterministic and continuous

physical state of the system
deterministic and continuous (unitary evolution)

Orthogonal states

- ① ψ is in 1-to-1 correspondence with the physical state
- Evolution of ψ (when system is isolated) is deterministic
- ③ ④ If basis $\{\phi_k\}$ is measured on ψ , $\text{Prob}(k)$



② If basis $\{\phi_k\}$ is measured on ψ , $\text{Prob}(k) = |\psi \cdot \phi_k|^2$

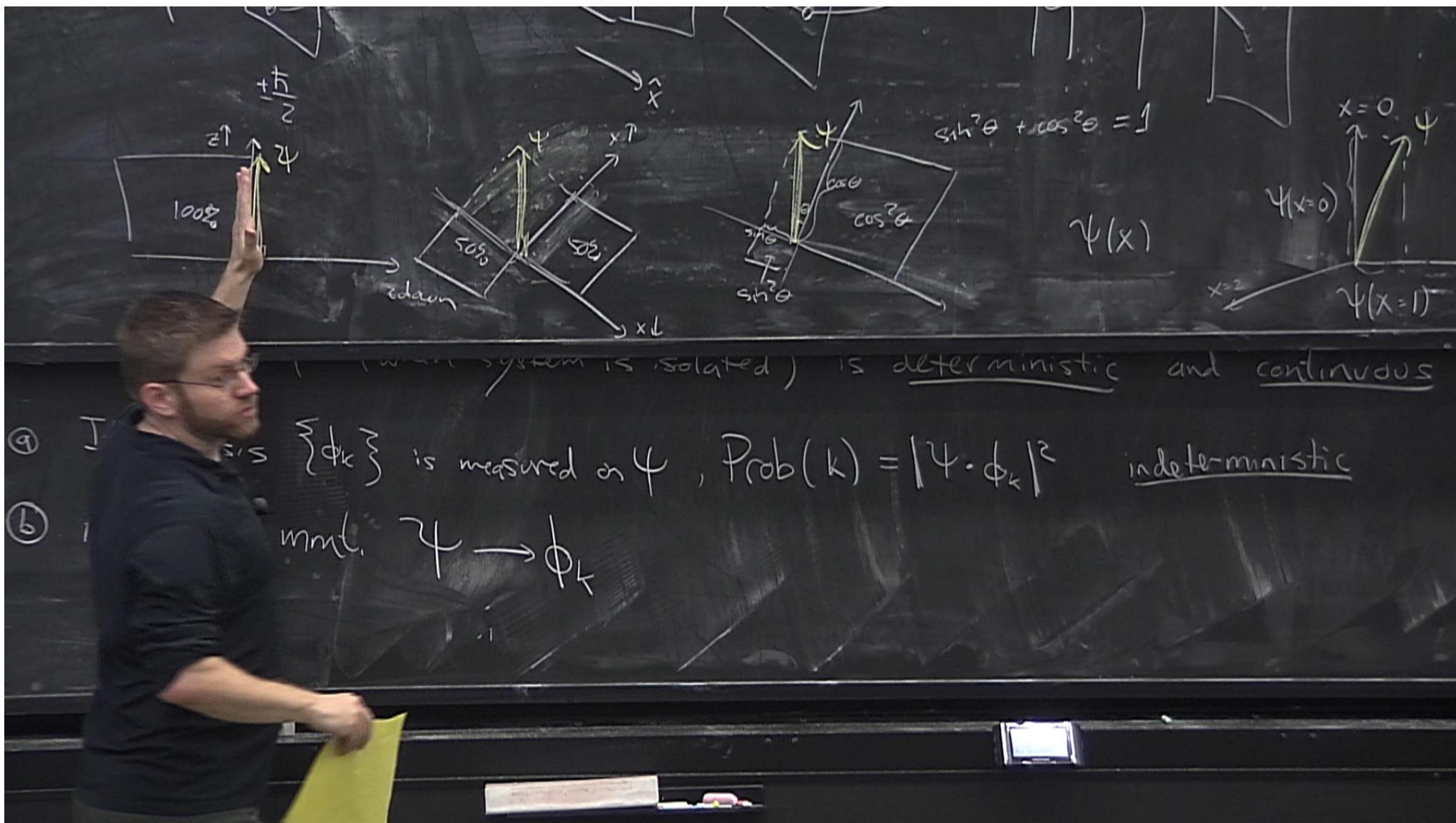
Orthodox postulates

- ① ψ is in 1-to-1 correspondence with the physical state of the system
- ② Evolution of ψ (when system is isolated) is deterministic and
- ③ ④ If basis $\{\phi_k\}$ is measured on ψ , $\text{Prob}(k) = |\psi \cdot \phi_k|^2$ independent of time

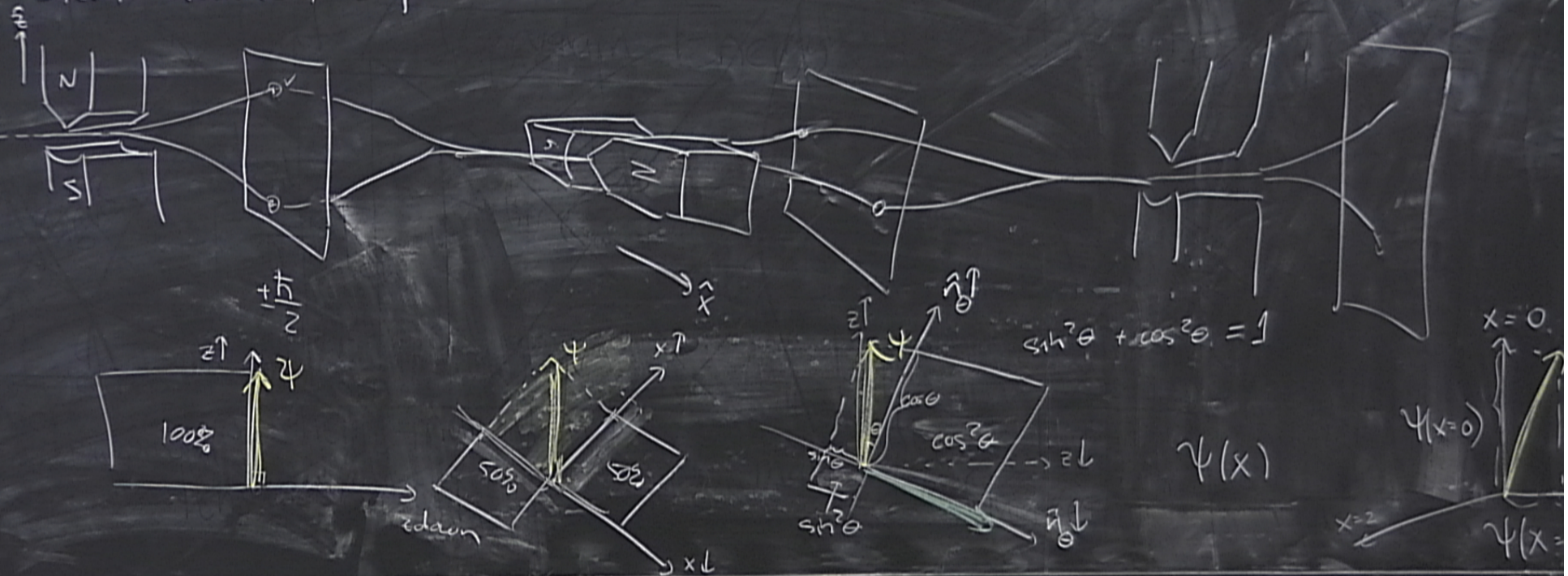
dependence with the physical state of the system
(is isolated) is deterministic and continuous (unitary evolution)
on ψ , $\text{Prob}(k) = |\psi \cdot \phi_k|^2$ indeterministic

Orthodox postulates

- ① Ψ is in 1-to-1 correspondence with the physical state
- ② Evolution of Ψ (when system is isolated) is deterministic
- ③ a If basis $\{\phi_k\}$ is measured on Ψ , $\text{Prob}(k) = |\langle \phi_k | \Psi \rangle|^2$ is the probability of outcome k
b After the mmt. $\Psi \rightarrow \phi_k$



Stern-Gerlach expt.



(quantum system is isolated) is deterministic and continuous

- ⑨ If basis $\{\phi_k\}$ is measured on ψ , $\text{Prob}(k) = |\psi \cdot \phi_k|^2$ indeterministic
 After the mmt. $\psi \rightarrow \phi_k$

Orthodox postulates

- ① Ψ is in 1-to-1 correspondence with the physical state of the system
- ② Evolution of Ψ (when system is isolated) is deterministic and continuous
- ③ If basis $\{\phi_k\}$ is measured on Ψ , $\text{Prob}(k) = |\Psi \cdot \phi_k|^2$ indeterministic
- ④ After the mmt. $\Psi \rightarrow \phi_k$ discontinuous

Inconsistencies

mut externally
system evolves indeterministically

mut internally
system evolves deterministically

Inconsistencies

mut externally

system evolves indeterministically

- discontinuous

mut internally

system evolves deterministically

continuous

Linearity of unitary evolution

Inconsistencies

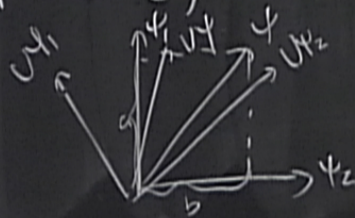
not externally
system evolves indeterministically
discontinuous

not internally

system evolves deterministically
continuous

Linearity of unitary evolution

$$U(a\psi_1 + b\psi_2) = aU\psi_1 + bU\psi_2$$



Inconsistencies

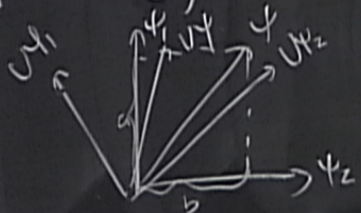
not externally
 system evolves indeterministically
 discontinuous

$$|\psi\rangle = a|z\uparrow\rangle + b|z\downarrow\rangle \longrightarrow \begin{matrix} |z\uparrow\rangle & \text{w/ prob. } |a|^2 \\ |z\downarrow\rangle & \dots \dots |b|^2 \end{matrix}$$

not internally
 system evolves deterministically
 continuous

Linearity of unitary evolution

$$U(a\psi_1 + b\psi_2) = aU\psi_1 + bU\psi_2$$



$$1) \text{ w/ prob } |a|^2$$

$$2) \text{ } |b|^2$$

$$|1\rangle |ready\rangle \rightarrow U(|1\rangle |ready\rangle) = |1\rangle |up\rangle$$

really
evolves deterministically
continuous

$$\begin{array}{l}
 1) \text{ w/ prob } |a|^2 \\
 2) \text{ .. } |b|^2
 \end{array}$$

$$\begin{aligned}
 | \uparrow \rangle | \text{"ready"} \rangle &\rightarrow U(| \uparrow \rangle | \text{"ready"} \rangle) = | \uparrow \rangle | \text{"up"} \rangle \\
 | \downarrow \rangle | \text{"ready"} \rangle &\rightarrow U(| \downarrow \rangle | \text{"ready"} \rangle) = | \downarrow \rangle | \text{"down"} \rangle \\
 (a| \uparrow \rangle + b| \downarrow \rangle) | \text{"ready"} \rangle &\rightarrow U(a| \uparrow \rangle | \text{"ready"} \rangle + b| \downarrow \rangle | \text{"ready"} \rangle) \\
 &= a| \uparrow \rangle | \text{"up"} \rangle + b| \downarrow \rangle | \text{"down"} \rangle
 \end{aligned}$$

evolves deterministically
 continuously

physical state of the system

deterministic and continuous (unitary evolution)

$|\psi\rangle = \sum_k \phi_k |k\rangle$ indeterministic

Deny② - collapse theories

Deny① → hidden variable theories

Deny③ Many worlds

physical state of the system

deterministic and continuous (unitary evolution)

$$\Phi_k / 2$$

indeterministic



Deny ② - collapse theories

Deny ① → hidden variable theories

Deny ③ Many worlds

→ Ψ -ontic
 Ψ -epistemic