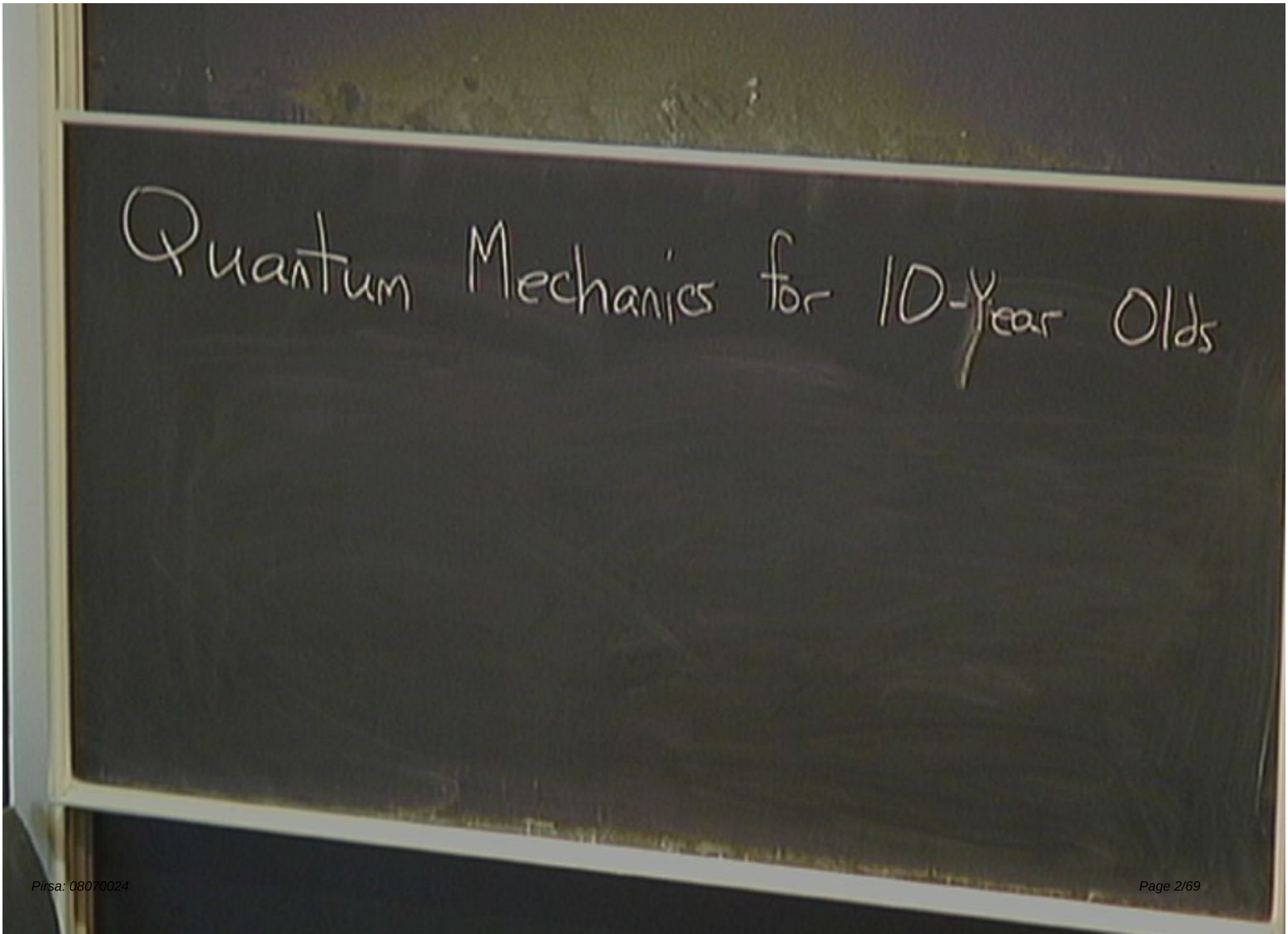
Title: Quantum Mechanics for 10-Year Olds

Date: Jul 07, 2008 10:30 AM

URL: http://pirsa.org/08070024

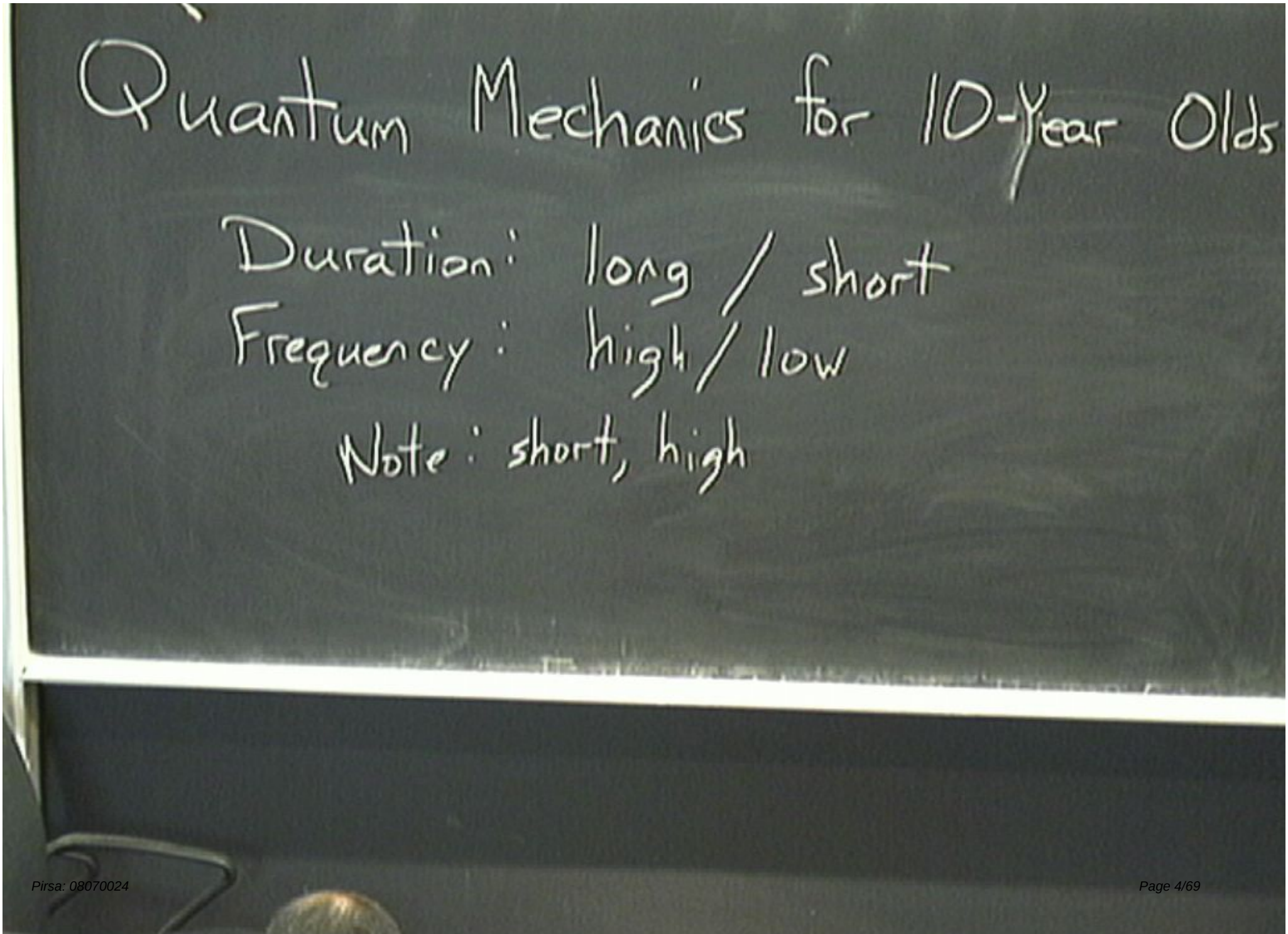
Abstract: The world as experienced by single atoms is radically different from the everyday world we, as gigantic humans, are used to: the laws of quantum mechanics replace the laws of classical physics. Because the quantum realm is alien from our daily experience, many common quantum effects are surprising and unintuitive. To understand the quantum world, it may be better to just start from scratch, as a child might, and develop intuition about the behavior of quantum objects by simply looking at a series of quantum examples rather than trying to analogize with classical physics. I will present a short introduction to quantum mechanics from this point of view, and make ties to current research in the field of quantum information.

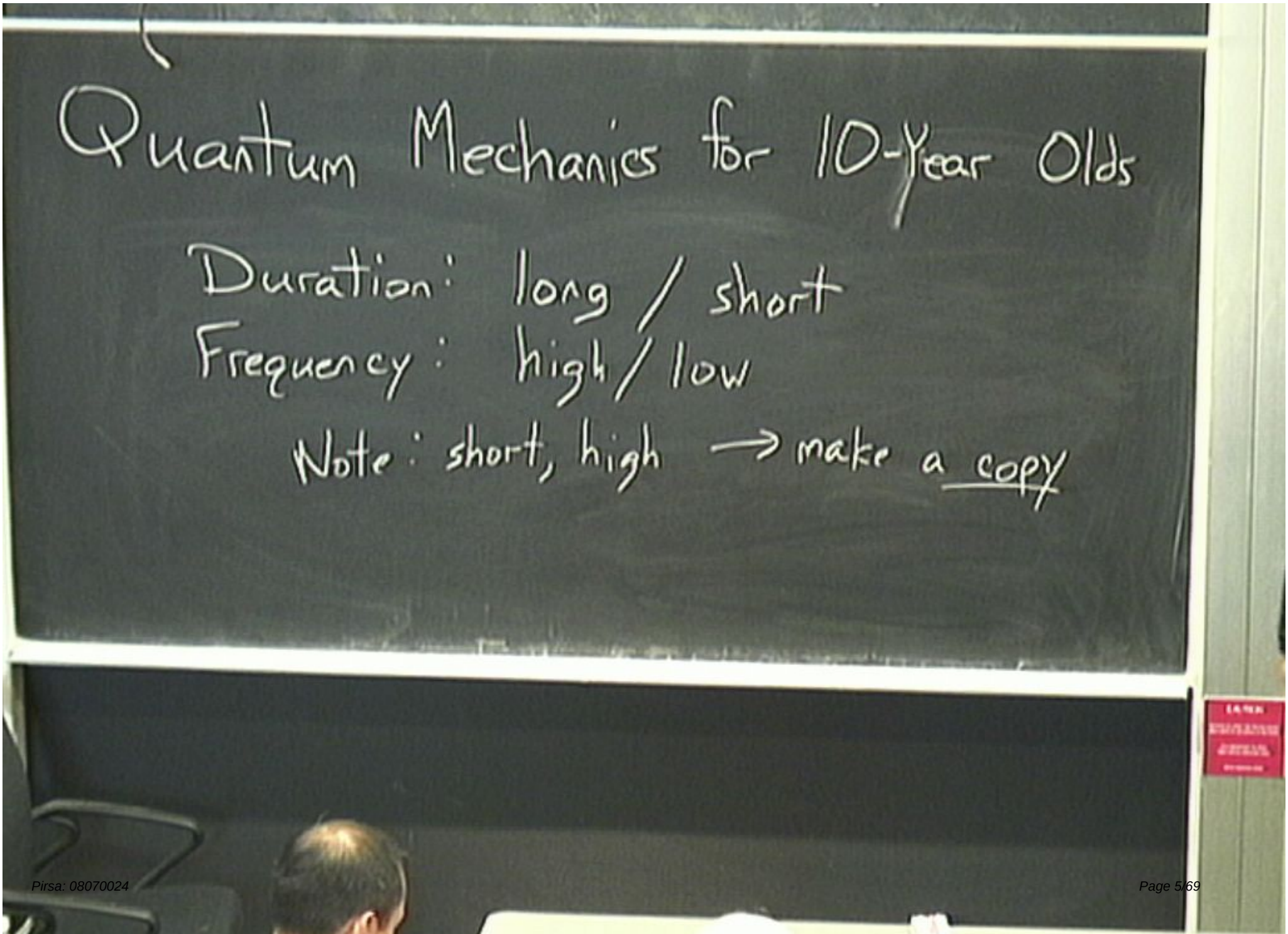

Quantum Mechanics for 10-Year Olds

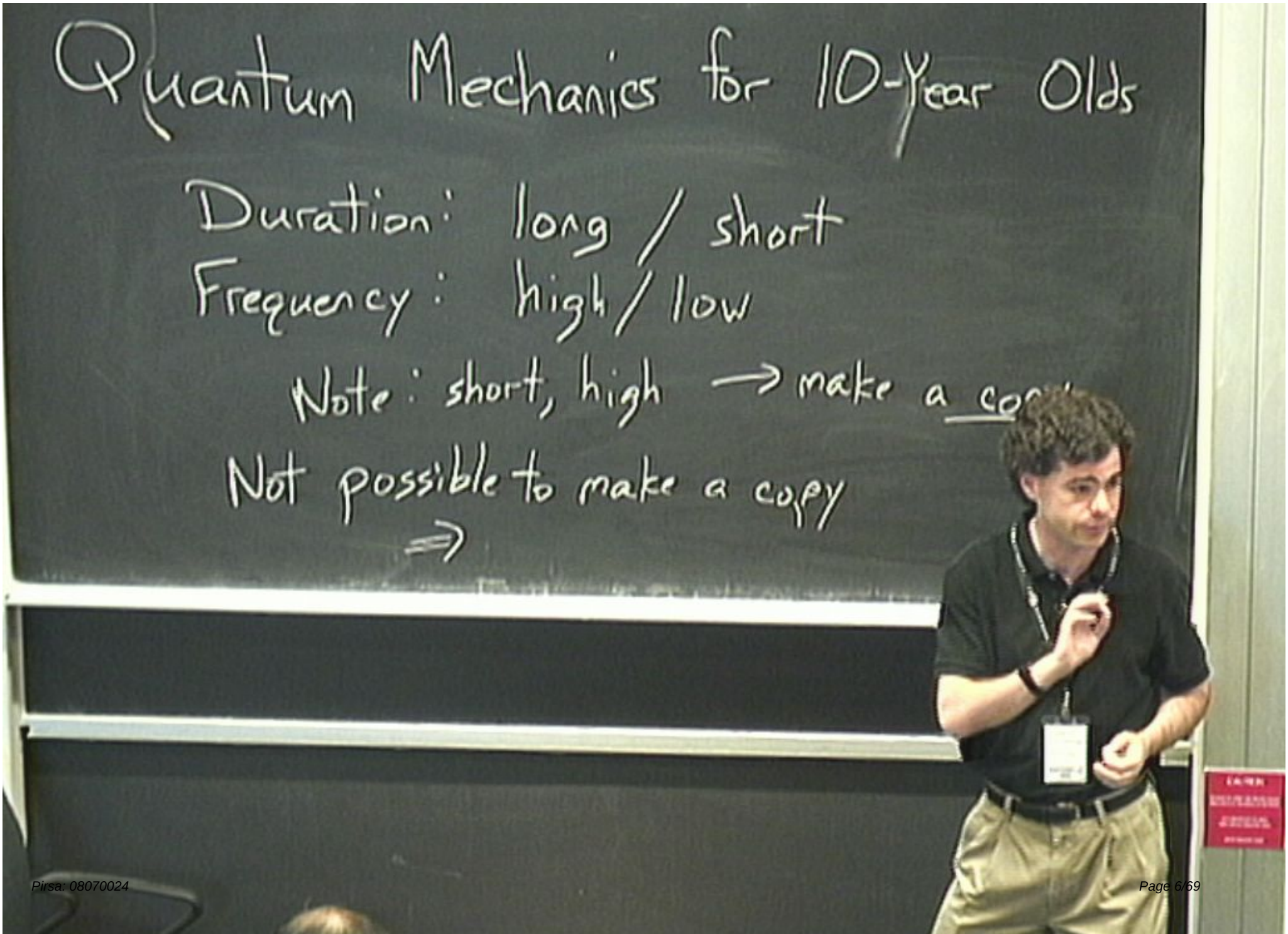
Quantum Mechanics for 10-Year Olds

Duration: long / short

Frequency: high / low


Quantum Mechanics for 10-Year Olds
Duration: long / short
Frequency: high / low
Note: short, high


Quantum Mechanics for 10-Year Olds
Duration: long / short
Frequency: high / low
Note: short, high → make a copy


Quantum Mechanics for 10-Year Olds
Duration: long / short
Frequency: high / low
Note: short, high → make a co
Not possible to make a copy
⇒

Quantum Mechanics for 10-Year Olds

Duration: long / short

Frequency: high / low

Note: short, high → make a copy

Not possible to make a copy

⇒ Cannot learn both properties

Can make copy ⇒

Can make copy $\Rightarrow$ Can learn both properties.

Can make copy $\Rightarrow$ Can learn both properties.

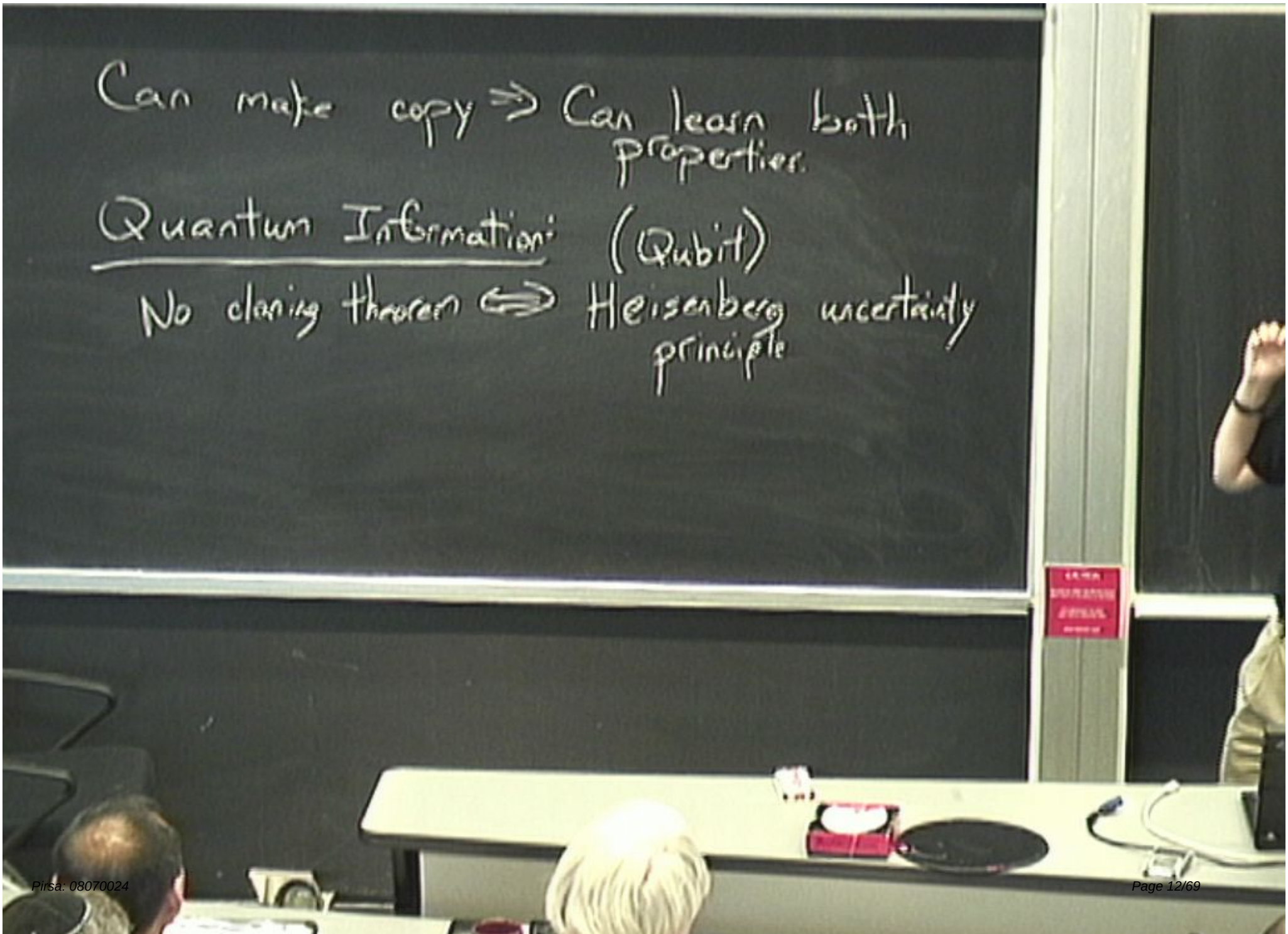
Quantum Information

No cloning theorem

Can make copy ⇒ Can learn both properties.

Quantum Information

No cloning theorem ⇔ Heisenberg uncertainty principle

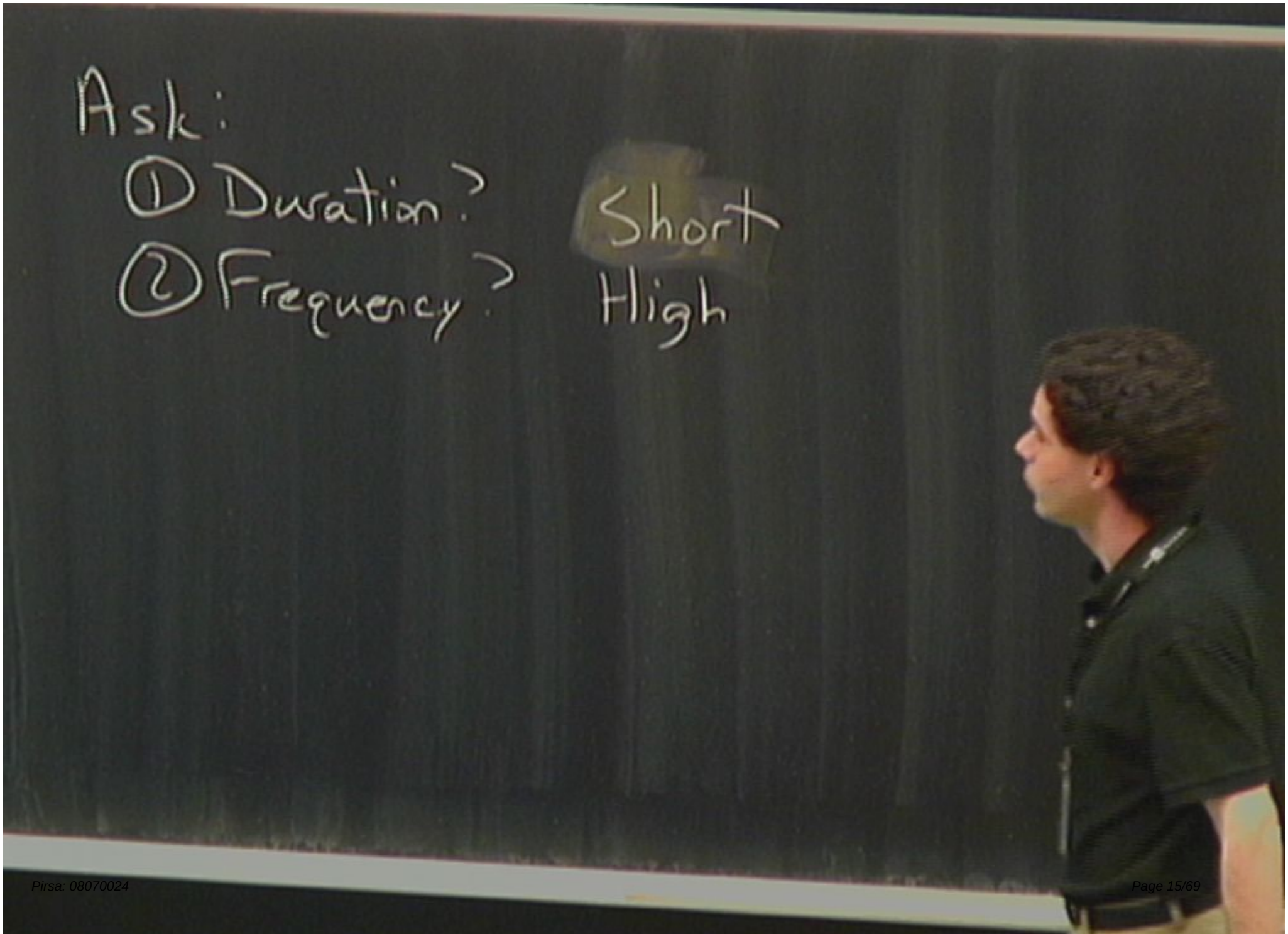

Can make copy ⇒ Can learn both properties.
Quantum Information: (Qubit)
No cloning theorem ⇔ Heisenberg uncertainty principle

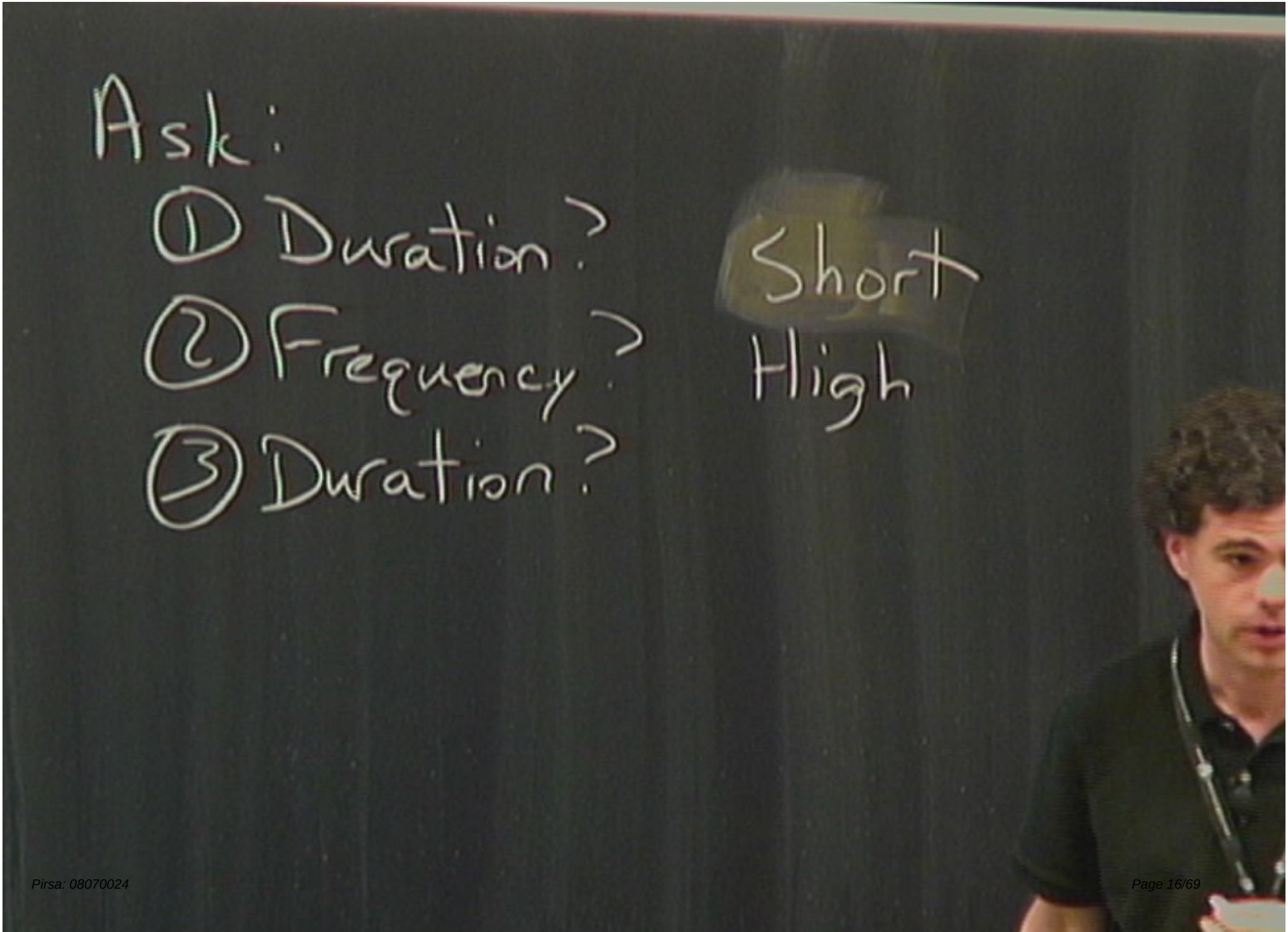
Can make copy $\Rightarrow$ Can learn both properties.

Quantum Information: (Qubit)

No cloning theorem $\Leftrightarrow$ Heisenberg uncertainty principle


Ask:
① Duration?
② Frequency?


Ask:
① Duration? Short
② Frequency? High

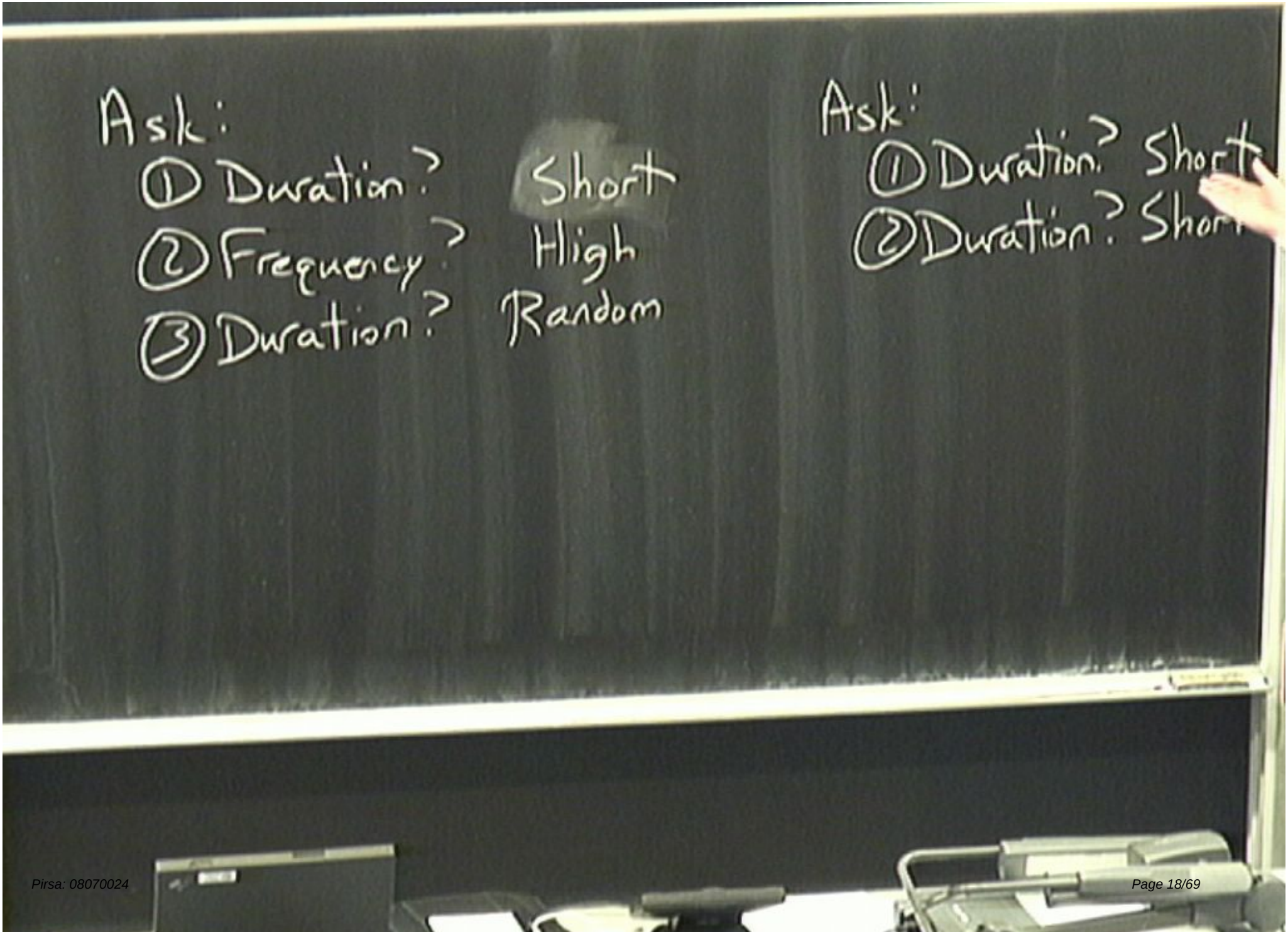

Ask:
① Duration?
② Frequency?
③ Duration?
Short
High

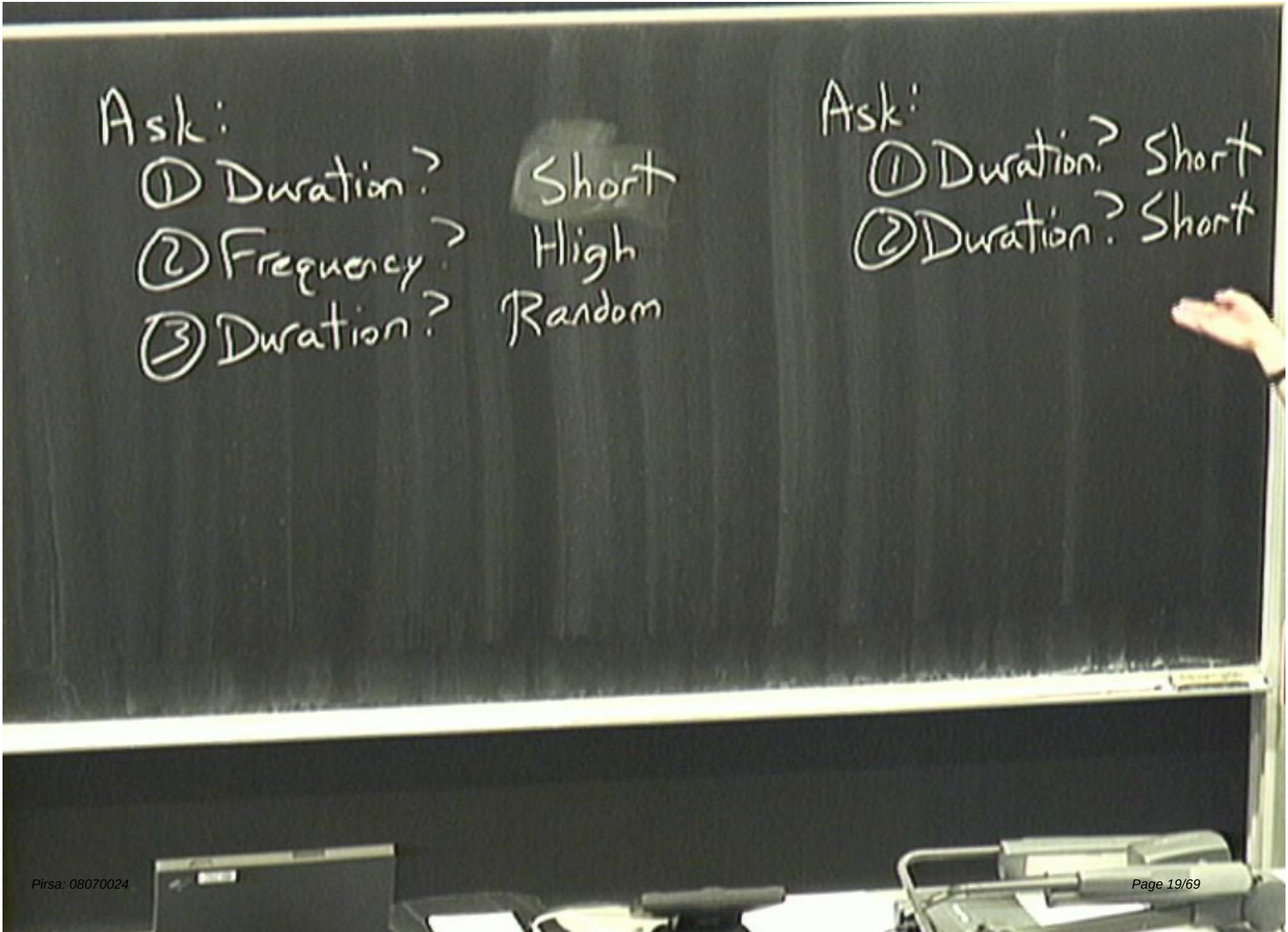
Ask:

① Duration? Short

② Frequency? High

③ Duration? Random


Ask:
① Duration? Short
② Frequency? High
③ Duration? Random
Ask:
① Duration? Short
② Duration? Short


Ask:
① Duration? Short
② Frequency? High
③ Duration? Random
Ask:
① Duration? Short
② Duration? Short

Ask:

① Duration? Short

② Frequency? High

③ Duration? Random

Superpositions:

Ask:

① Duration? Short

② Duration? Short

Ask:

① Duration? Short

② Frequency? High

③ Duration? Random

Ask:

① Duration? Short

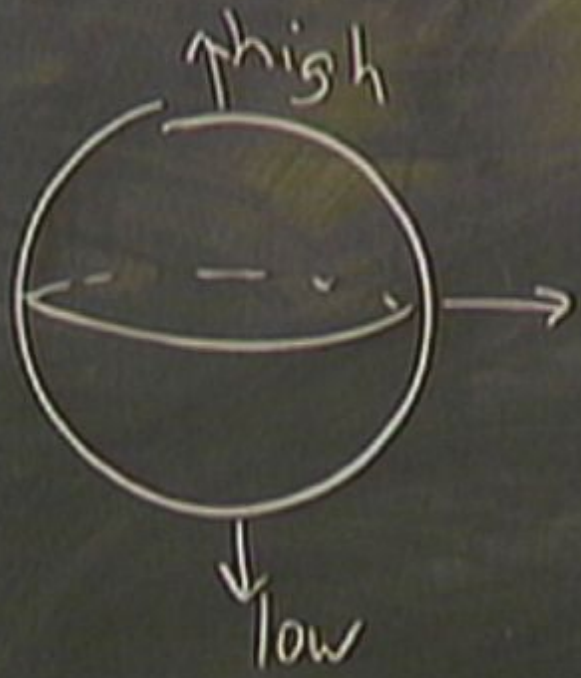
② Duration? Short

Superpositions: Can have any prob. of short vs. long or of high vs. low

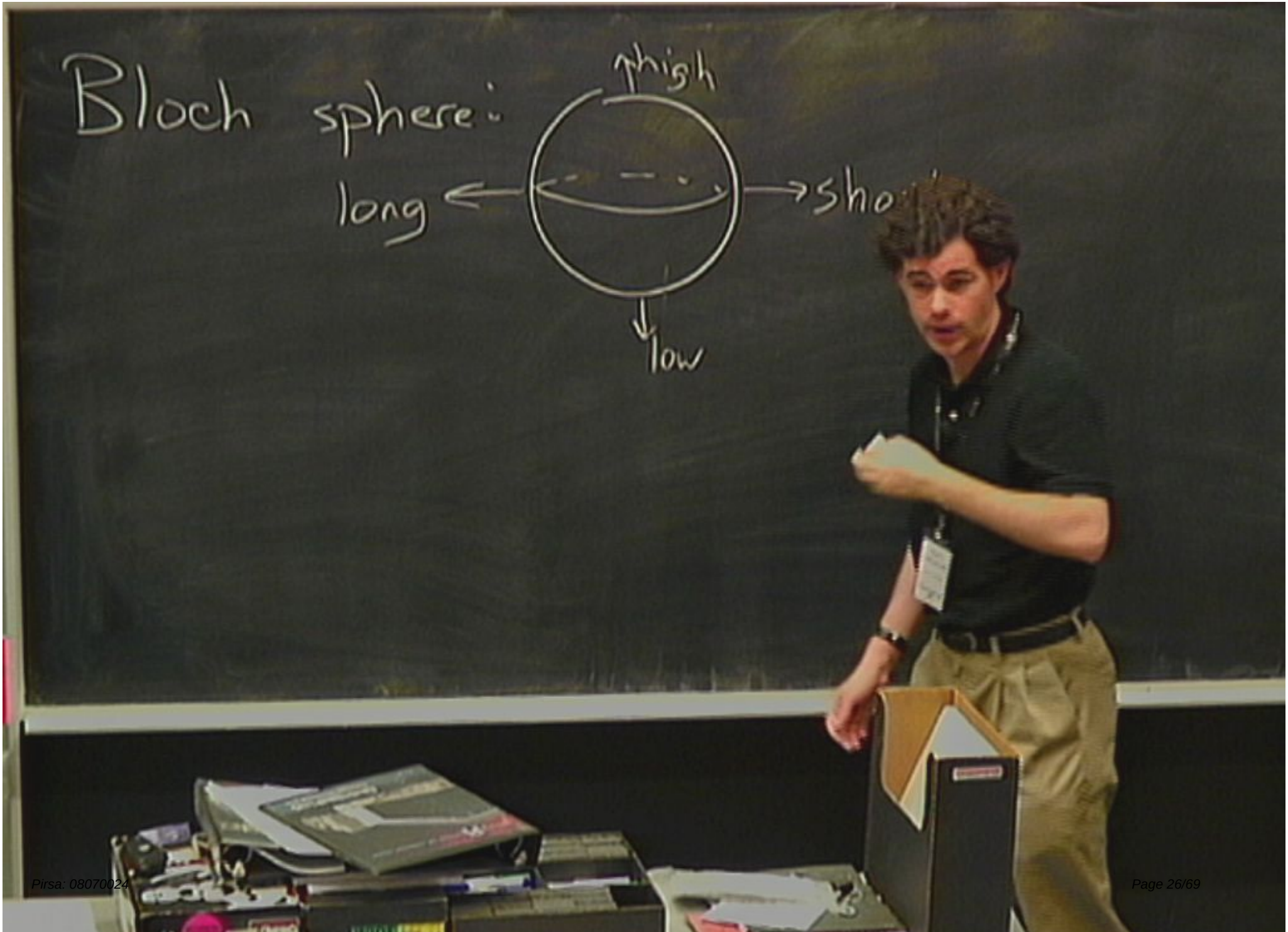
Bloch sphere:

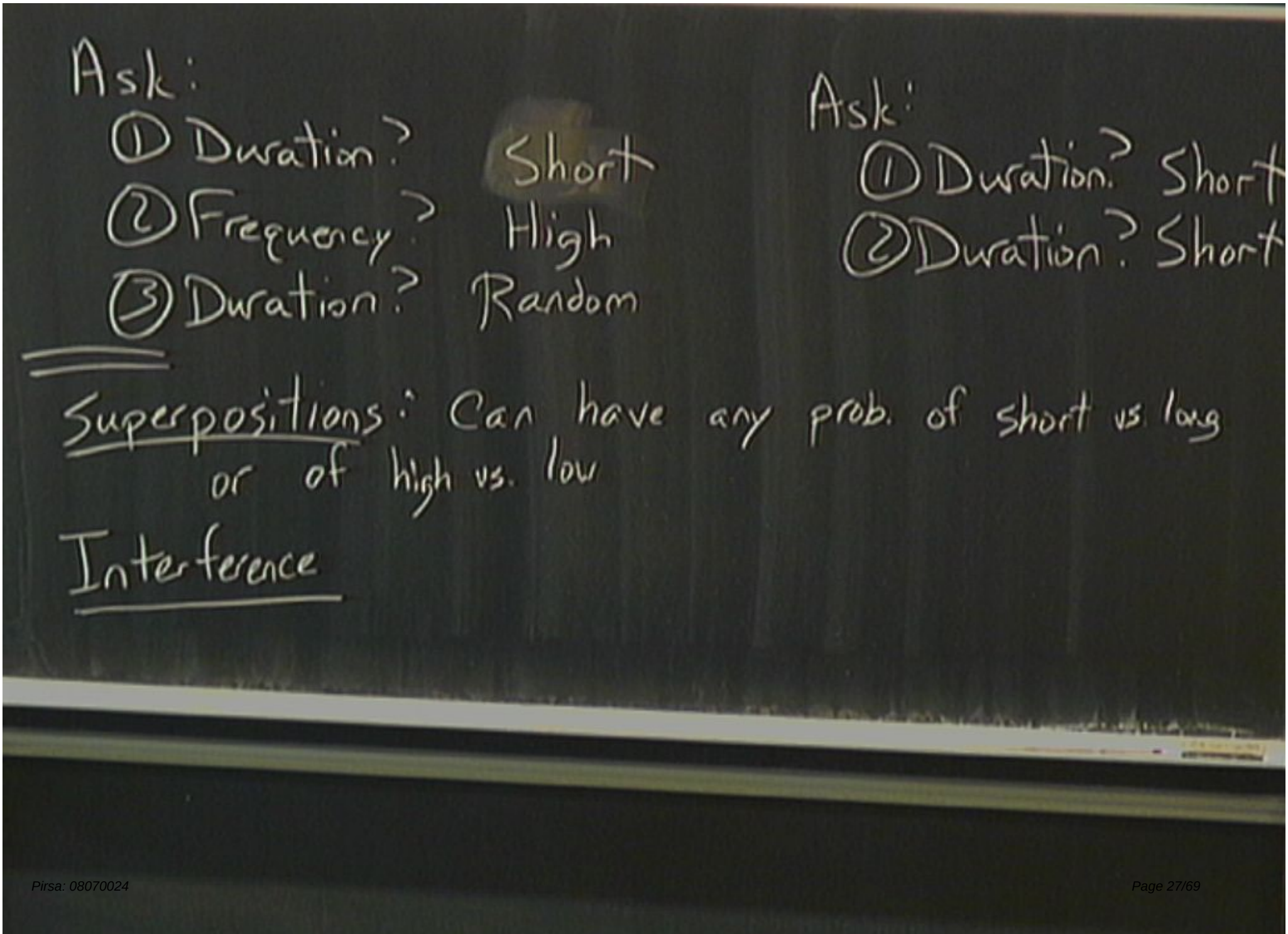
Bloch sphere:

Bloch sphere:




Bloch sphere:
high
long
short
low


Bloch sphere:
thigh
long
low


Ask:
① Duration? Short
② Frequency? High
③ Duration? Random
Ask:
① Duration? Short
② Duration? Short
Superpositions: Can have any prob. of short vs. long
or of high vs. low
Interference

Ask:

① Duration? Short

② Frequency? High

③ Duration? Random

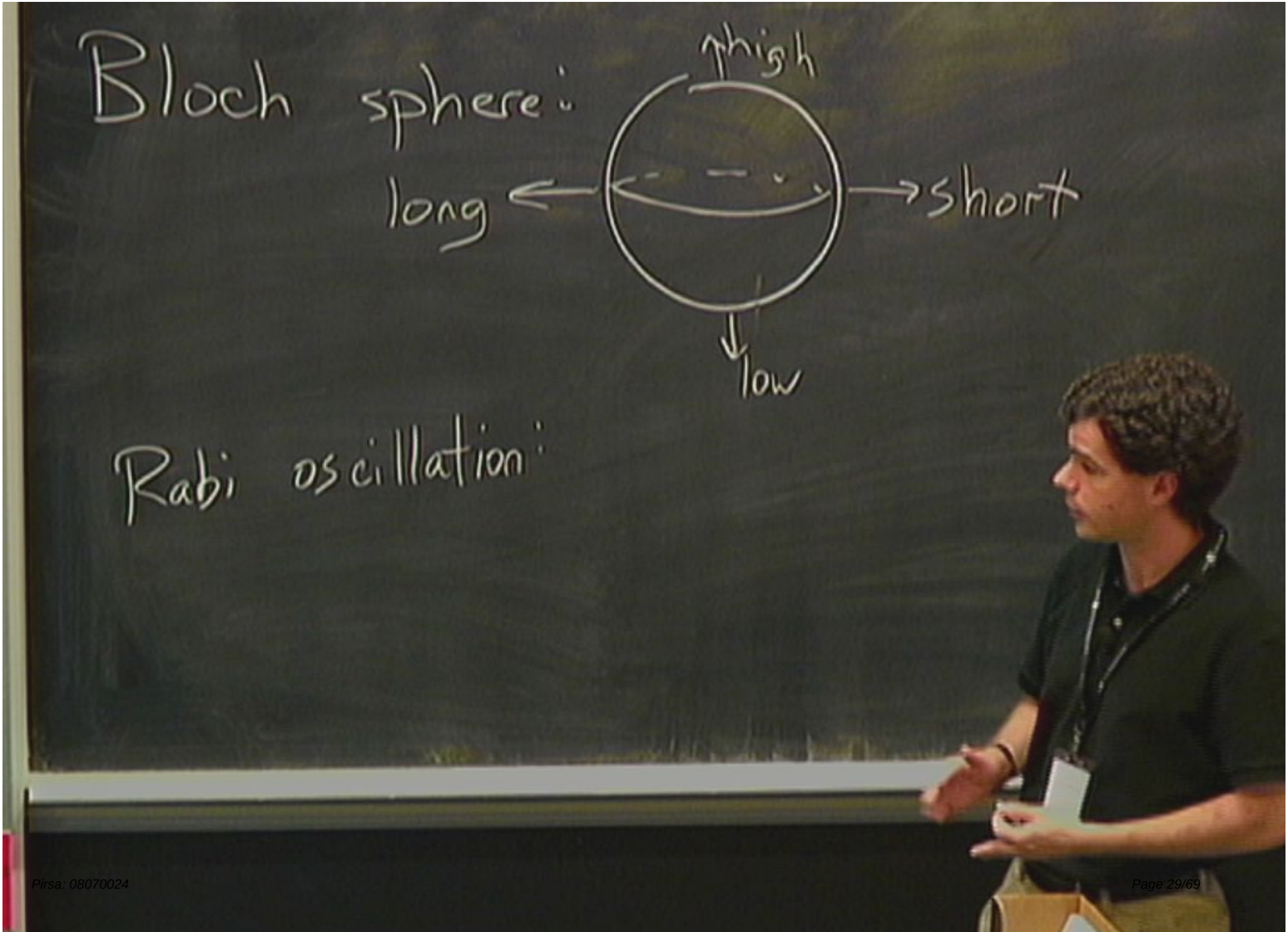
Ask:

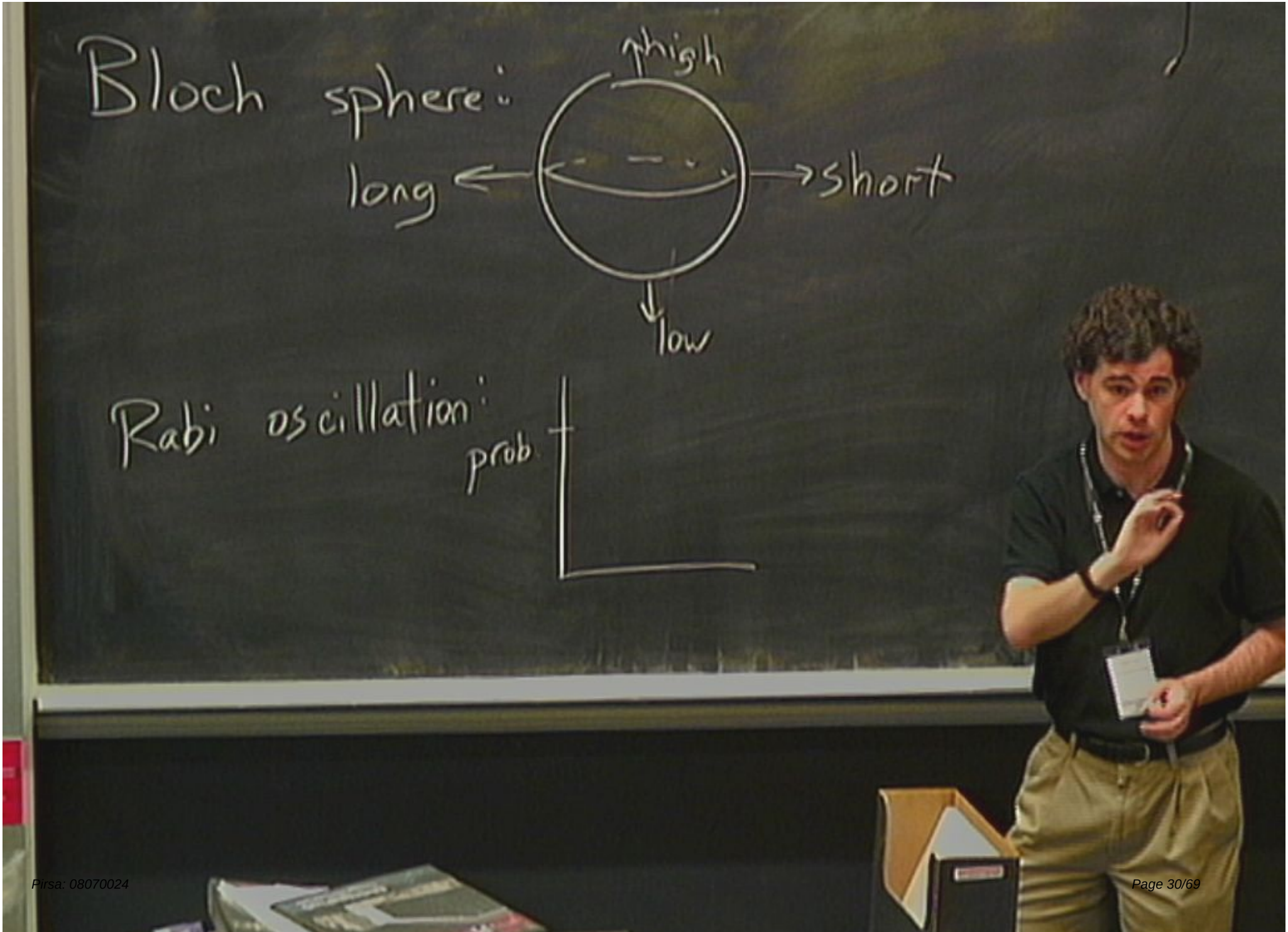
① Duration? Short

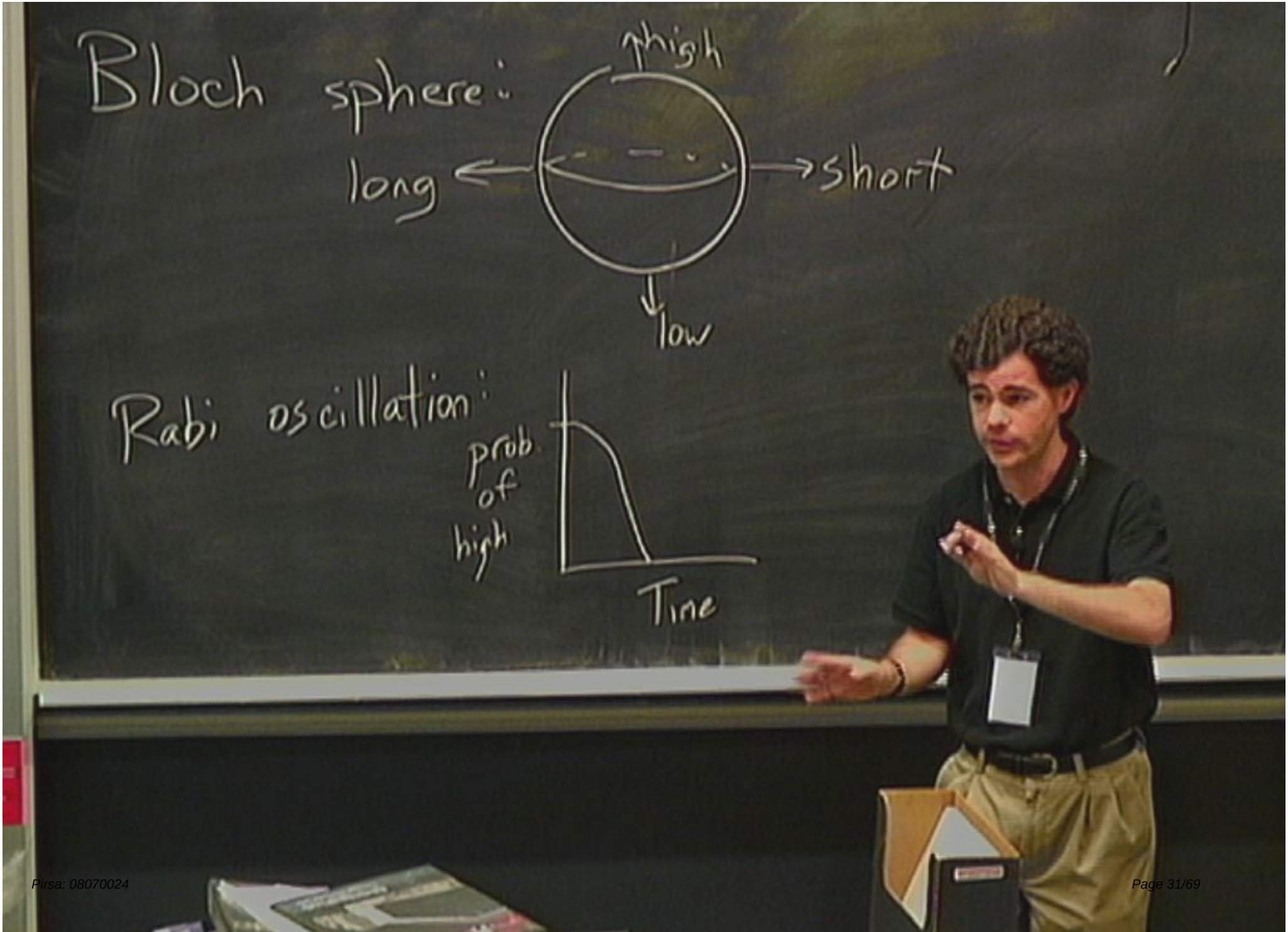
② Duration? Short

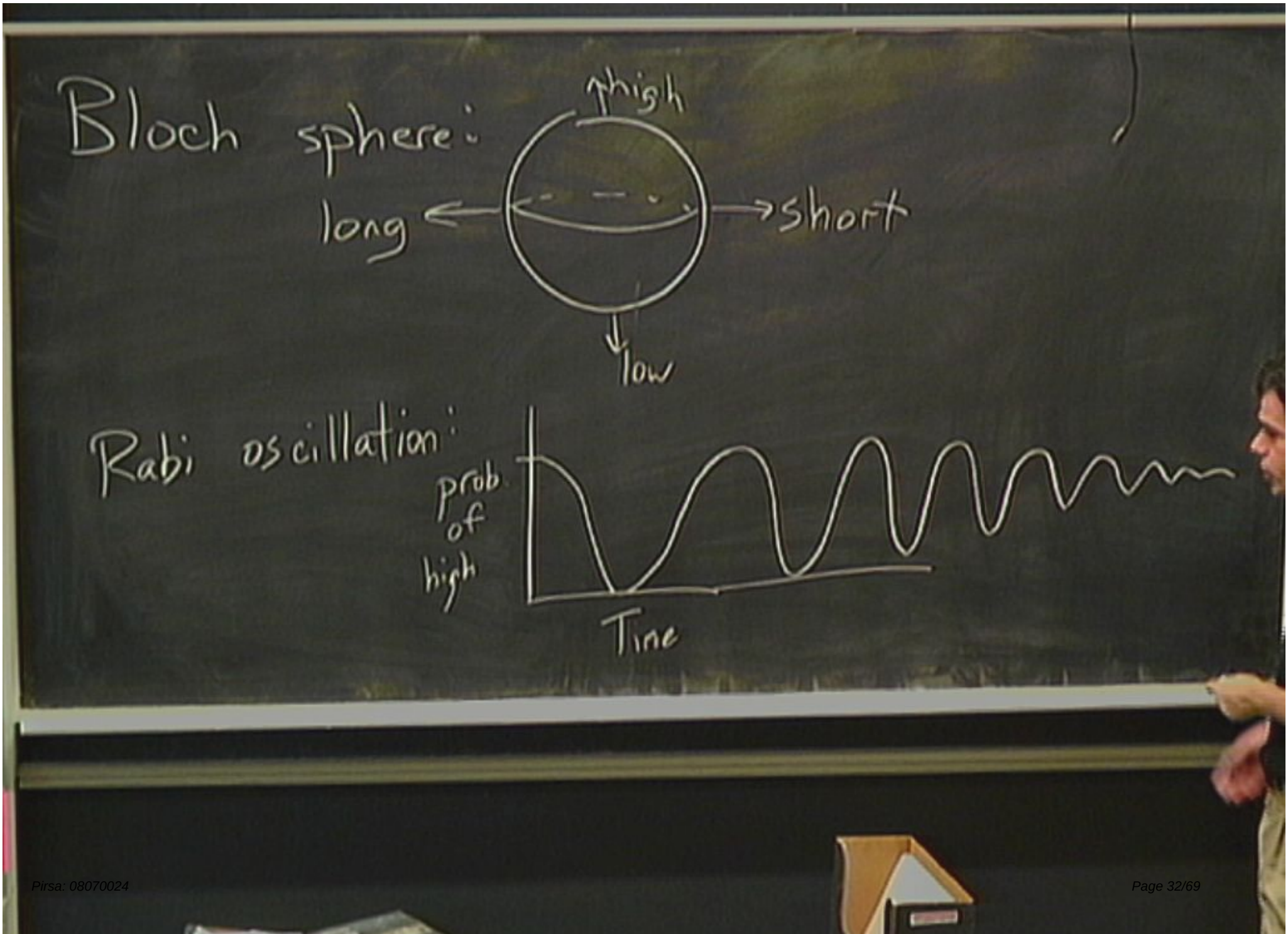
Superpositions: Can have any prob. of short vs. long or of high vs. low

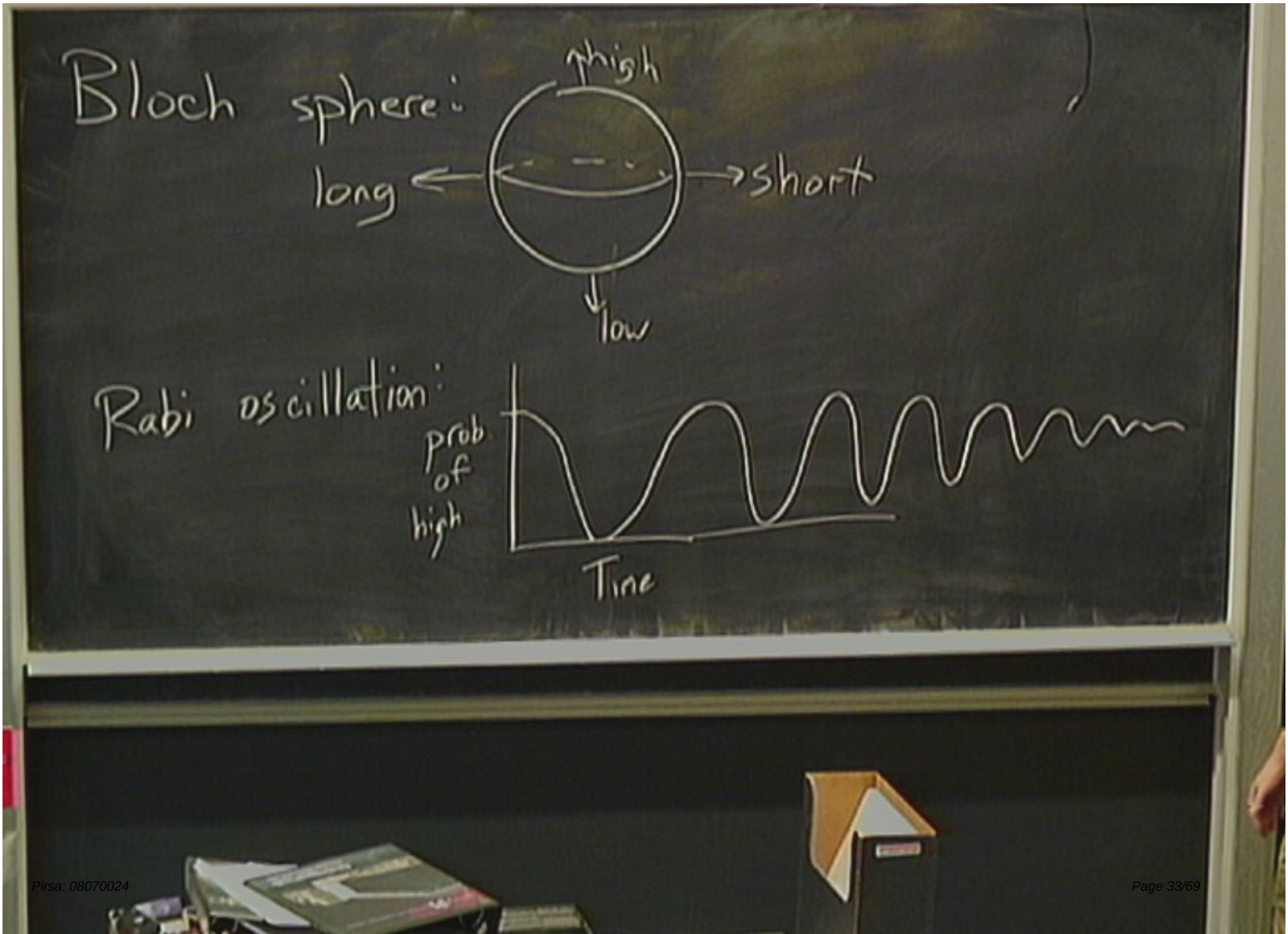
Interference: Interference of probabilities

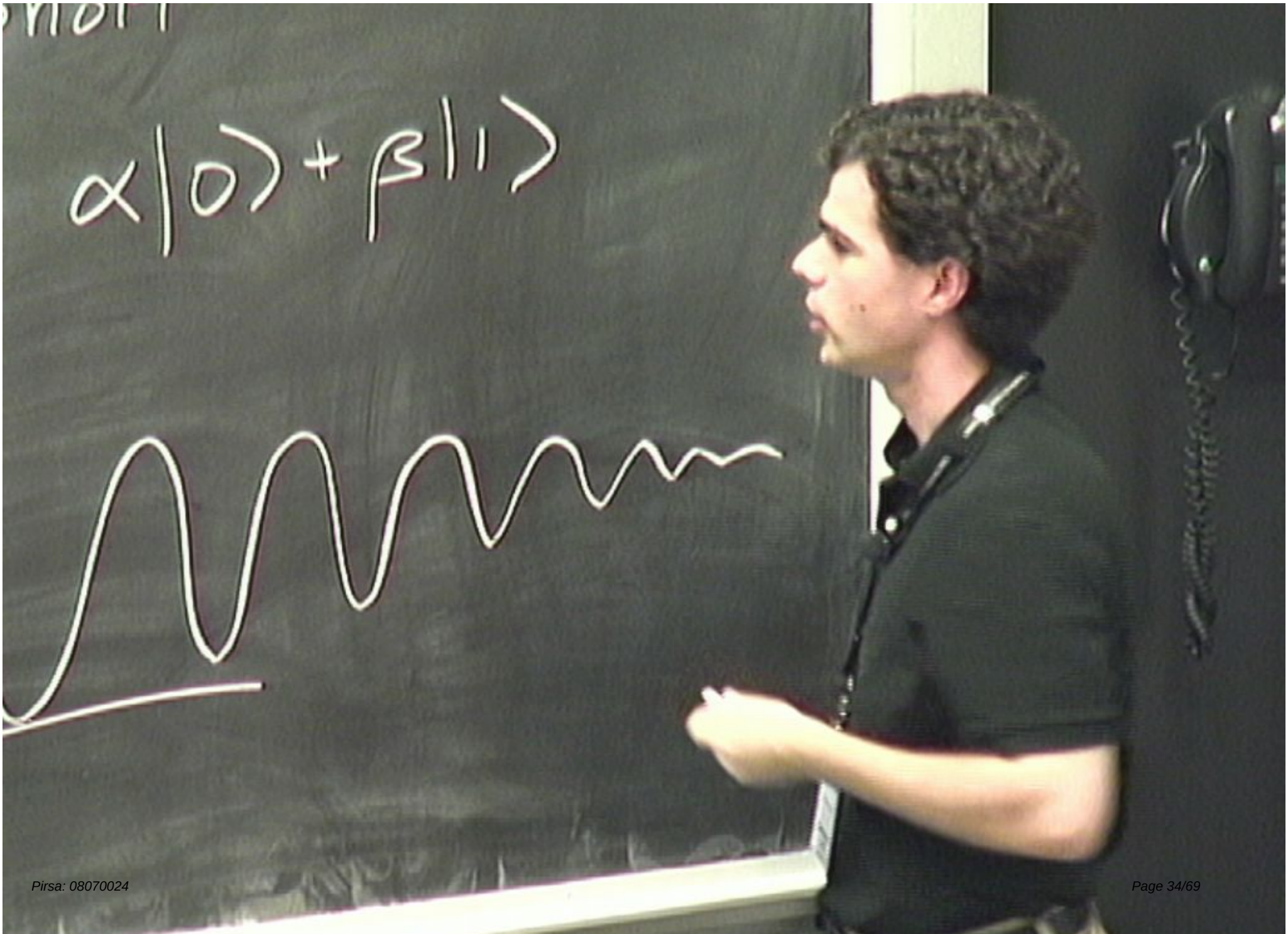

Bloch sphere:
high
long
short
low
Rabi oscillation:

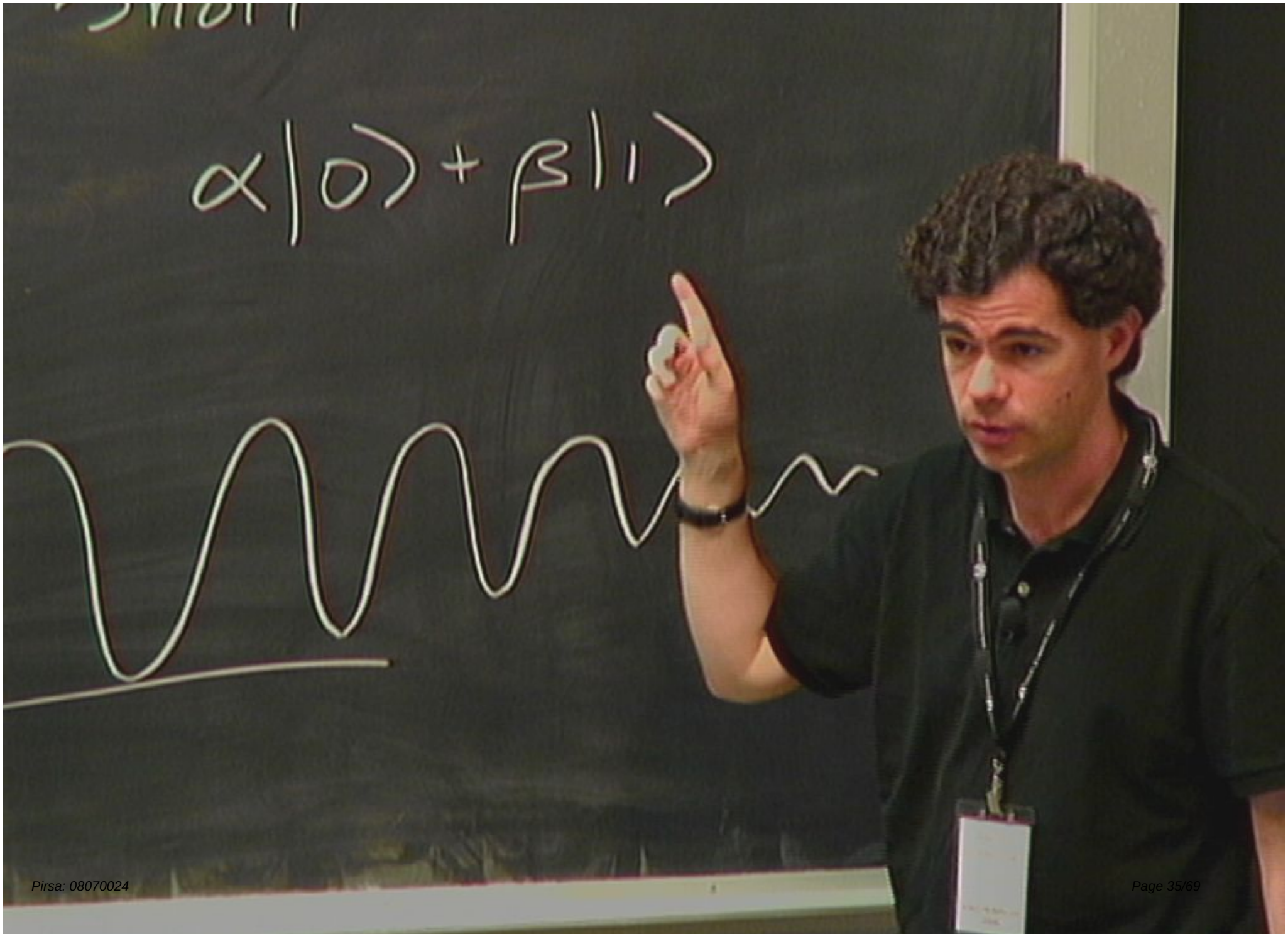

Bloch sphere:
high
long
short
low
Rabi oscillation:
prob

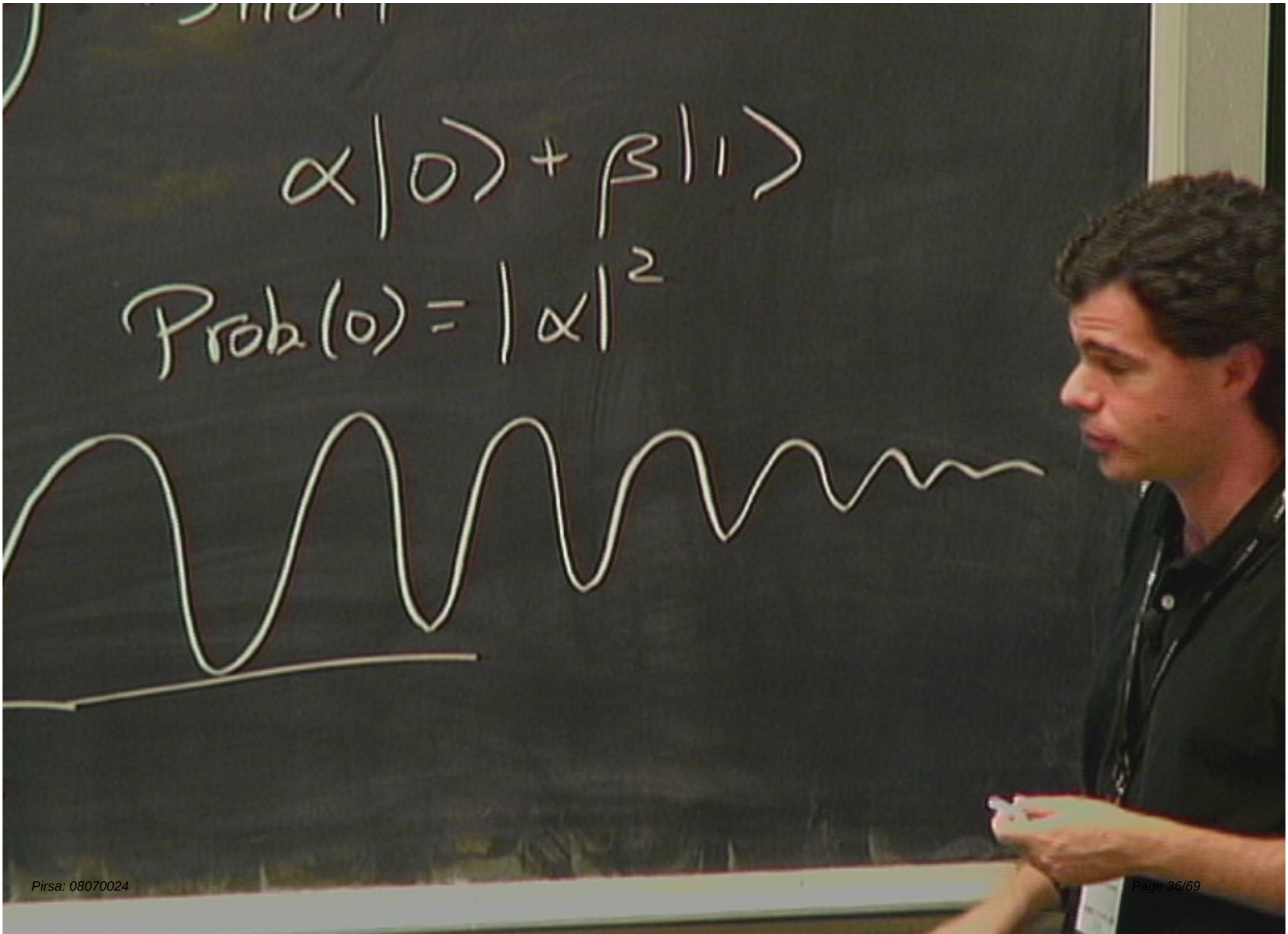

Bloch sphere:
high
long
short
low
Rabi oscillation:
Prob of high
Time

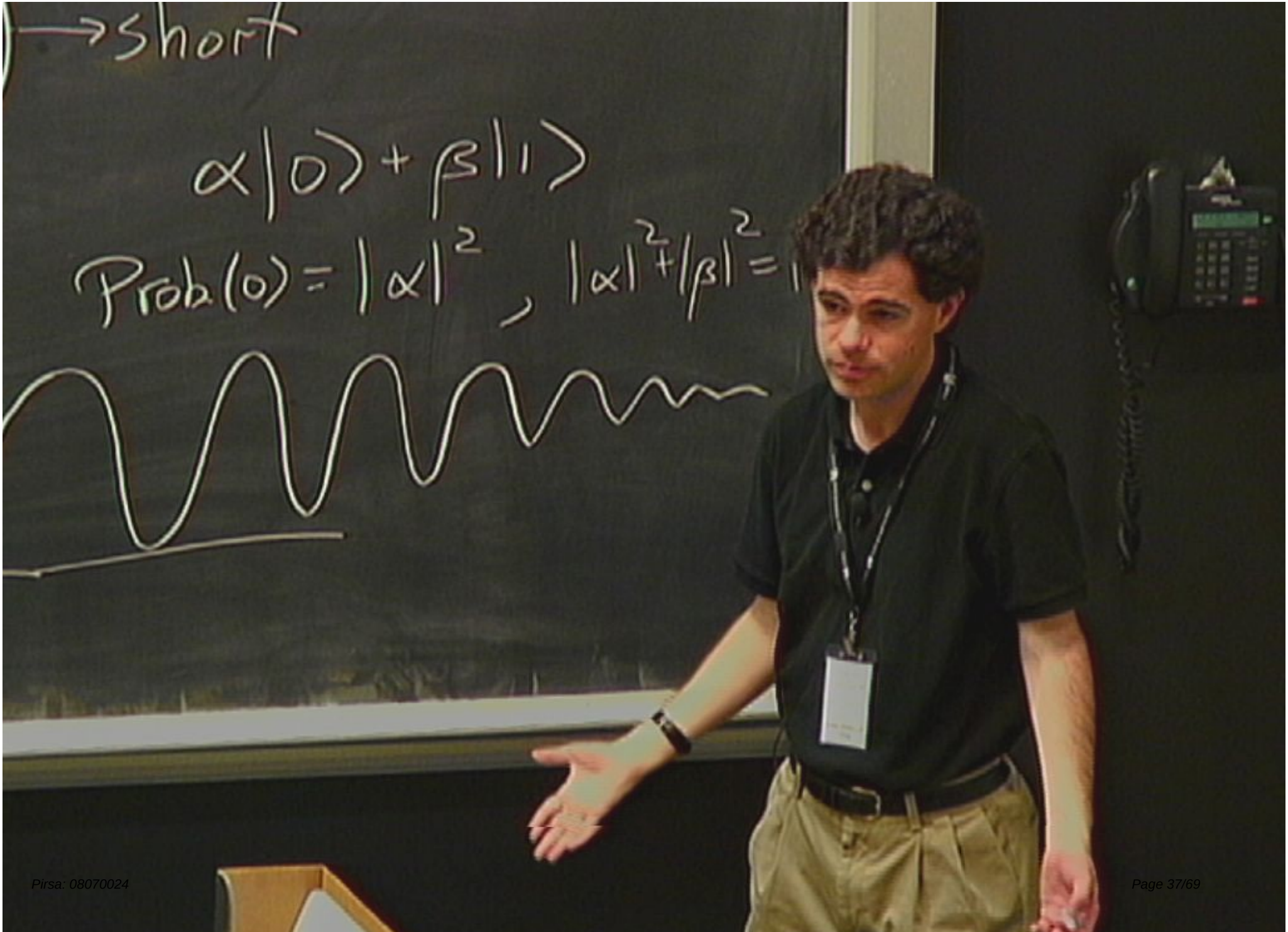

Bloch sphere:
high
long
short
low
Rabi oscillation:
Prob of high
Time

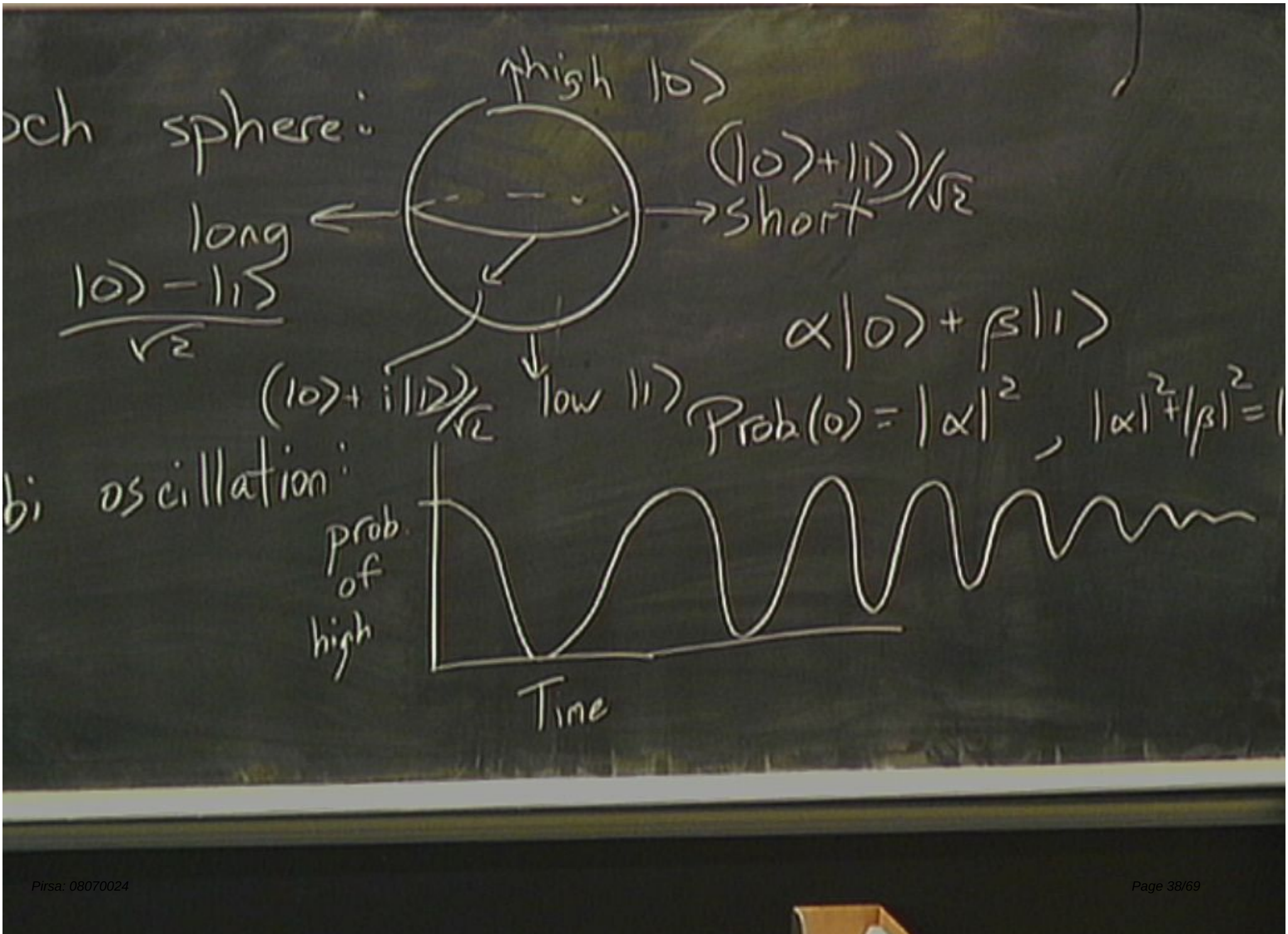

Bloch sphere:
high
long
short
low
Rabi oscillation:
Prob of high
Time

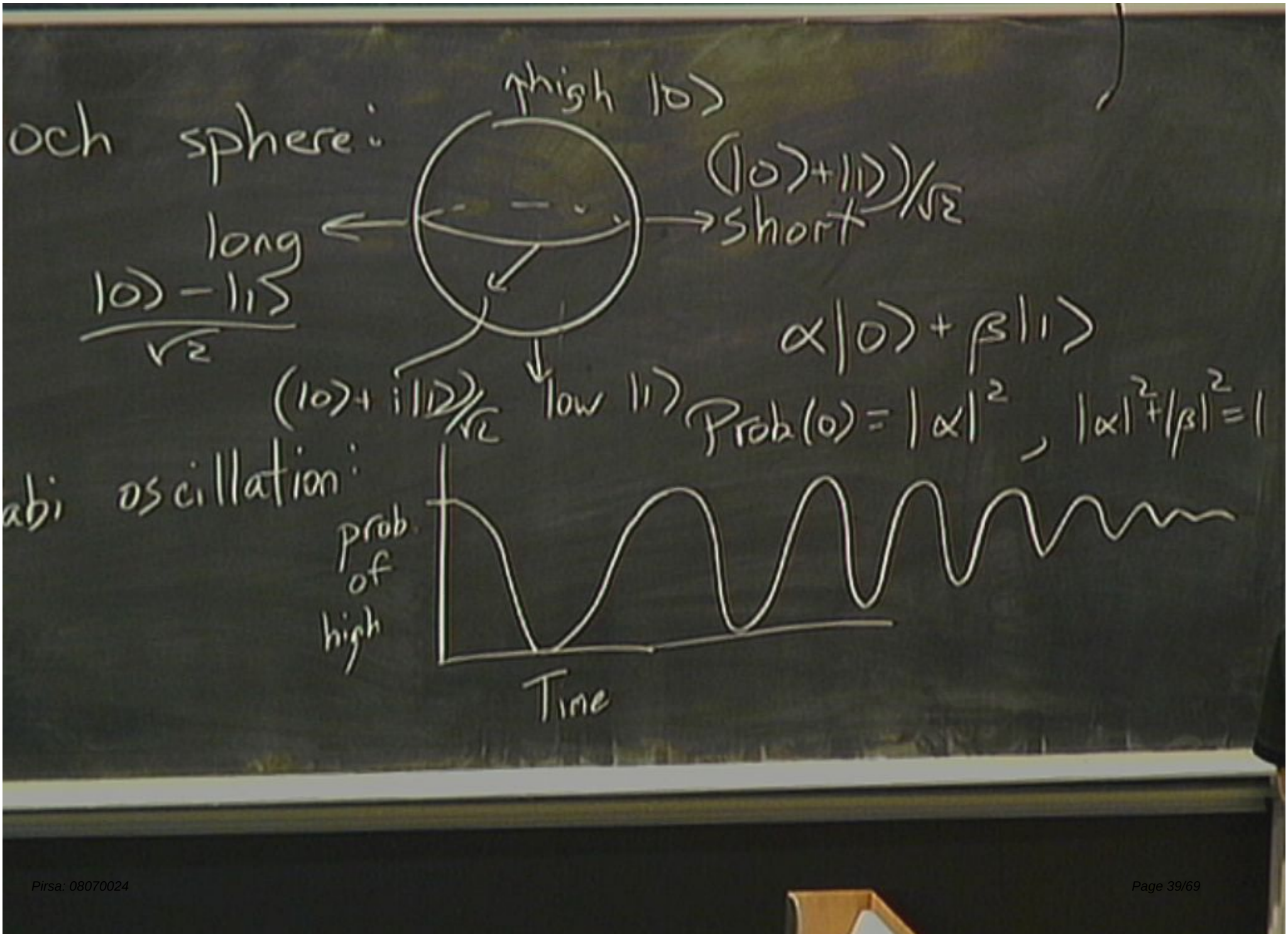

α|0⟩ + β|1⟩

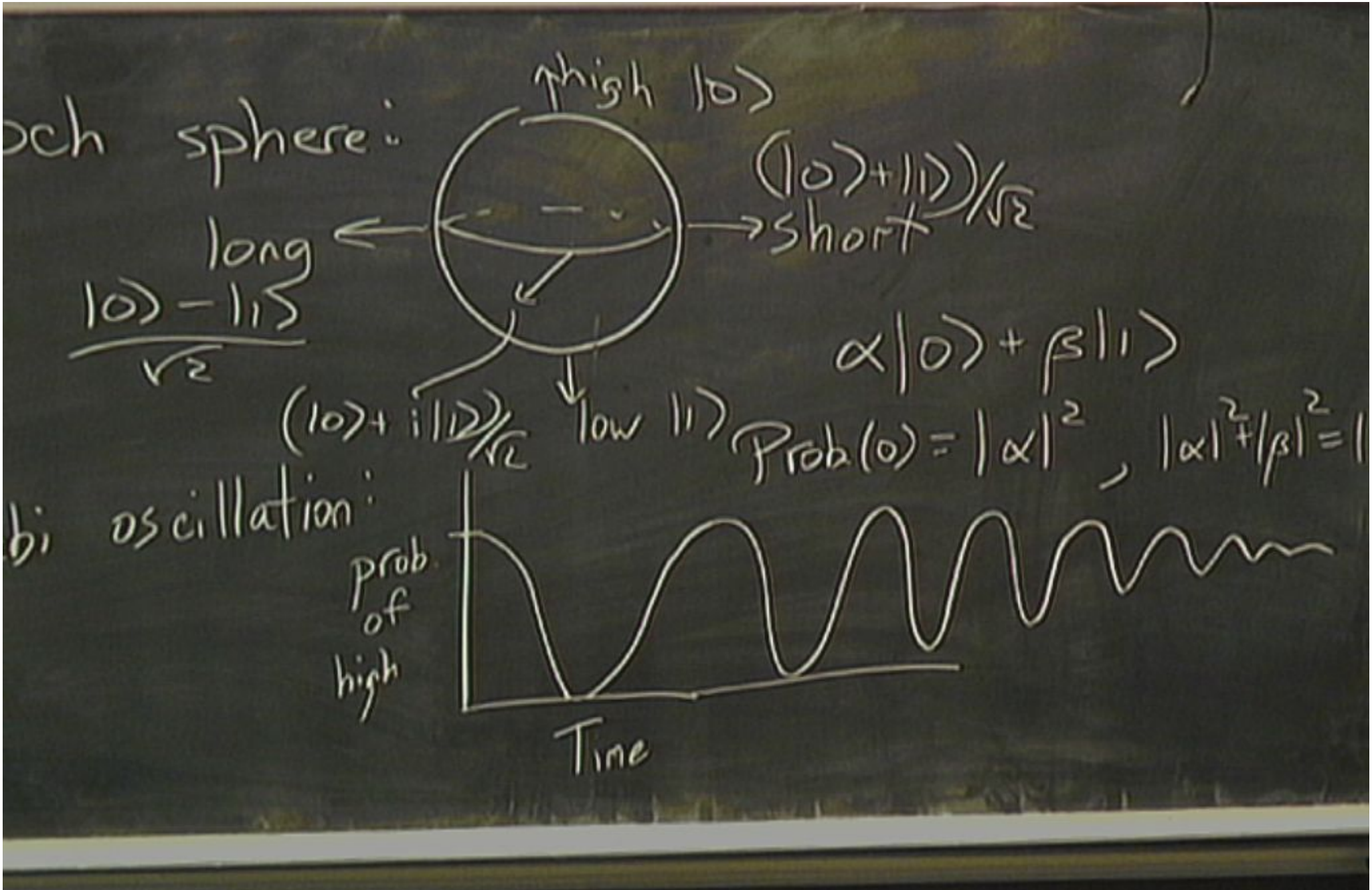

α|0⟩ + β|1⟩

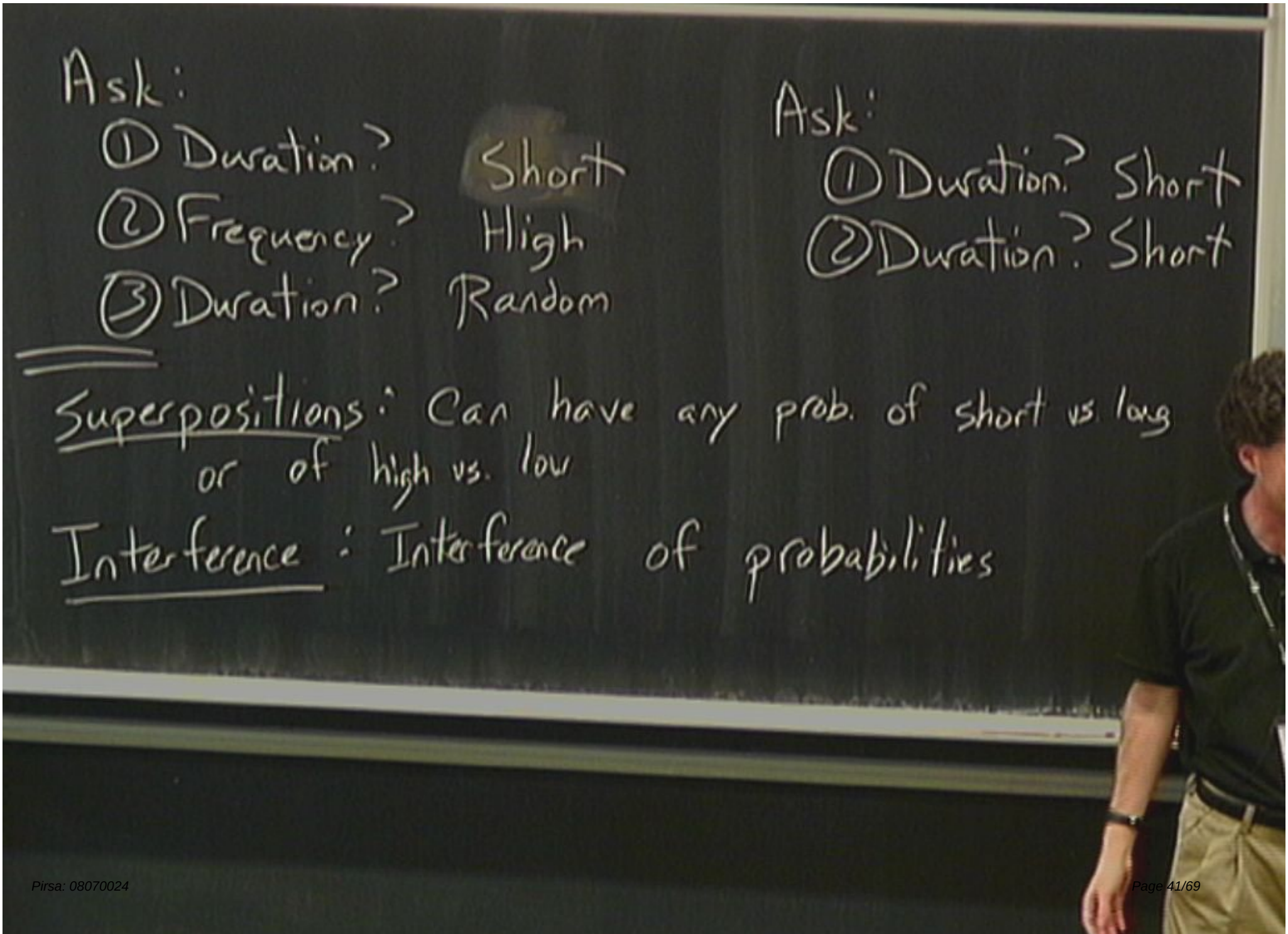

$\alpha|0\rangle + \beta|1\rangle$
$\text{Prob}(0) = |\alpha|^2$


→short
α|0⟩ + β|1⟩
Prob(0) = |α|²
|α|² + |β|² = 1

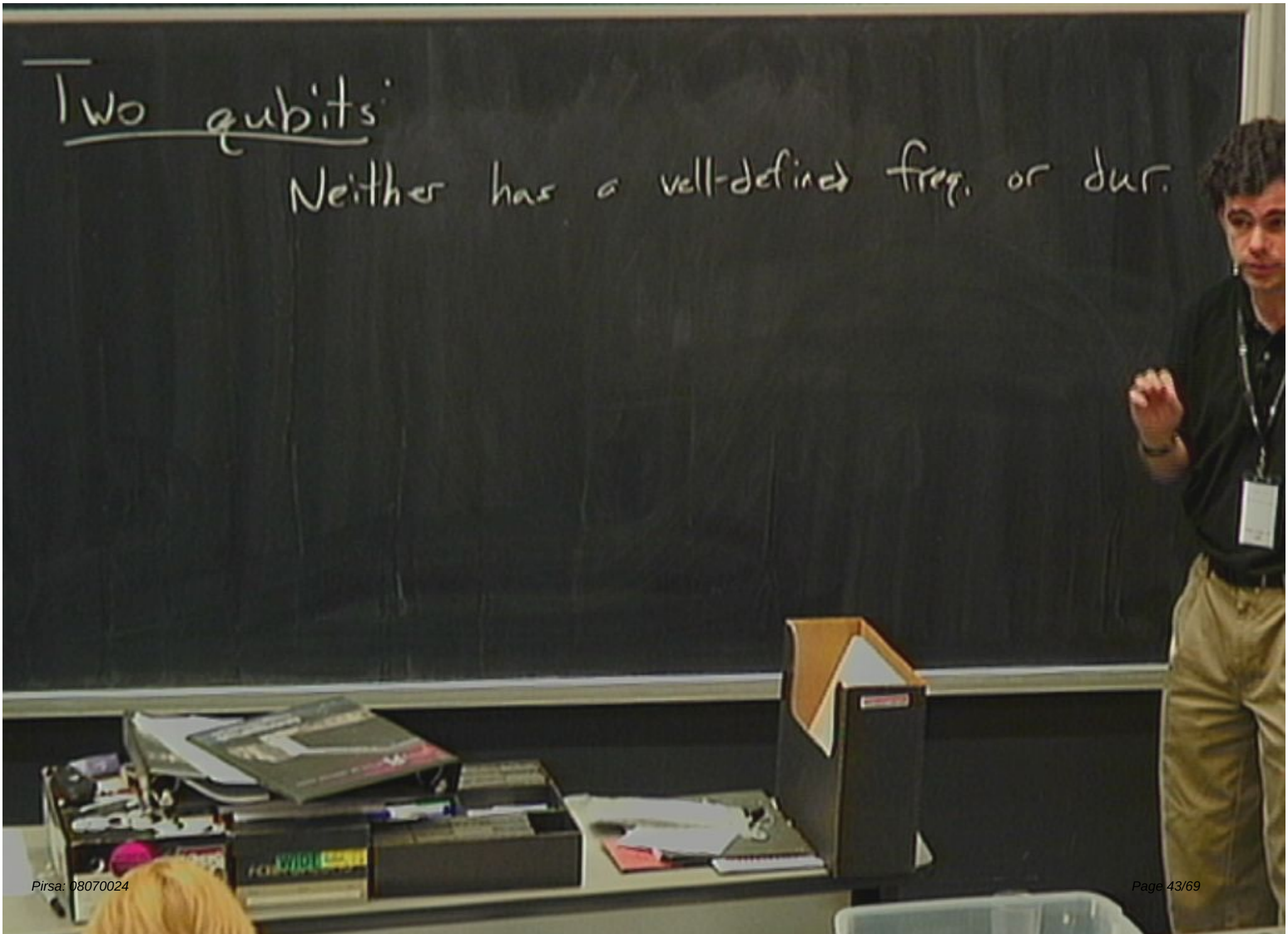

ch sphere:
high |0⟩
(|0⟩+|1⟩)/√2
short
long
|0⟩−|1⟩/√2
(|0⟩+i|1⟩)/√2
low |1⟩
α|0⟩+β|1⟩
Prob(0) = |α|²
, |α|²+|β|²=1
bi oscillation:
prob of high
Time

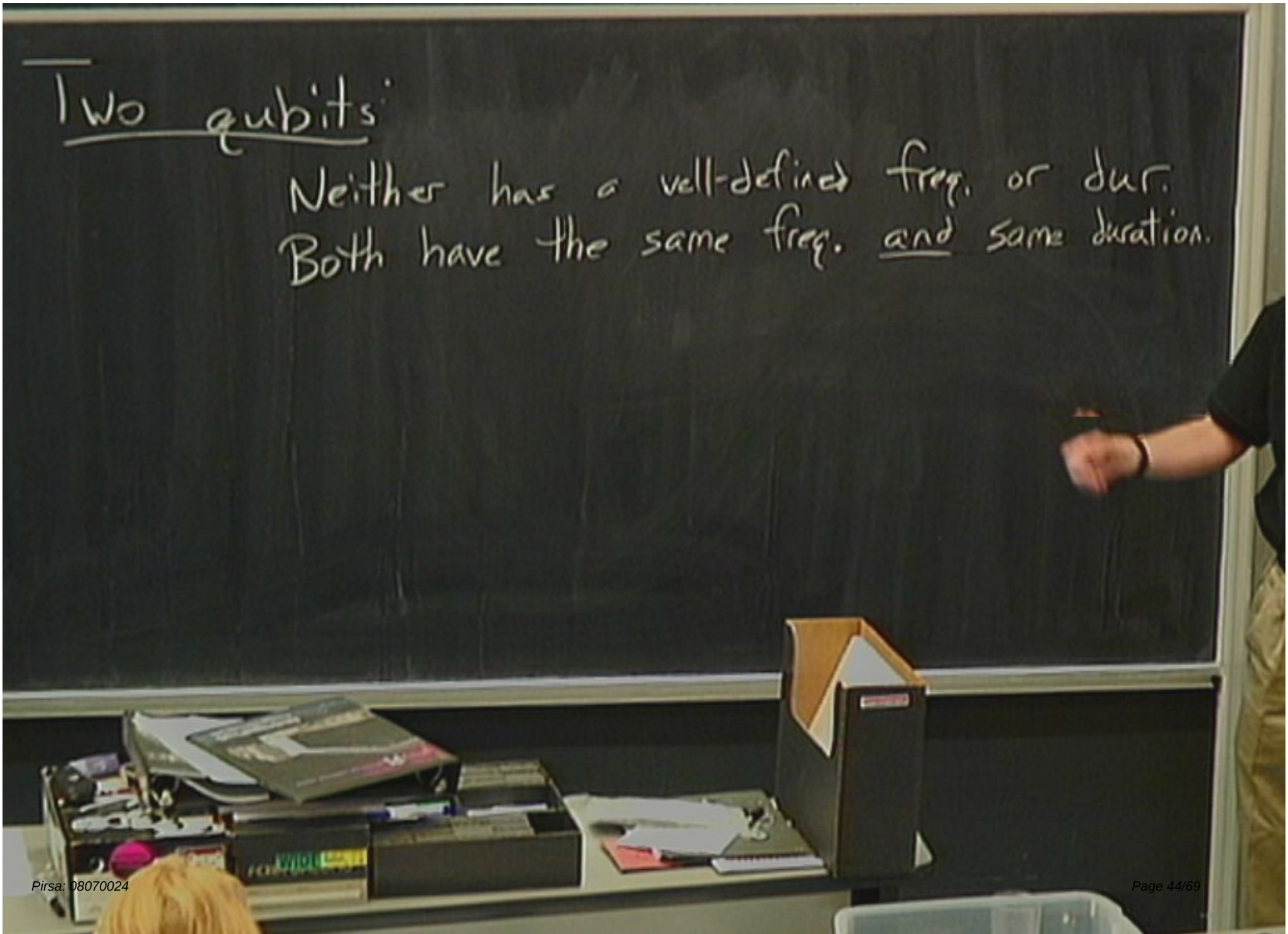

och sphere:
high |0⟩
(|0⟩+|1⟩)/√2
short
long
|0⟩ − |1⟩
√2
(|0⟩+ i|1⟩)/√2
low |1⟩
α|0⟩ + β|1⟩
Prob(0) = |α|²
, |α|²+|β|²=1
abi oscillation:
prob. of high
Time

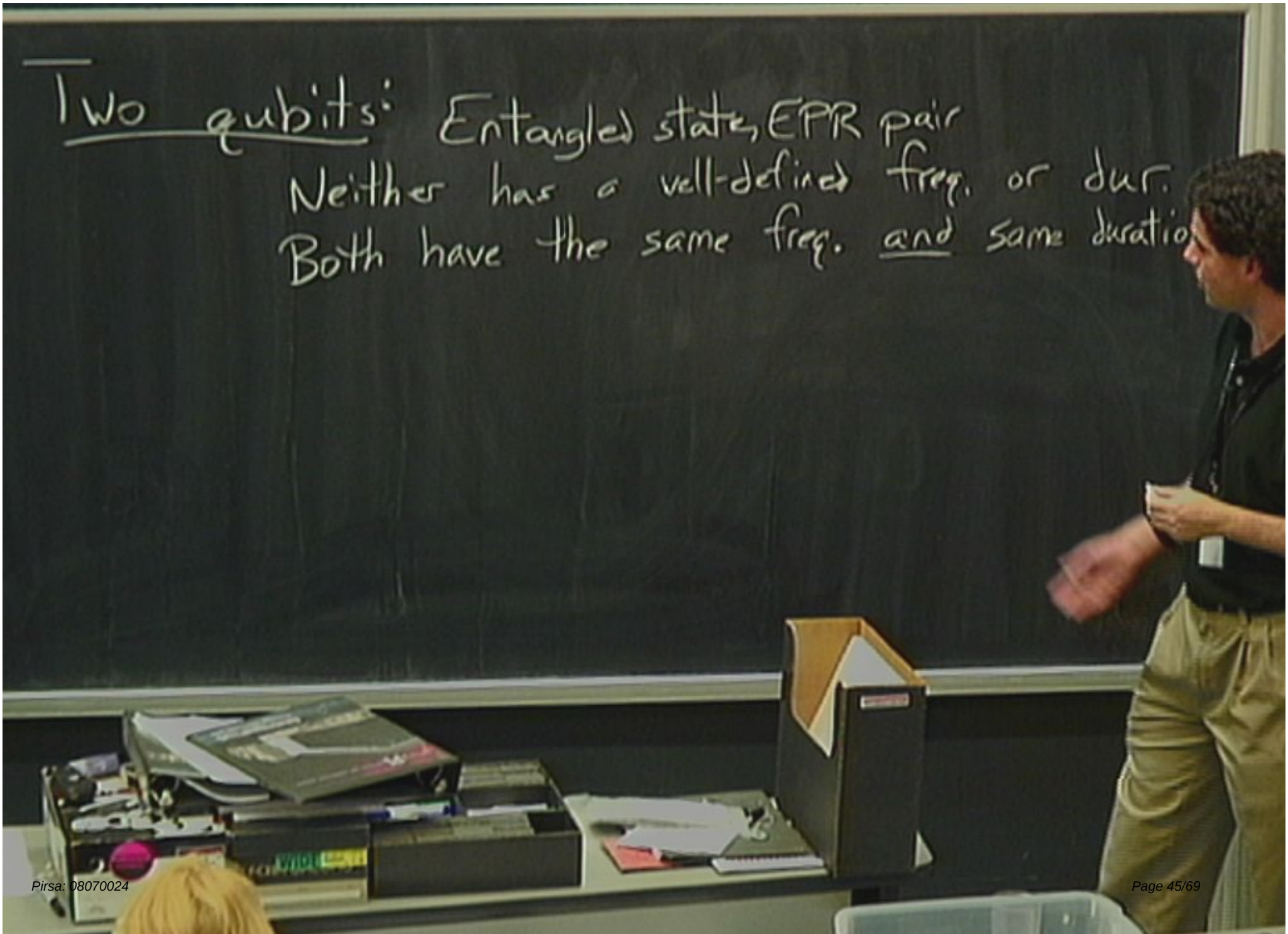

ch sphere:
high |0⟩
(|0⟩+|1⟩)/√2
short
long
|0⟩−|1⟩/√2
α|0⟩ + β|1⟩
(|0⟩+ i|1⟩)/√2
low |1⟩
Prob(0) = |α|²
|α|²+|β|² = 1
bi oscillation:
Prob of high
Time

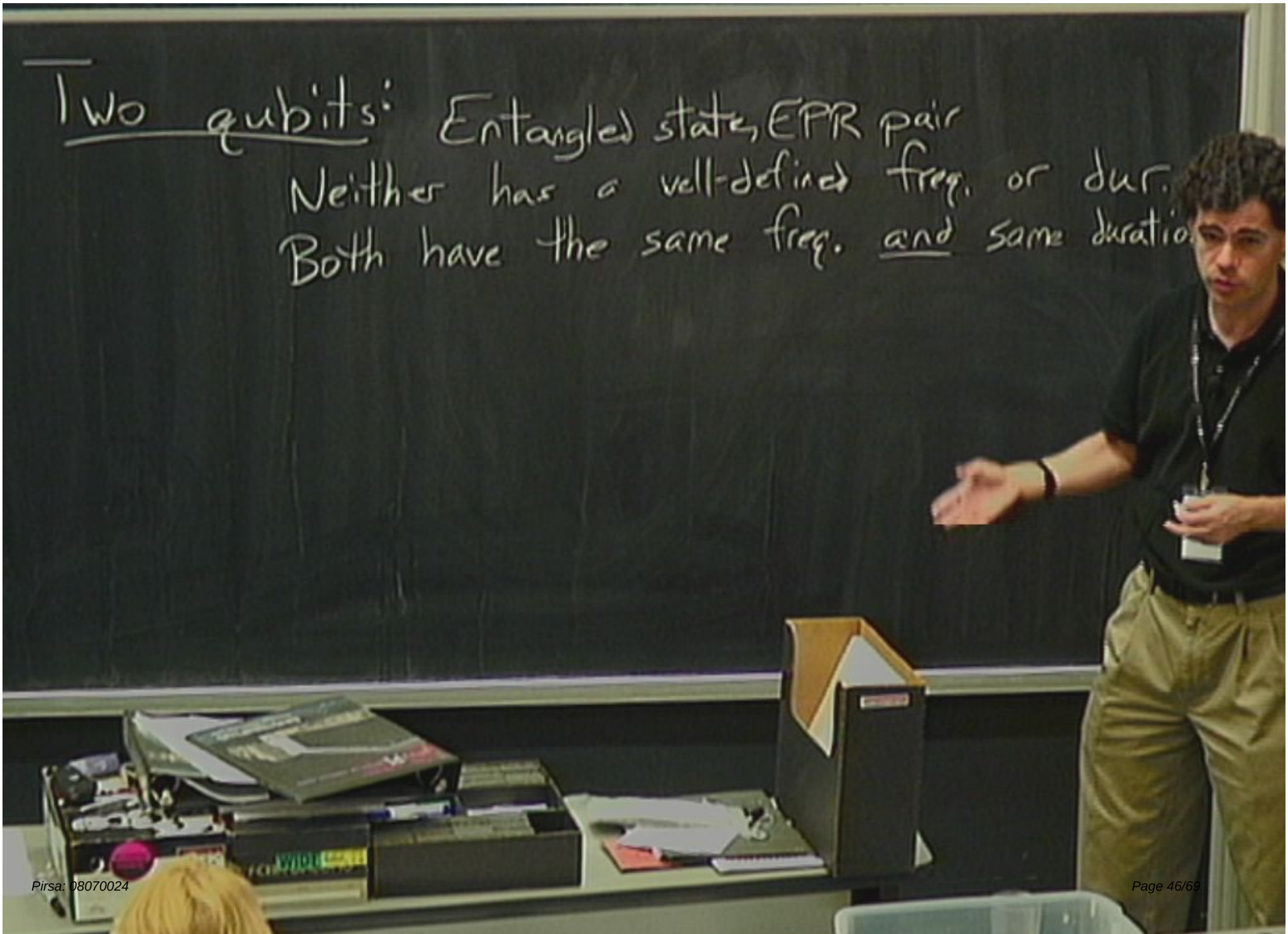

Ask:
① Duration? Short
② Frequency? High
③ Duration? Random
Ask:
① Duration? Short
② Duration? Short
Superpositions: Can have any prob. of short vs. long or of high vs. low
Interference: Interference of probabilities

Two qubits:


Two qubits:
Neither has a well-defined freq. or dur.


Two qubits:
Neither has a well-defined freq. or dur.
Both have the same freq. and same duration.


Two qubits: Entangled state, EPR pair
Neither has a well-defined freq. or dur.
Both have the same freq. and same duratio


Two qubits: Entangled state, EPR pair
Neither has a well-defined freq. or dur.
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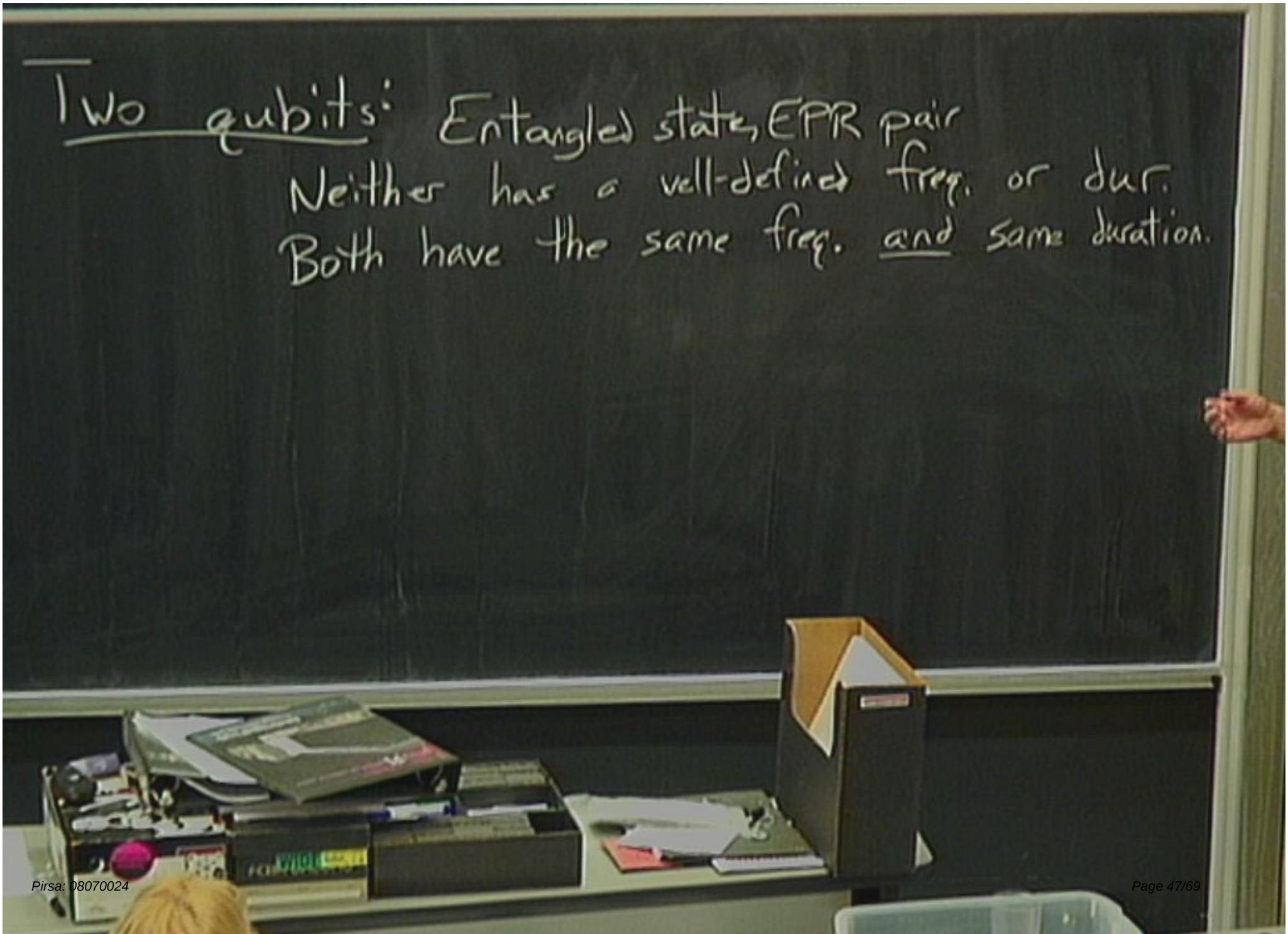
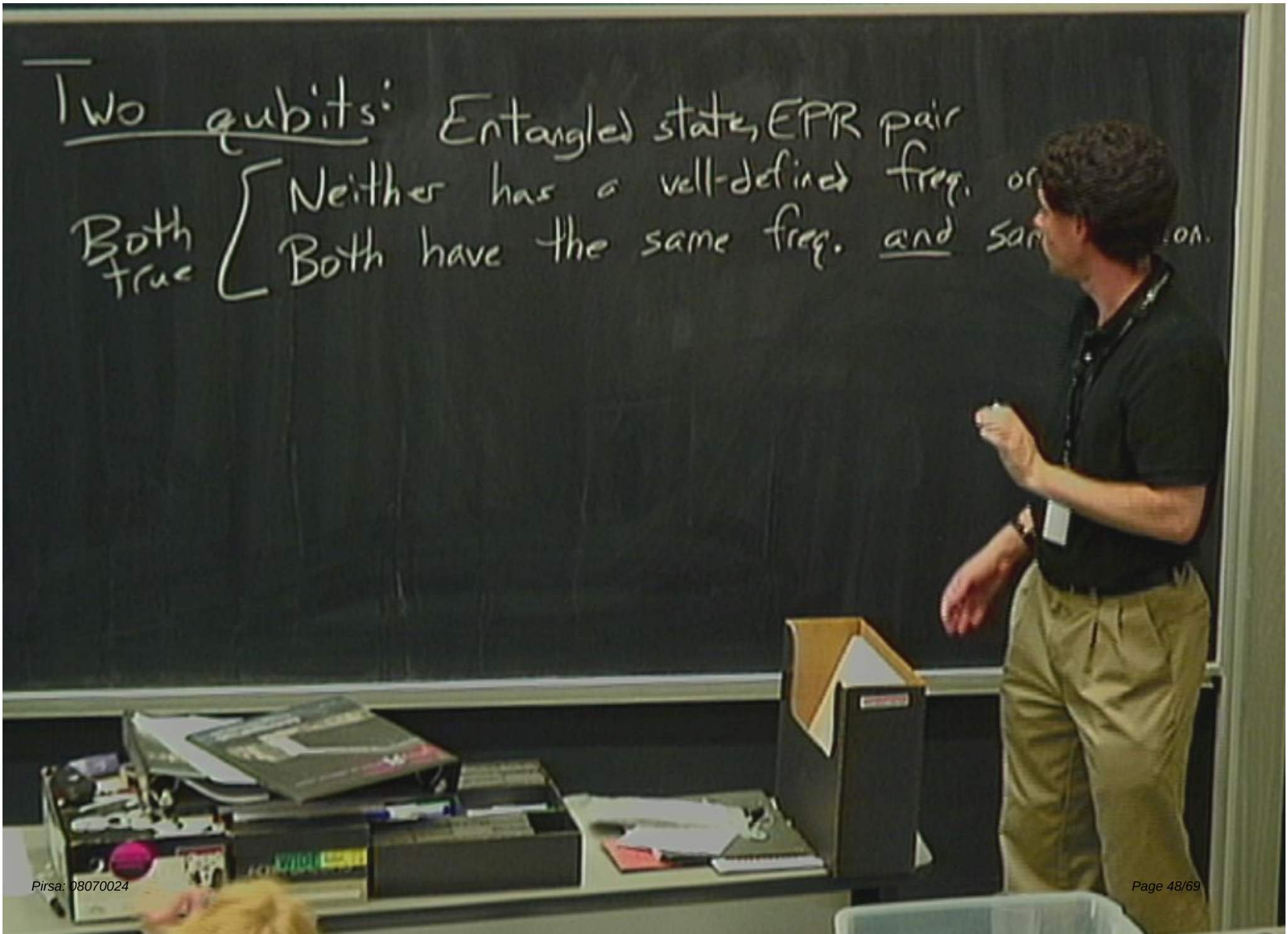
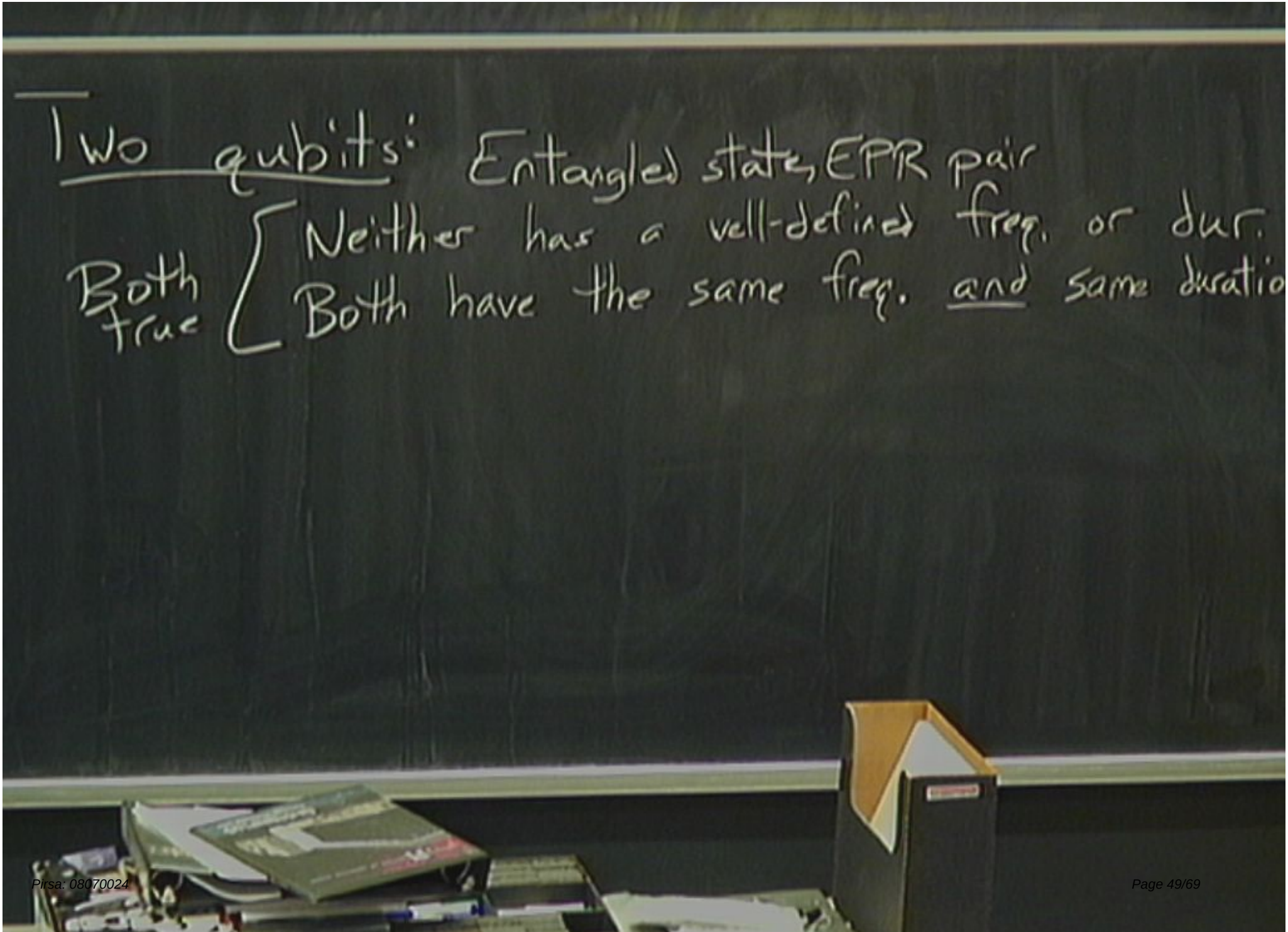
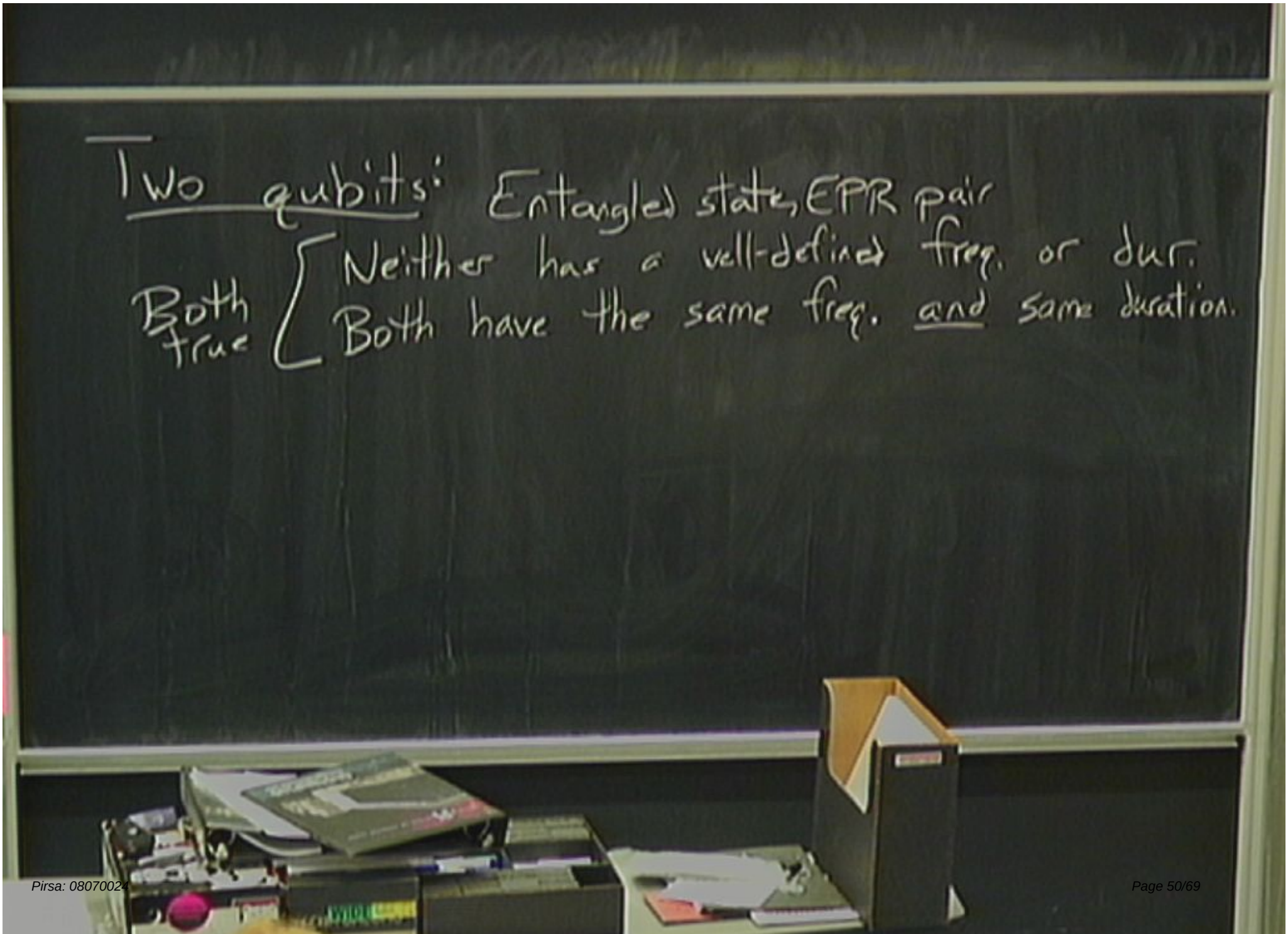
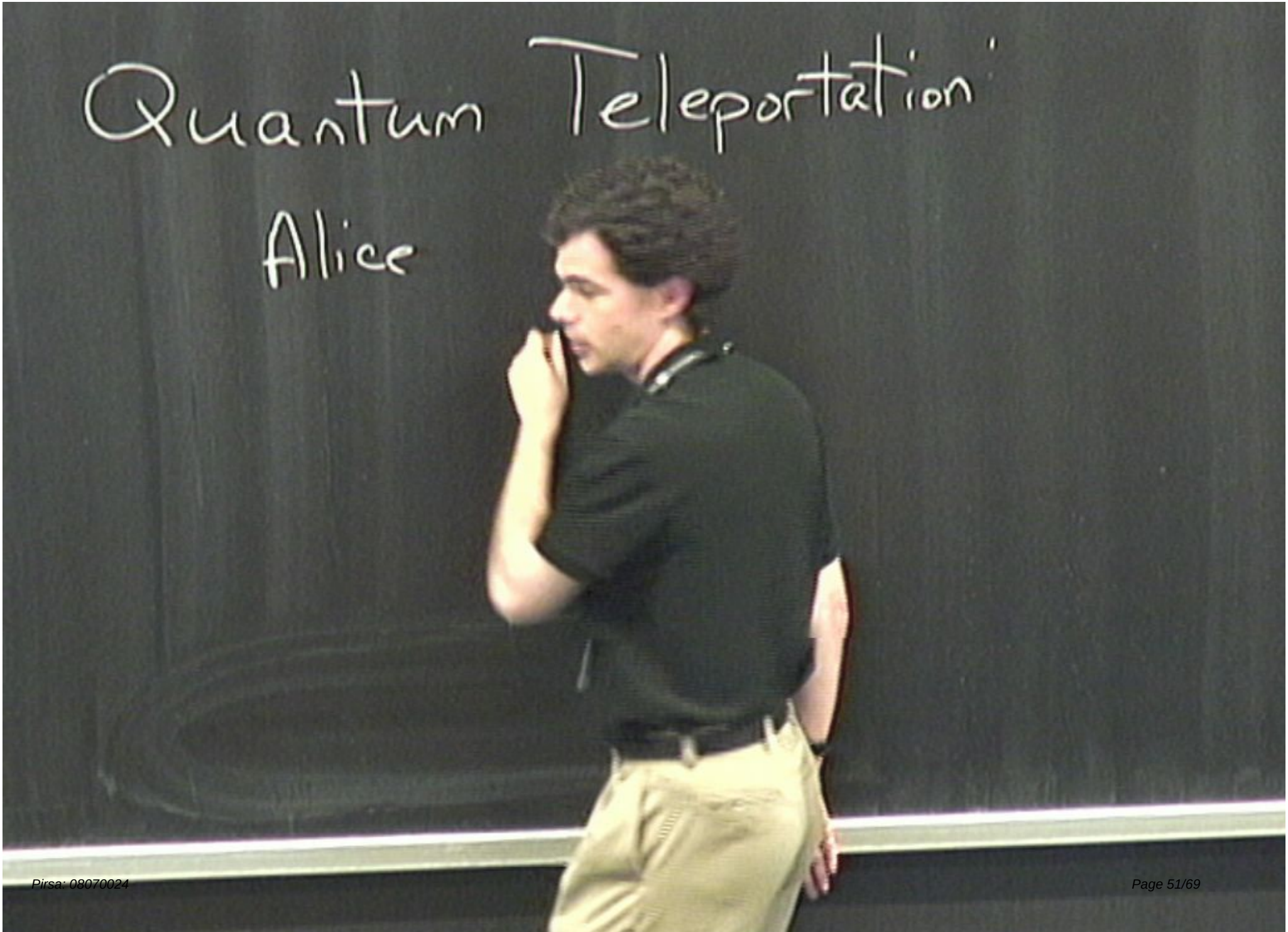
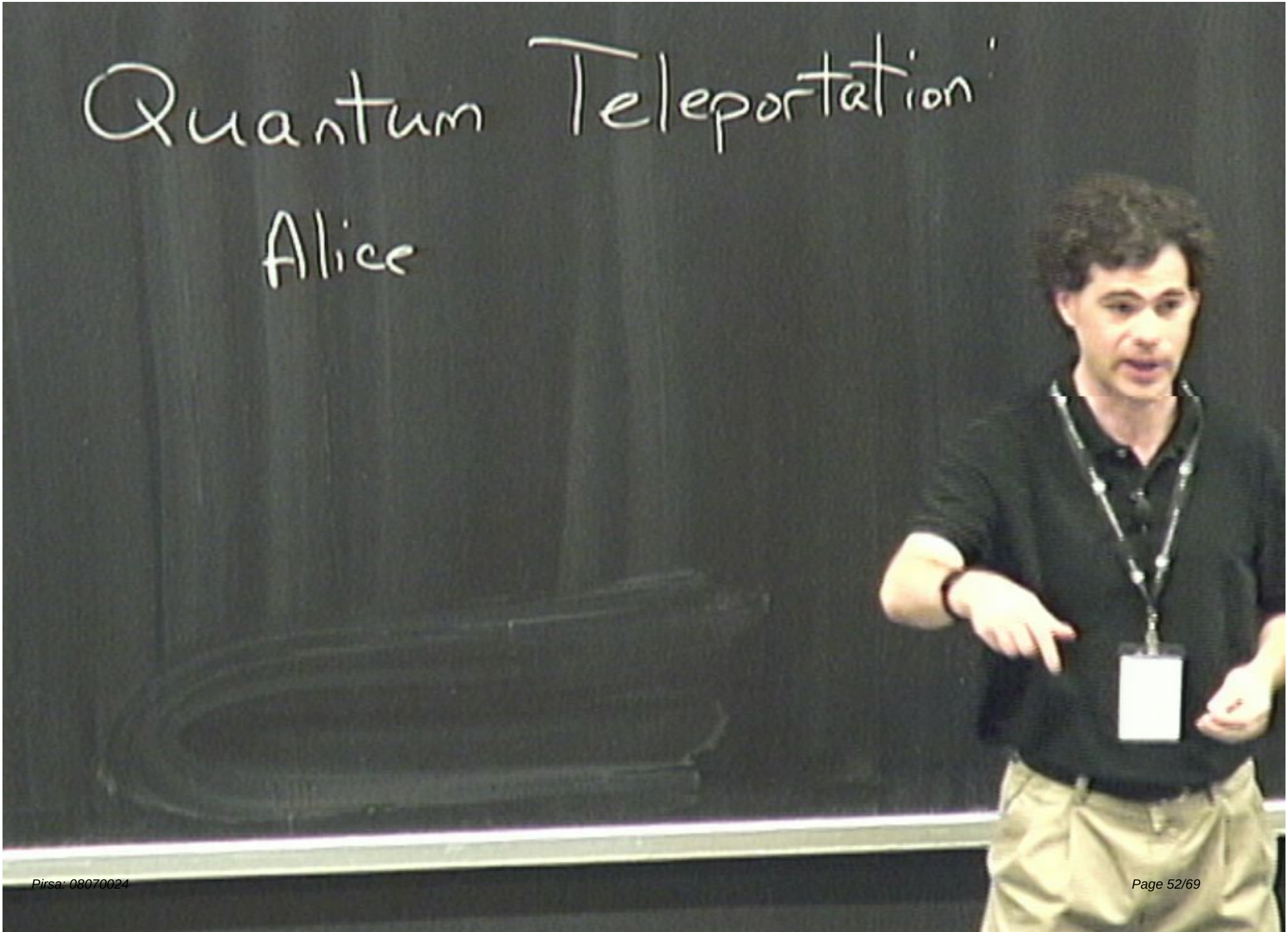

Two qubits: Entangled state, EPR pair
Neither has a well-defined freq. or dur.
Both have the same freq. and same duration.

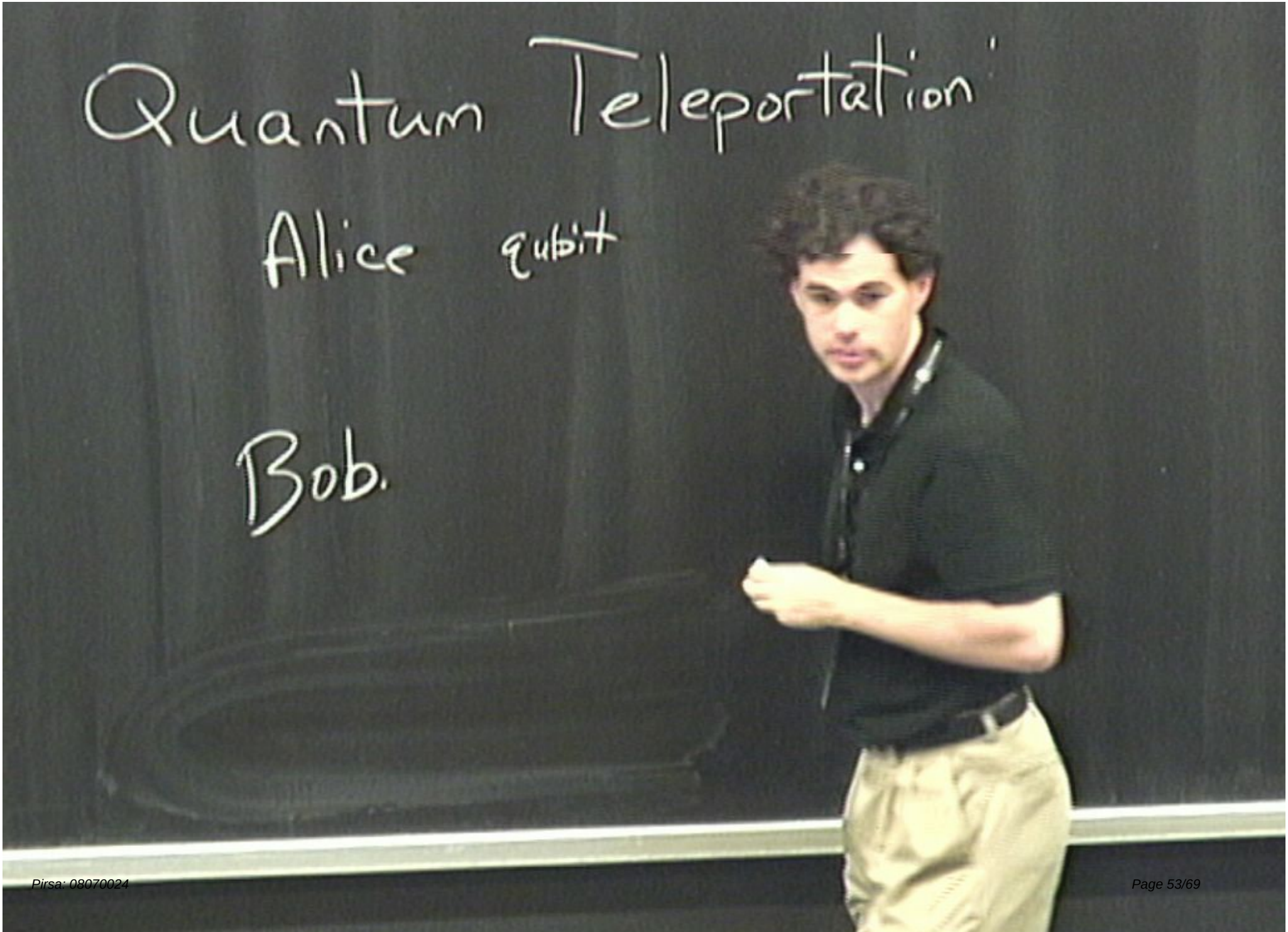

Two qubits: Entangled state, EPR pair
Both true
Neither has a well-defined freq. or
Both have the same freq. and sa
on.

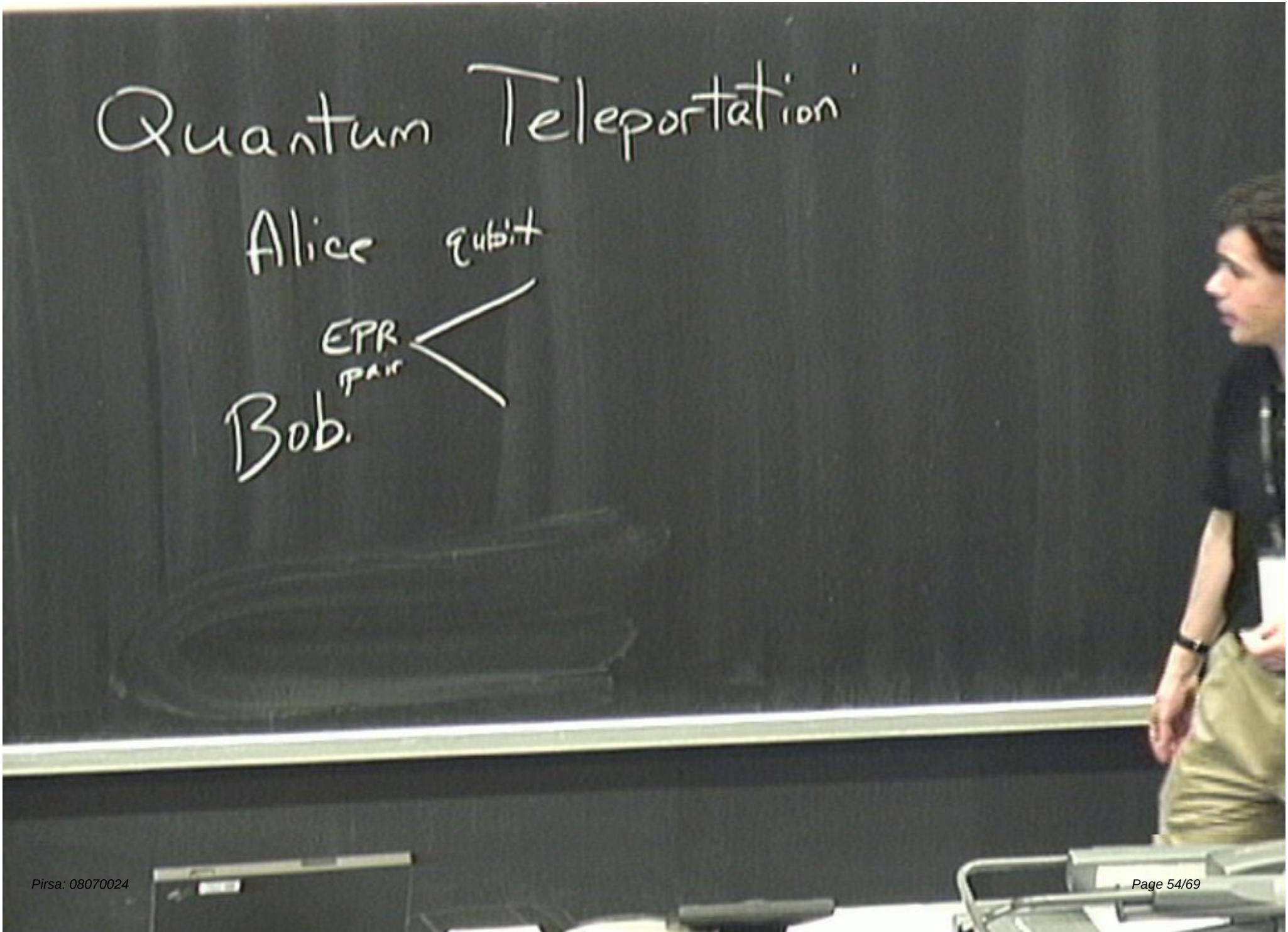

Two qubits: Entangled state, EPR pair
Both true
Neither has a well-defined freq. or dur.
Both have the same freq. and same duratio


Two qubits: Entangled state, EPR pair
Both true
Neither has a well-defined freq. or dur.
Both have the same freq. and same duration.

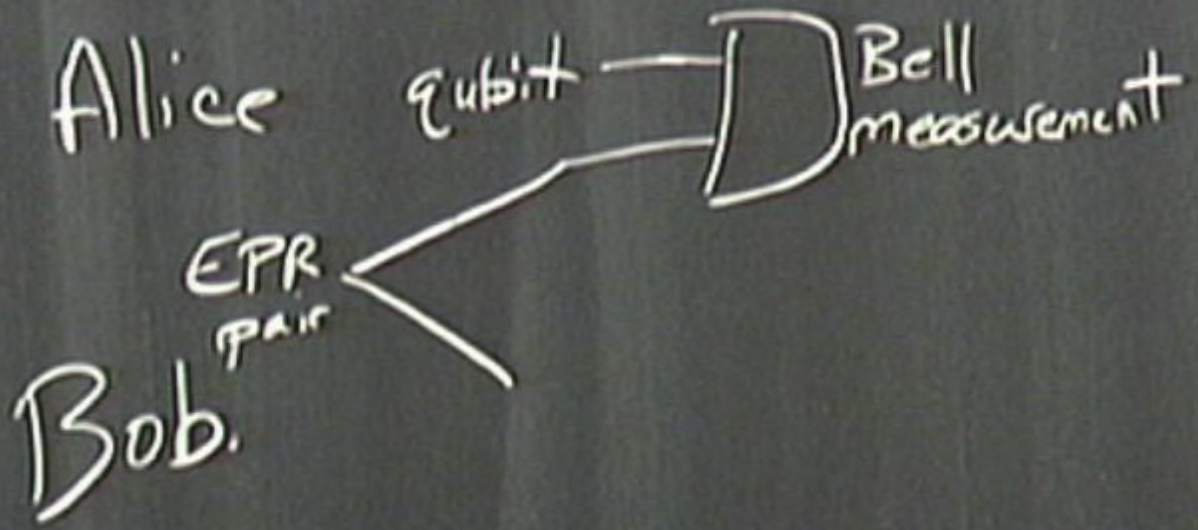

Quantum Teleportation
Alice

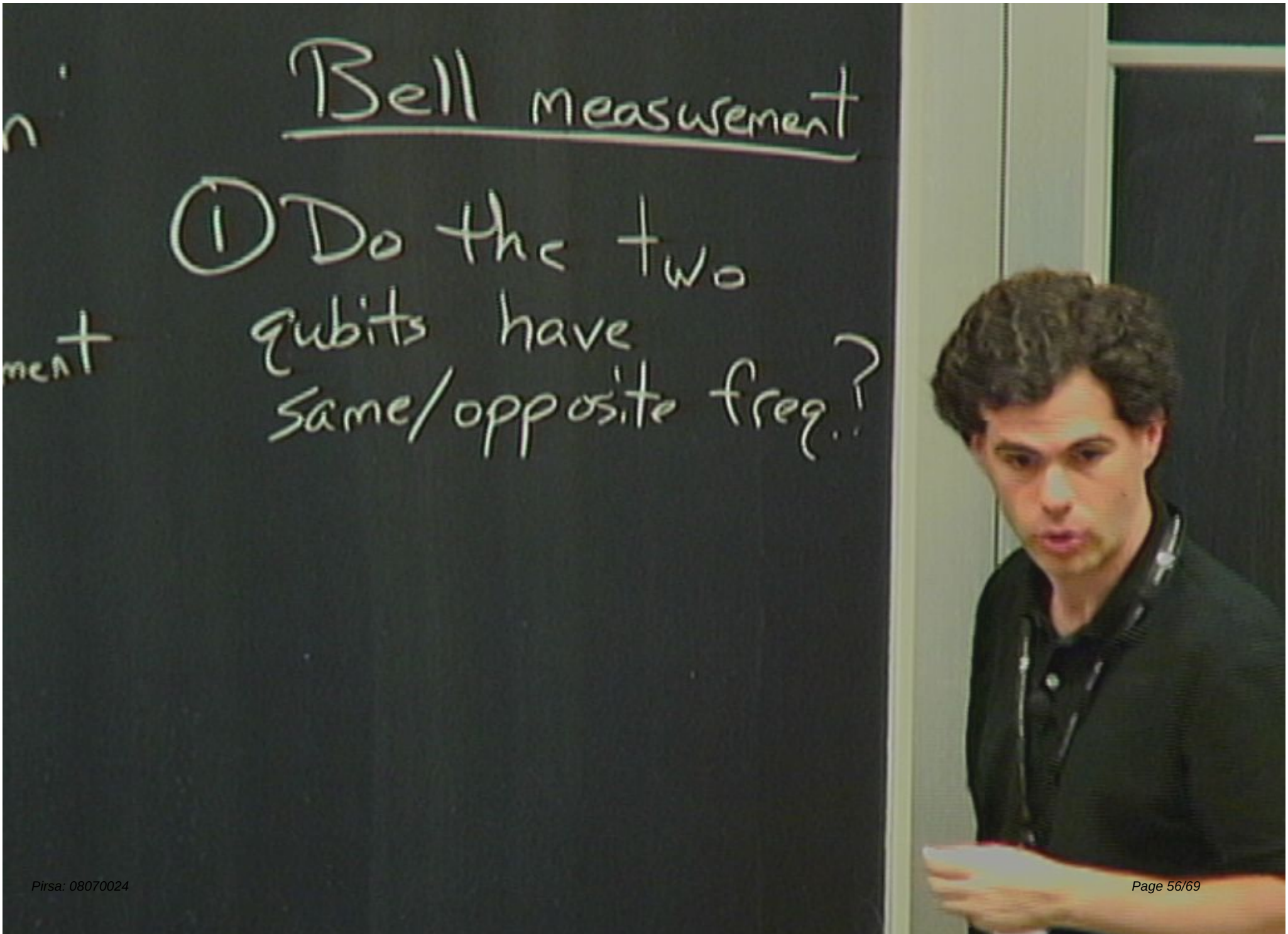

Quantum Teleportation
Alice

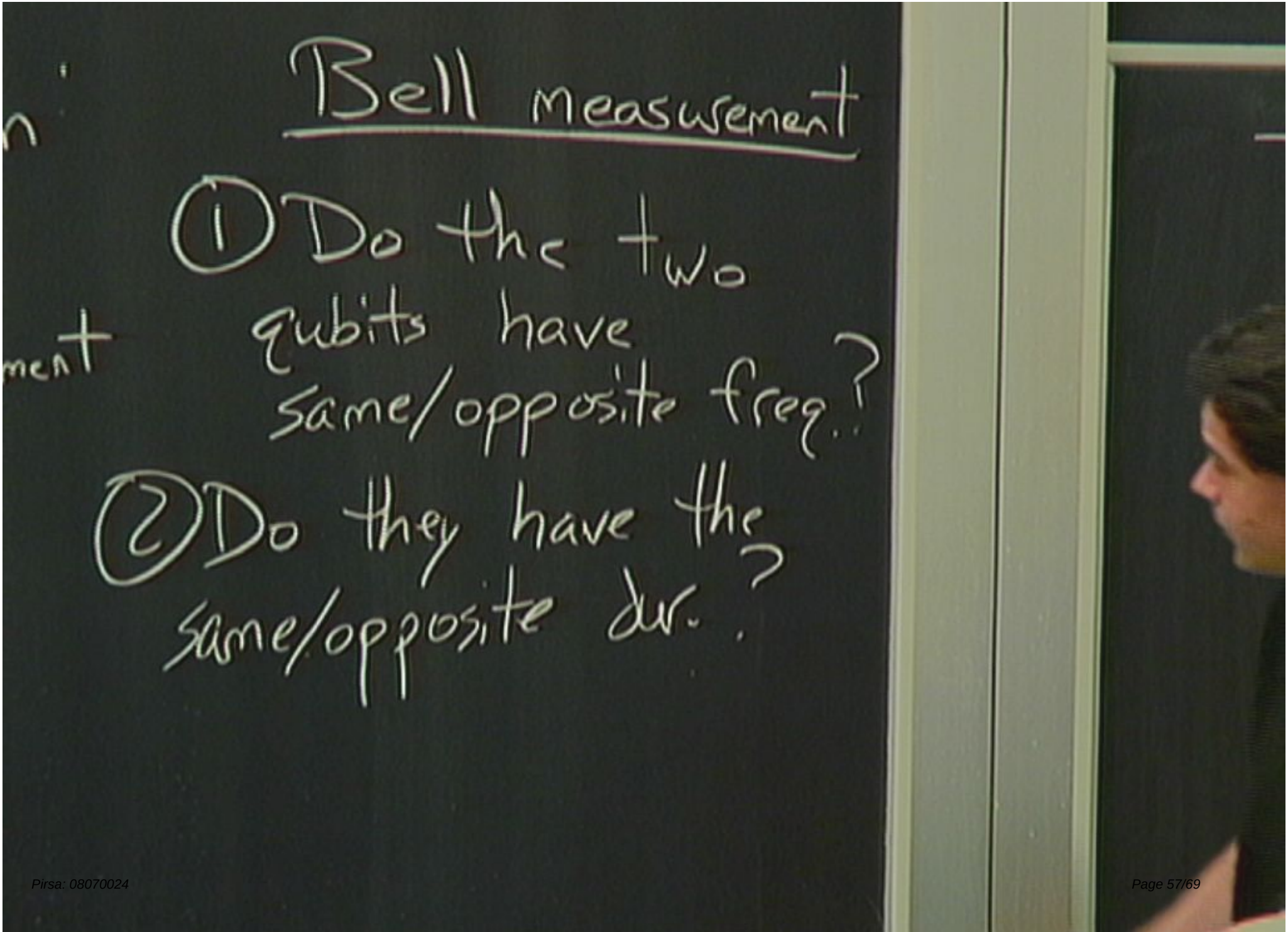

Quantum Teleportation
Alice qubit
Bob.

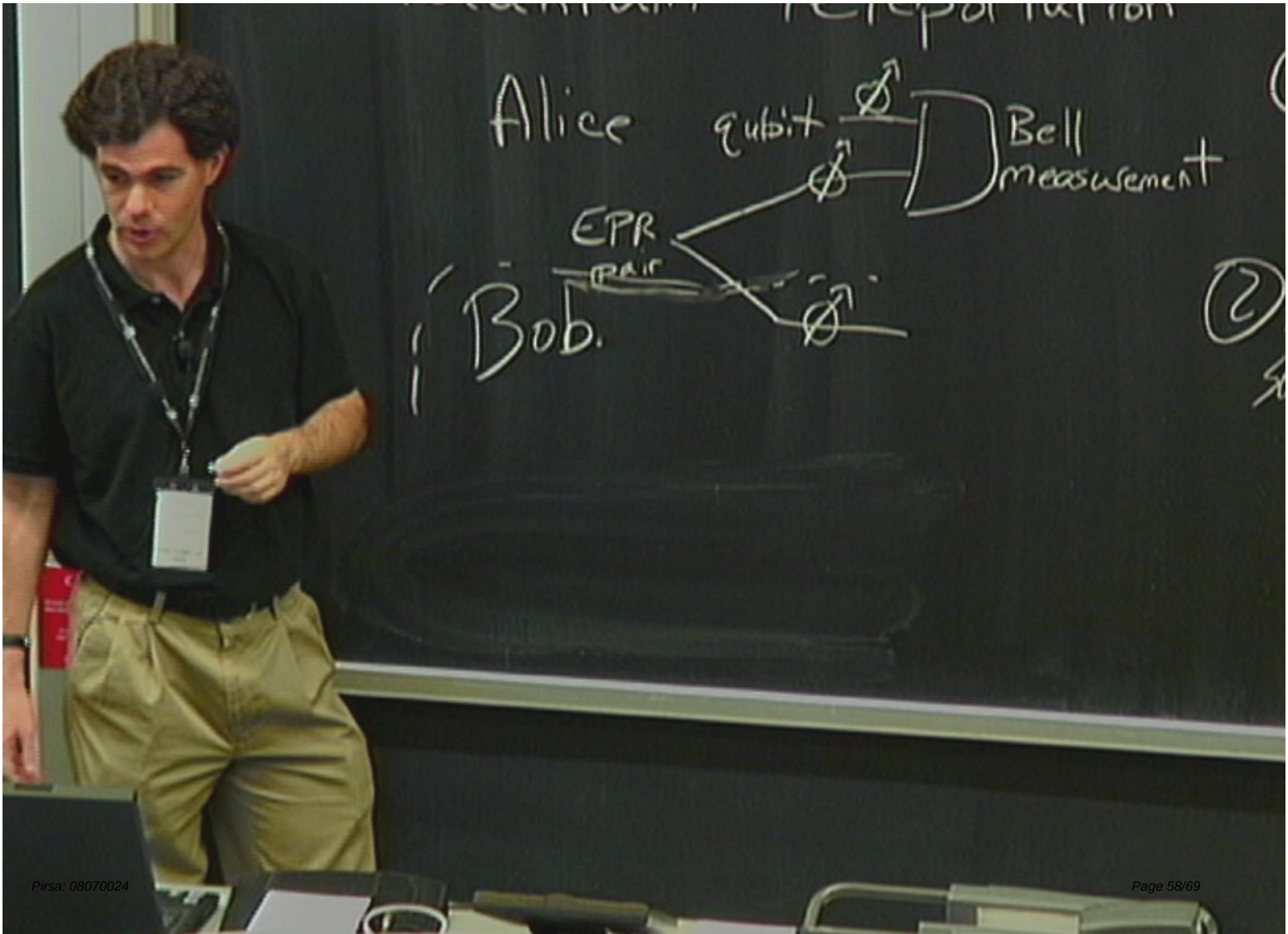

Quantum Teleportation
Alice
qubit
EPR pair
Bob

Quantum Teleportation




Bell measurement
① Do the two qubits have same/opposite freq.?


Bell measurement
① Do the two qubits have same/opposite freq.?
② Do they have the same/opposite dur.?


Alice
qubit
Bell
measurement
EPR
pair
Bob.

Quantum Teleportation

Alice — qubit — Bell measurement

EPR pair

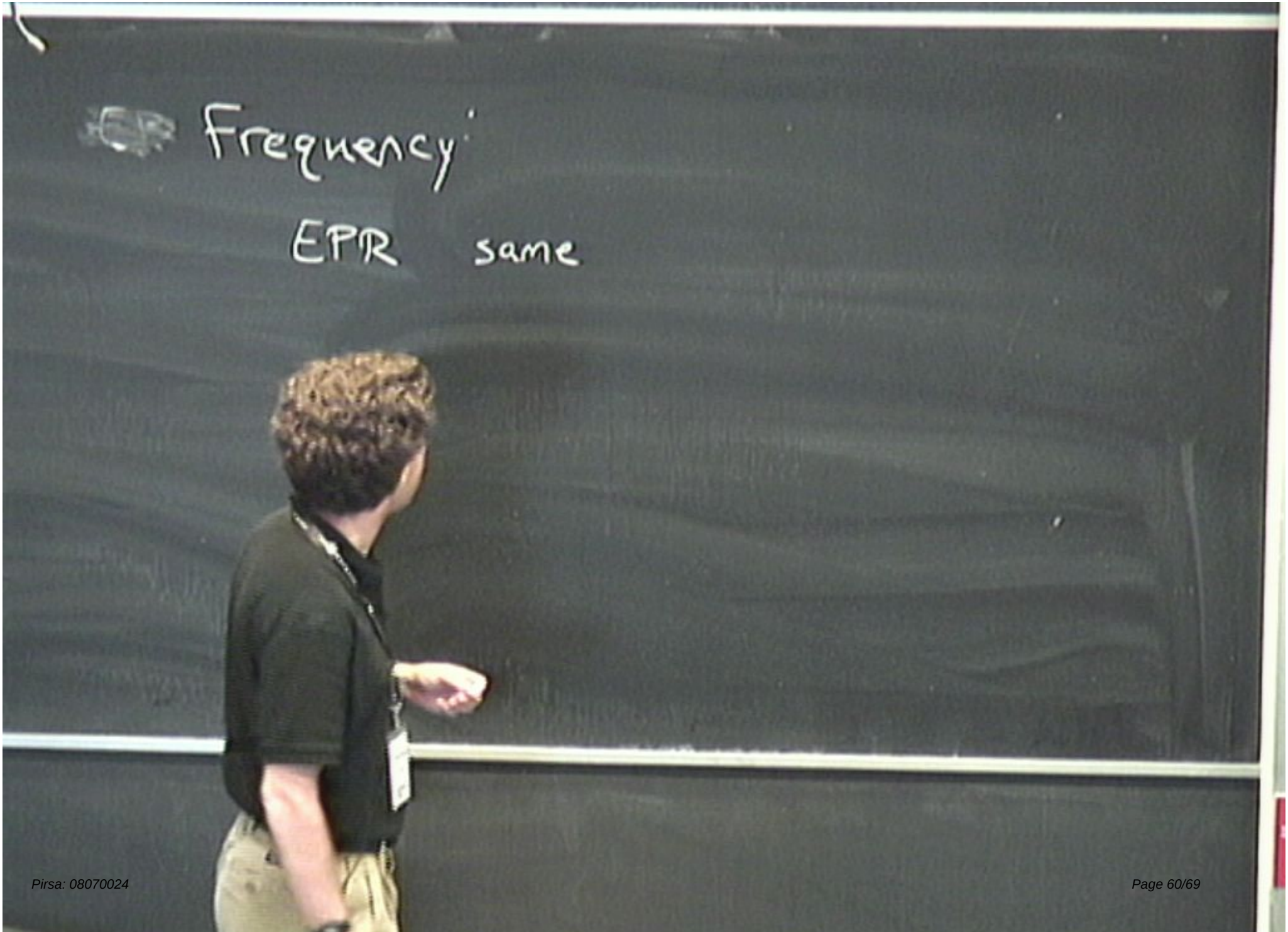
Bob.

Classical bits

Bell measurement

① Do the two qubits have same/opposite freq?

② Do they have the same/opposite dir.?


Frequency
EPR same

Frequency

EPR same

hex/EPR same

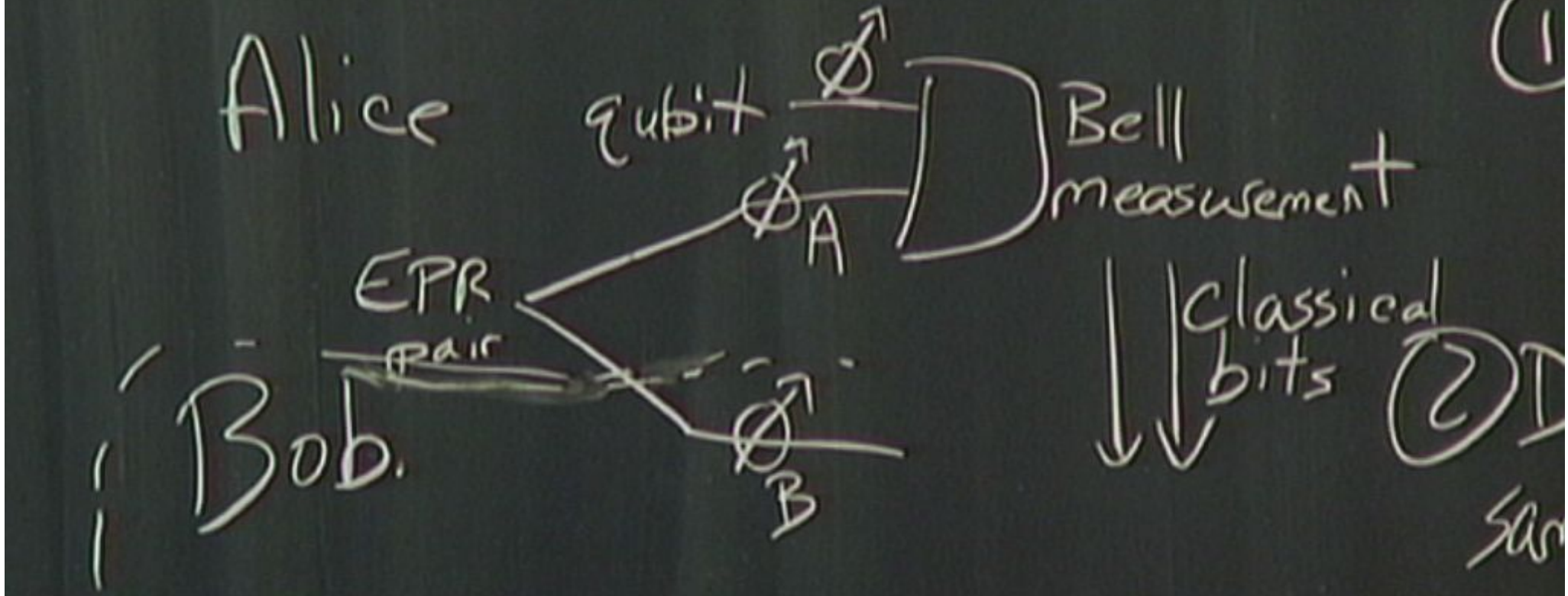
Frequency:

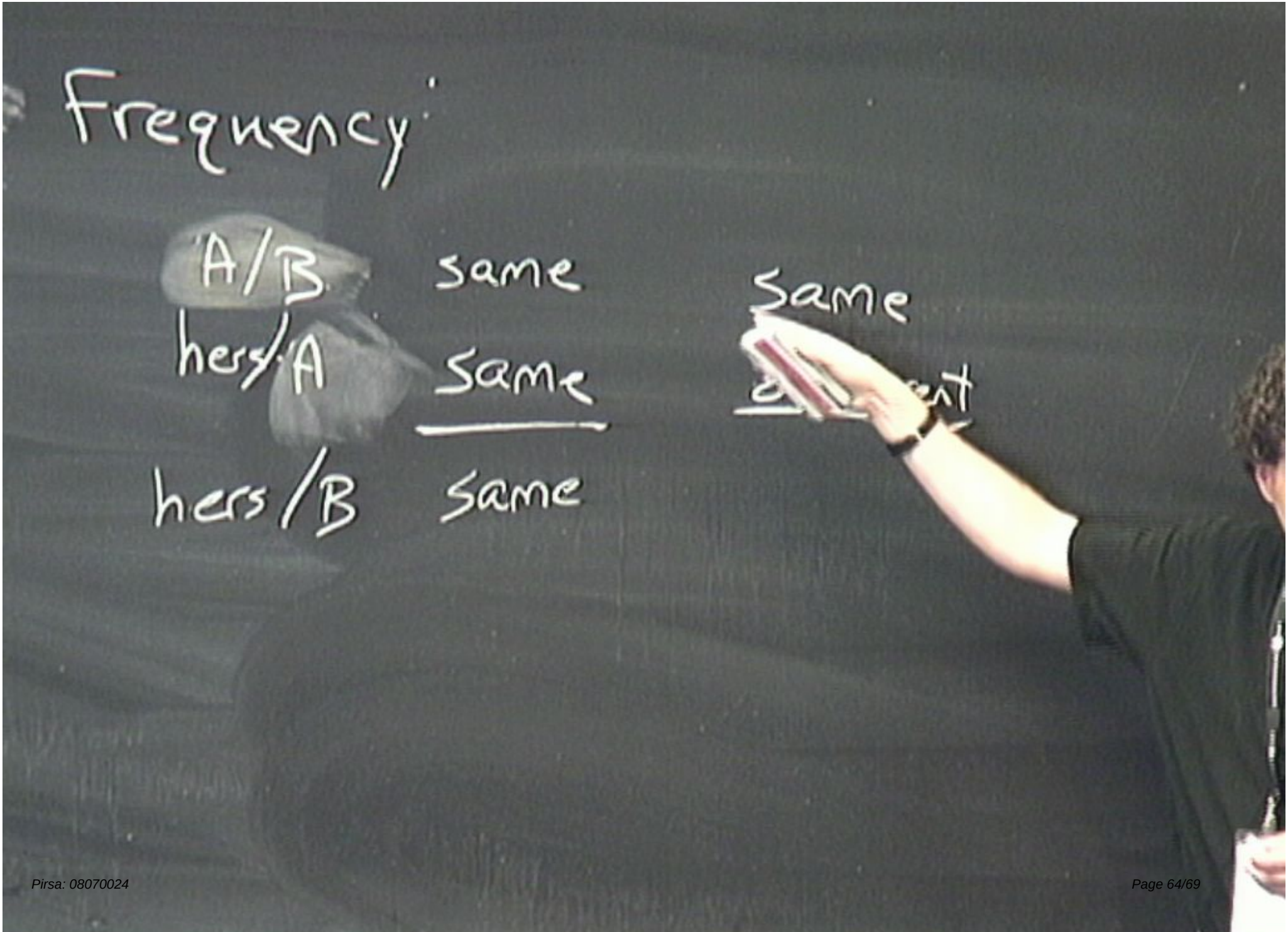
A/B same

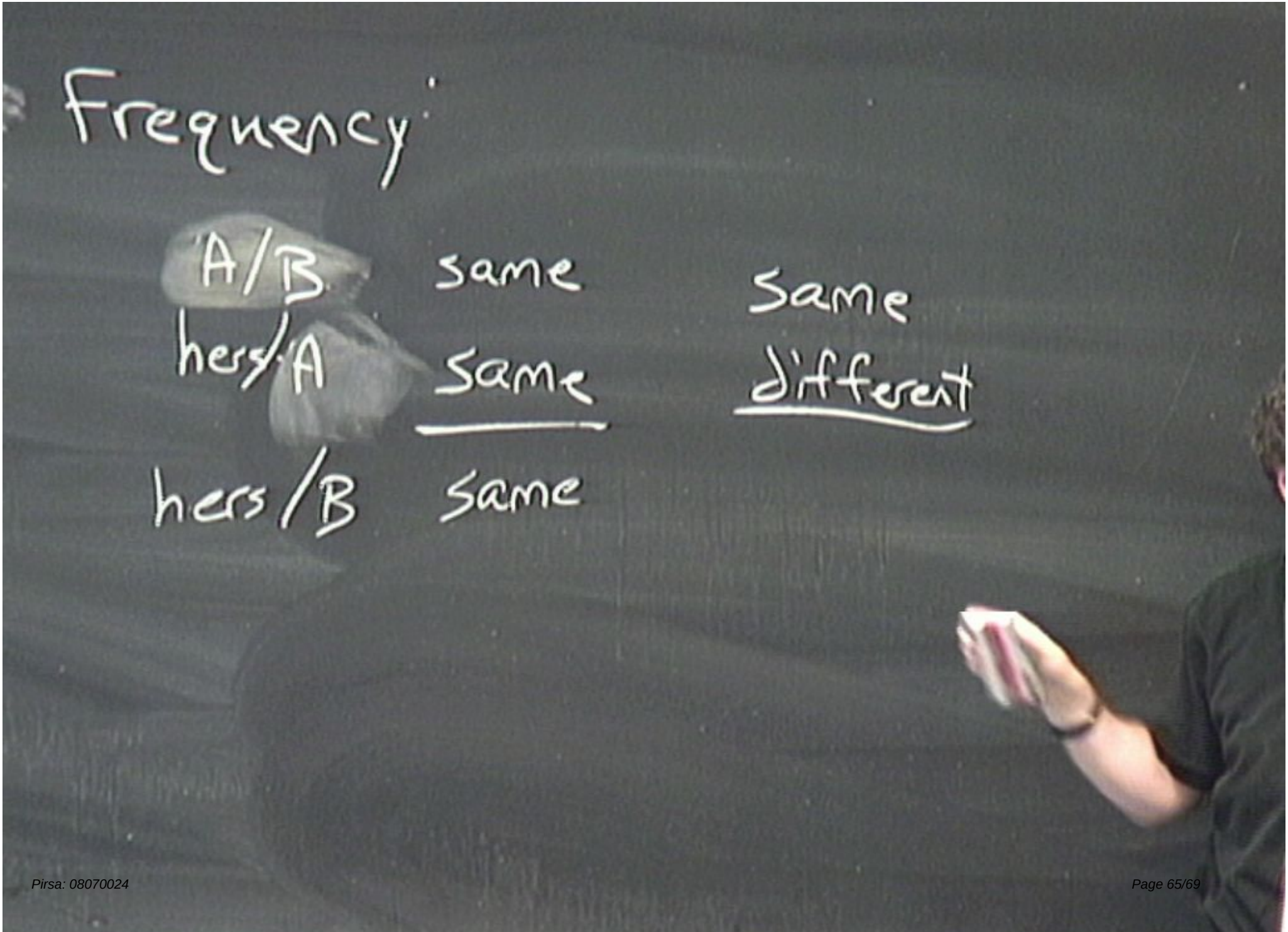
hers same

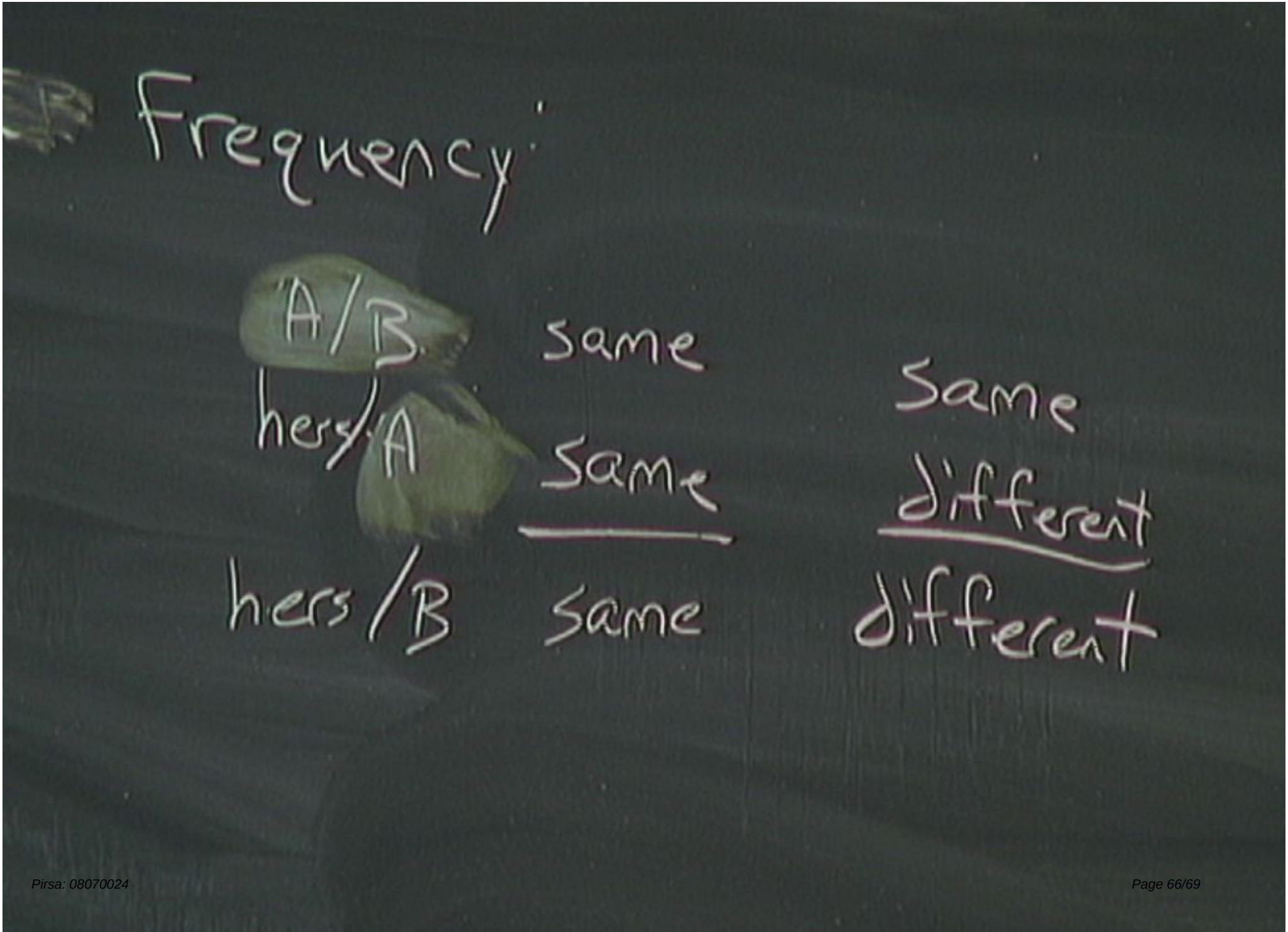
h

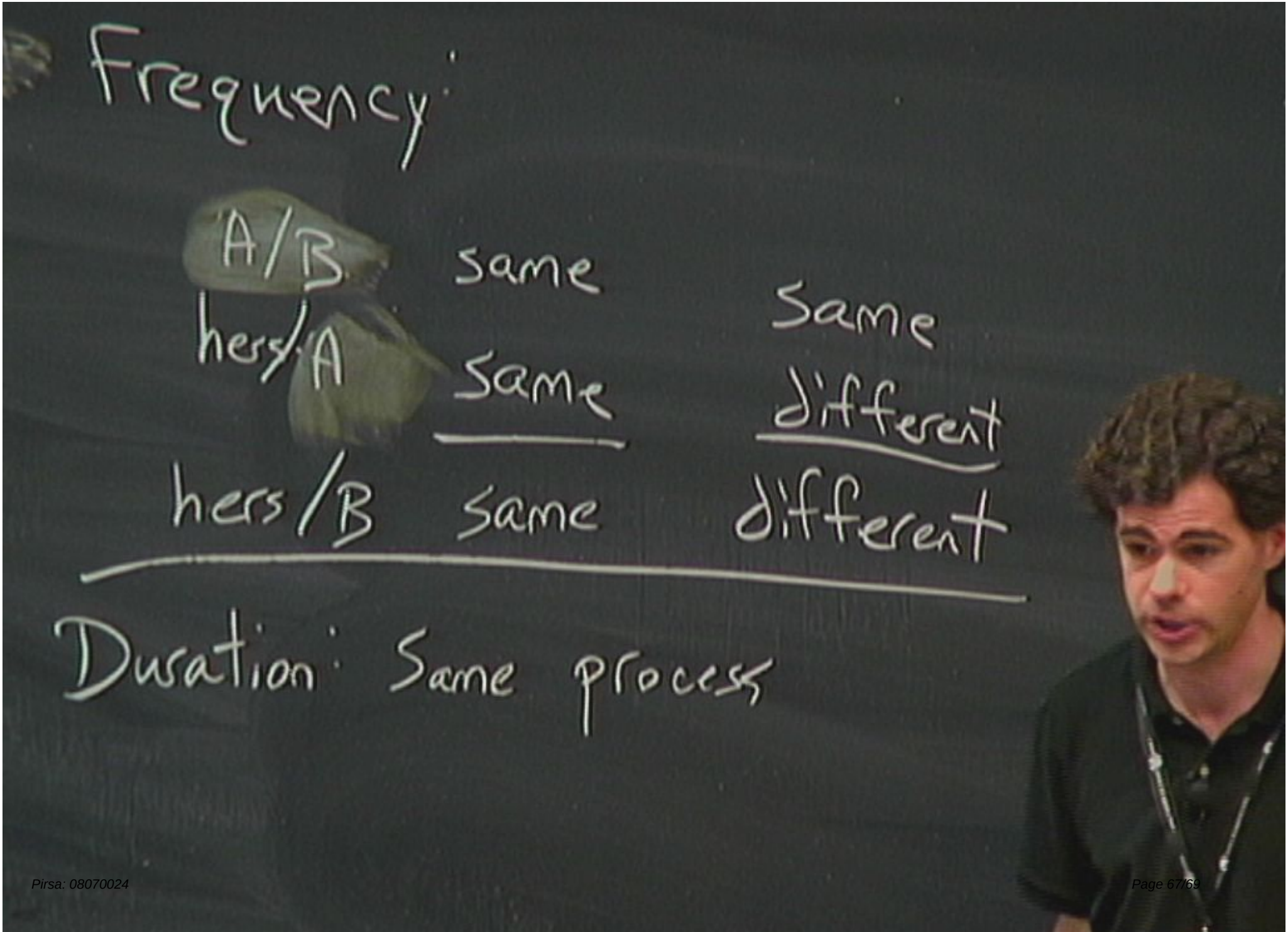
Quantum Teleportation

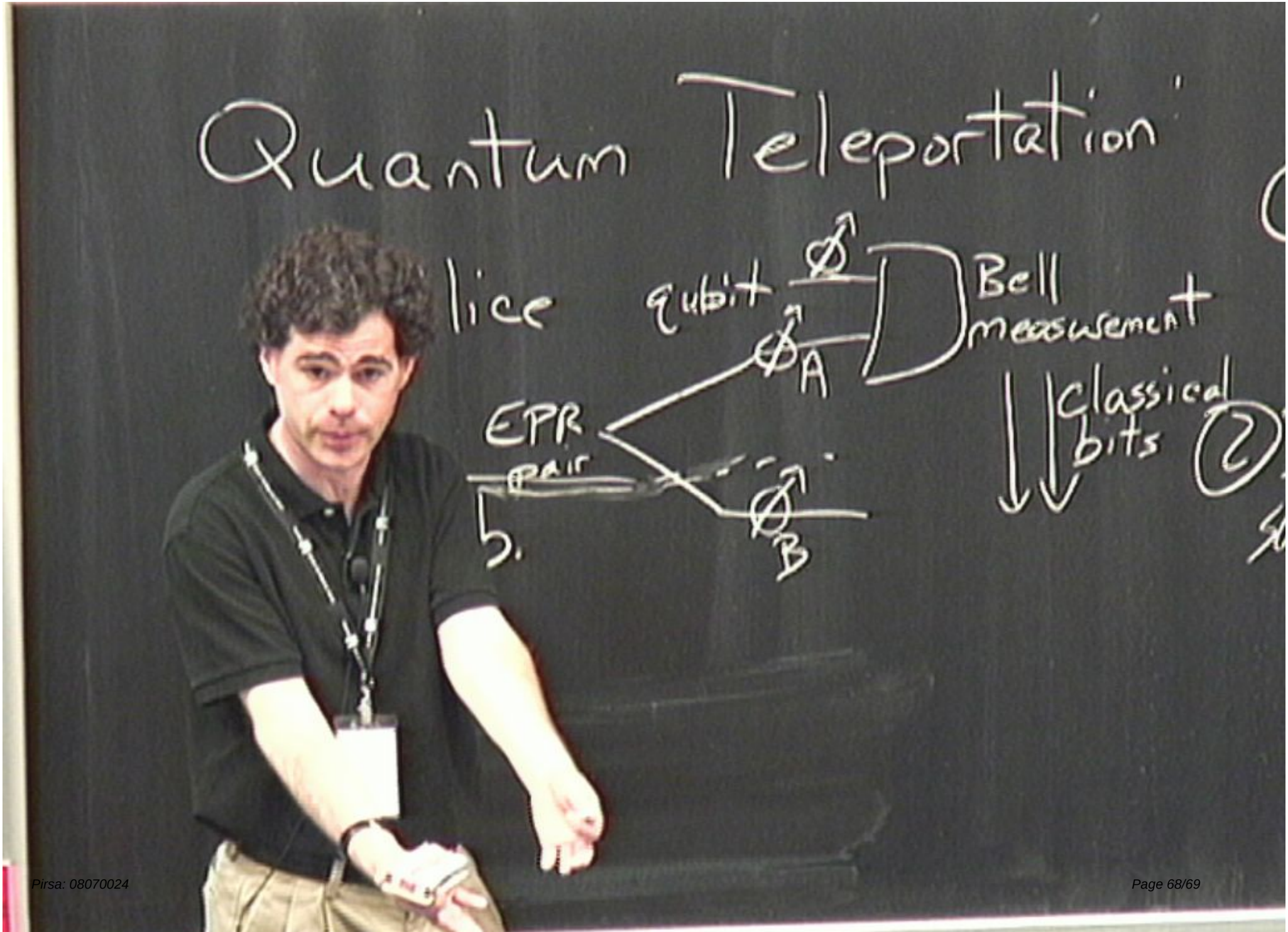


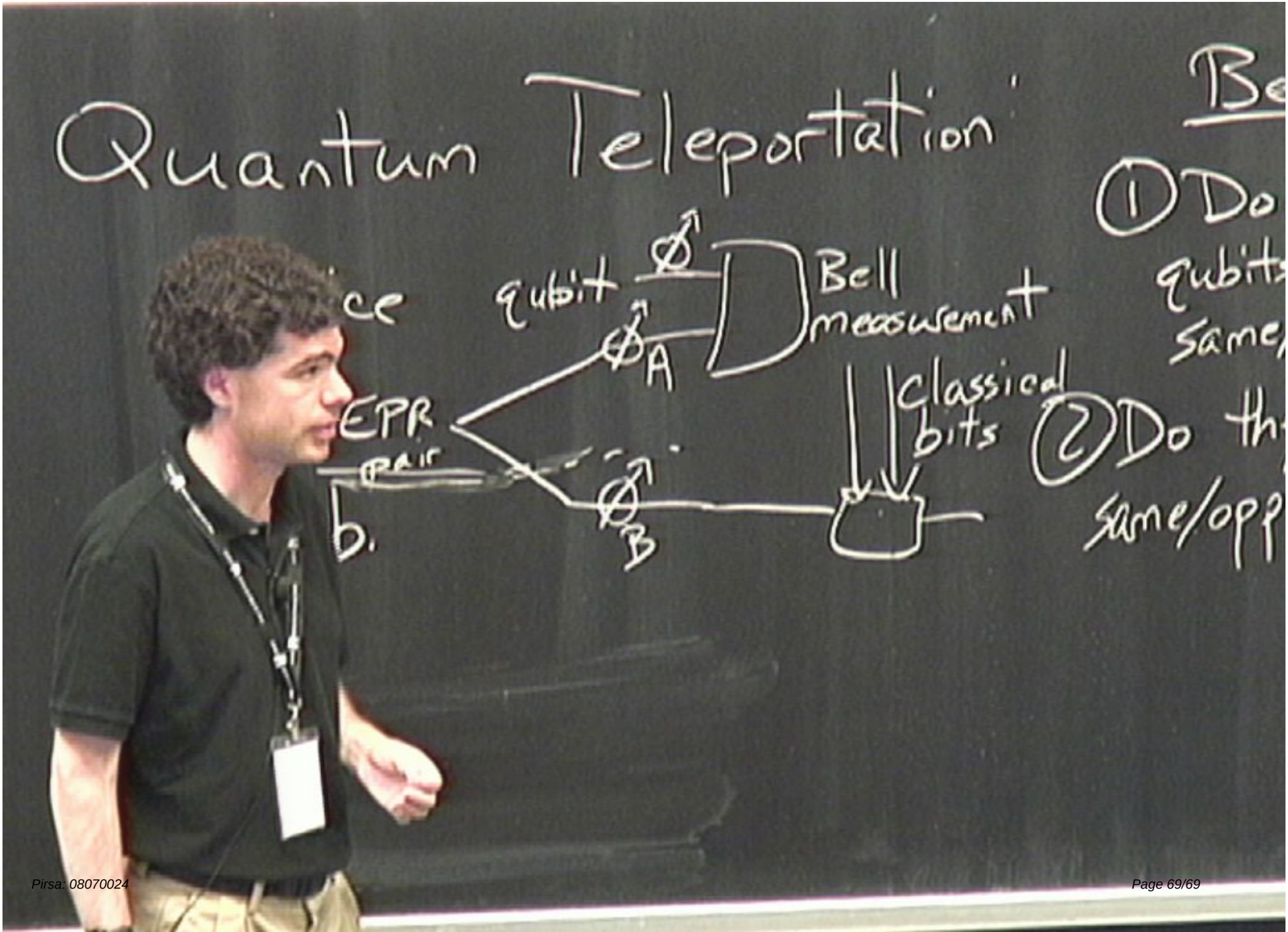

Frequency
A/B same
hers/A same
hers/B same
Same


Frequency
A/B same Same
hers/A same different
hers/B same


Frequency
A/B
hers/A
hers/B
same
same
same
same
different
different


Frequency:
A/B same Same
hers/A same different
hers/B same different
Duration: Same process


Quantum Teleportation
Alice
qubit
Bell measurement
EPR pair
classical bits
A
B


Quantum Teleportation
Bell measurement
qubit
EPR pair
classical bits
A
B
b.
same/opp