

Title: Explorations in Quantum Information - Lecture 13

Date: Mar 31, 2011 09:00 AM

URL: <http://pirsa.org/11030028>

Abstract:

From
Grains of
Pollen to
Evidence
for Atoms

How
Big Is A
Molecule?

$$E = \frac{\mu}{r_{ij}^3} \left[(m_i \cdot r_j) (m_j \cdot r_i) - (m_i \cdot m_j) \right]$$

$$\text{or } = \frac{\mu \mu}{r_{ij}^2}$$

From Grains of Pollen to Evidence for Atoms

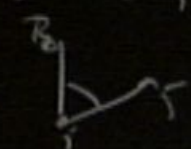
How Big Is A Molecule?

$\uparrow R_{0, z}$

1) scalar piece
 under $\mathcal{P} = \frac{1}{2} \frac{d}{dt} \dots$
 2)

$$E = \frac{\mu}{r_{ij}^3} \left[(m_i \cdot r_{ij}) (m_j \cdot r_{ij}) - (m_i \cdot m_j) \right]$$

$$\mathcal{P} = \frac{\gamma \gamma}{r_{ij}^2} \left[(1 - 3 \cos^2 \theta) \sigma_z \sigma_z + 3(1 - 3 \cos^2 \theta) (\sigma_+ \sigma_- + \sigma_- \sigma_+) + 2 \cos \theta \sin \theta \left[e^{i\phi} (\sigma_+ \sigma_z + \sigma_z \sigma_+) + e^{-i\phi} (\sigma_- \sigma_z + \sigma_z \sigma_-) \right] + 2 \cos \theta \sin \theta \left[e^{-i\phi} (\sigma_+ \sigma_+ + \sigma_- \sigma_-) \right] \right]$$

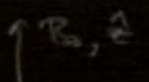


From
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How
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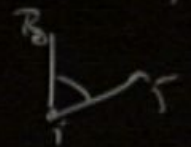
$$\mathcal{H}_{int}, \mathcal{H}_{2s} \} = 0$$

- 1) scalar piece under $\mathcal{H}_{int} = \omega_0 \hat{L}_z$
- 2)



$$E = \frac{\mu}{r_{ij}^3} \left[(m_i \cdot r_{ij}) (m_j \cdot r_{ij}) - (m_i \cdot m_j) \right]$$

$$\mathcal{H}_d = \frac{\gamma \hbar^2}{r_{ij}^3} \left[(1 - 3 \cos^2 \theta) \sigma_z \sigma_z \right. \\ \left. - \frac{3}{2} (1 - 3 \cos^2 \theta) (\sigma_+ \sigma_- + \sigma_- \sigma_+) \right. \\ \left. + \cos \theta \sin \theta \left[i (\sigma_+ \sigma_y + \sigma_y \sigma_+) + e^{-i\theta} (\sigma_+ \sigma_x + \sigma_x \sigma_+) \right] \right. \\ \left. + 2 \cos \theta \sin \theta \left[i \sigma_z \sigma_x + \sigma_z \sigma_x \right] \right]$$



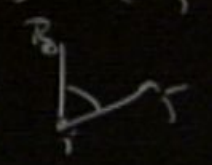
$$\{H_{int}, H_{0,2}\} = 0$$

- 1) scalar piece
under $\mathcal{P}_{int} = \omega_0 \sigma_z$
- 2)

$\uparrow R_{0,2}$

$$E = \frac{\mu}{r_{ij}^3} \left[(m_i \cdot r_{ij}) (m_j \cdot r_{ij}) - (m_i \cdot m_j) r_{ij}^2 \right]$$

$$\mathcal{P}_d = \frac{\gamma \delta}{r_{ij}^2} \left[(1 - 3 \cos^2 \theta) \sigma_z \sigma_z \right. \\ \left. - 3(1 - 3 \cos^2 \theta) (\sigma_+ \sigma_+ + \sigma_- \sigma_-) \right. \\ \left. + 2 \cos \theta \sin \theta \left[i (\sigma_+ \sigma_2 + \sigma_- \sigma_2) + e^{-i\theta} (\sigma_+ \sigma_1 + \sigma_- \sigma_1) \right] \right]$$



From
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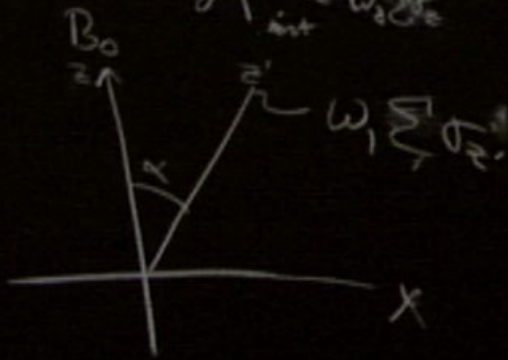
How
Big Is A
Molecule?

$$\left. \frac{\partial H_{int}}{\partial r_{ij}}, \frac{\partial H_{23}}{\partial r_{ij}} \right\} = 0$$

1) scalar piece

under $\frac{\partial H_{int}}{\partial r_{ij}} = \omega_1 \frac{\partial \sigma_1}{\partial r_{ij}}$

2)



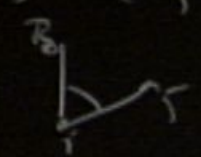
$$E = \frac{\mu}{r_{ij}^3} \left[(m_i \cdot r_{ij}) (m_j \cdot r_{ij}) - (m_i \cdot m_j) r_{ij}^2 \right]$$

$$\frac{\partial E}{\partial r_{ij}} = \frac{\mu}{r_{ij}^3} \left[(1 - 3 \cos^2 \theta) \sigma_1 \sigma_2 \right]$$

$$= \frac{\mu}{r_{ij}^3} \left[(1 - 3 \cos^2 \theta) (\sigma_1 \sigma_2 + r - \sigma_1 \sigma_2) \right]$$

$$+ \cos \theta \sin \theta \left[\frac{i \hbar}{r_{ij}} (\sigma_1 \sigma_2 + \sigma_2 \sigma_1) + e^{-i\theta} (\sigma_1 \sigma_2 - \sigma_2 \sigma_1) \right]$$

$$+ 2 \cos \theta \sin \theta \left[\frac{i \hbar}{r_{ij}} (\sigma_1 \sigma_2 + \sigma_2 \sigma_1) + e^{-i\theta} (\sigma_1 \sigma_2 - \sigma_2 \sigma_1) \right]$$



From
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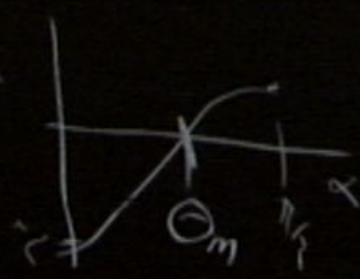
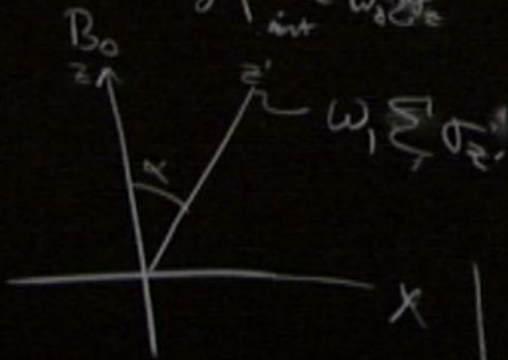
How
Big Is A
Molecule?

$$\langle H_{int}, H_{D_2} \rangle = 0$$

1) scalar piece

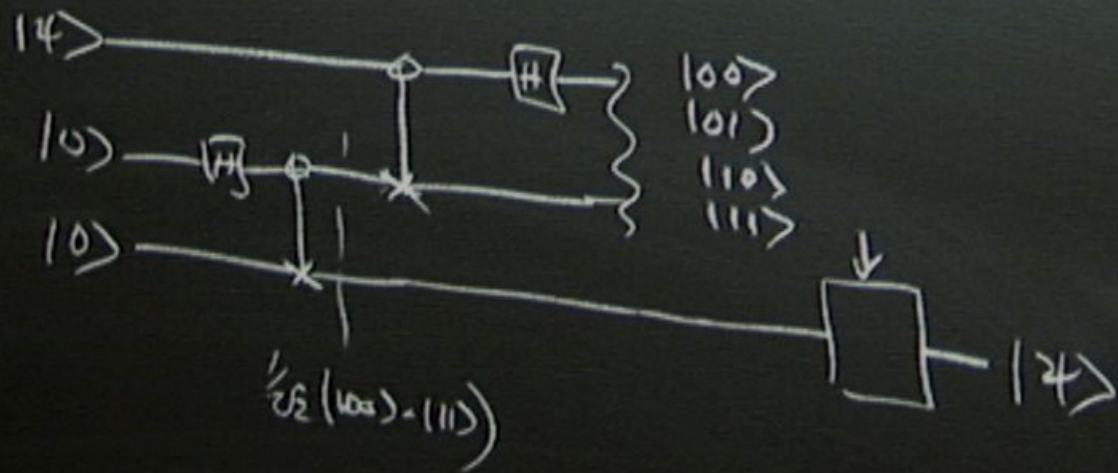
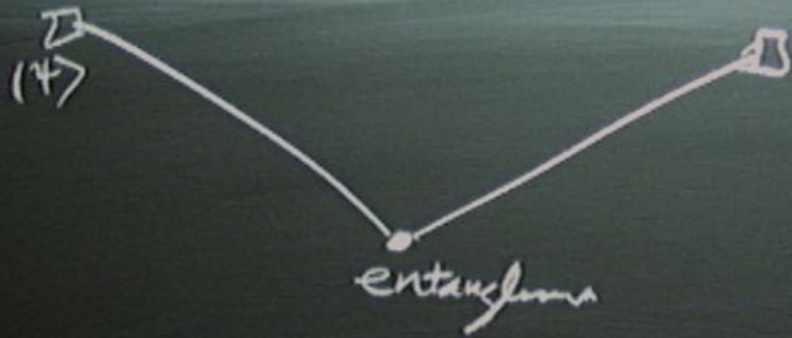
under $H_{int} = \omega_0 \sigma_z$

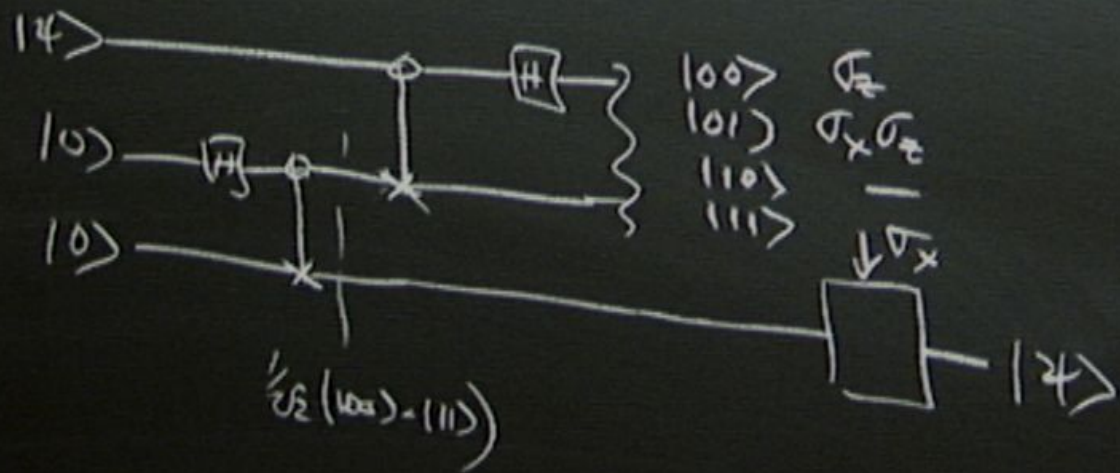
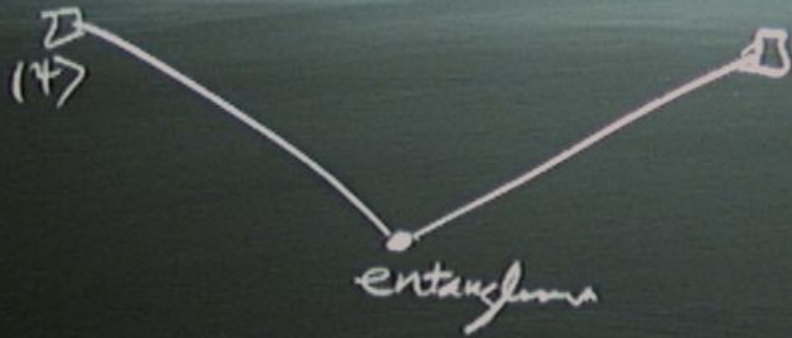
2)

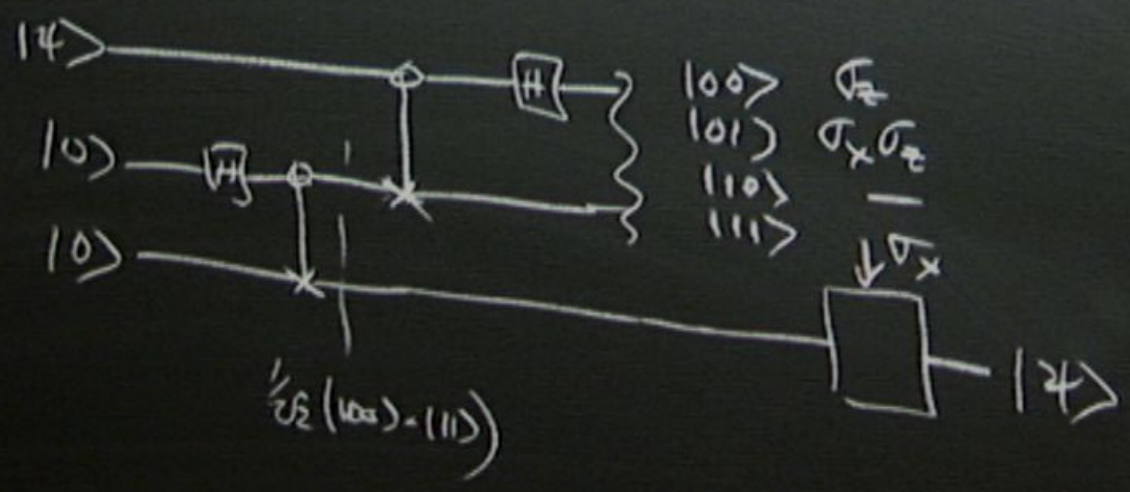
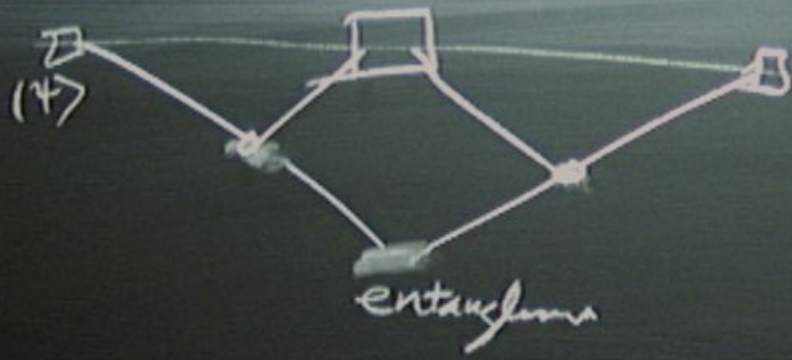


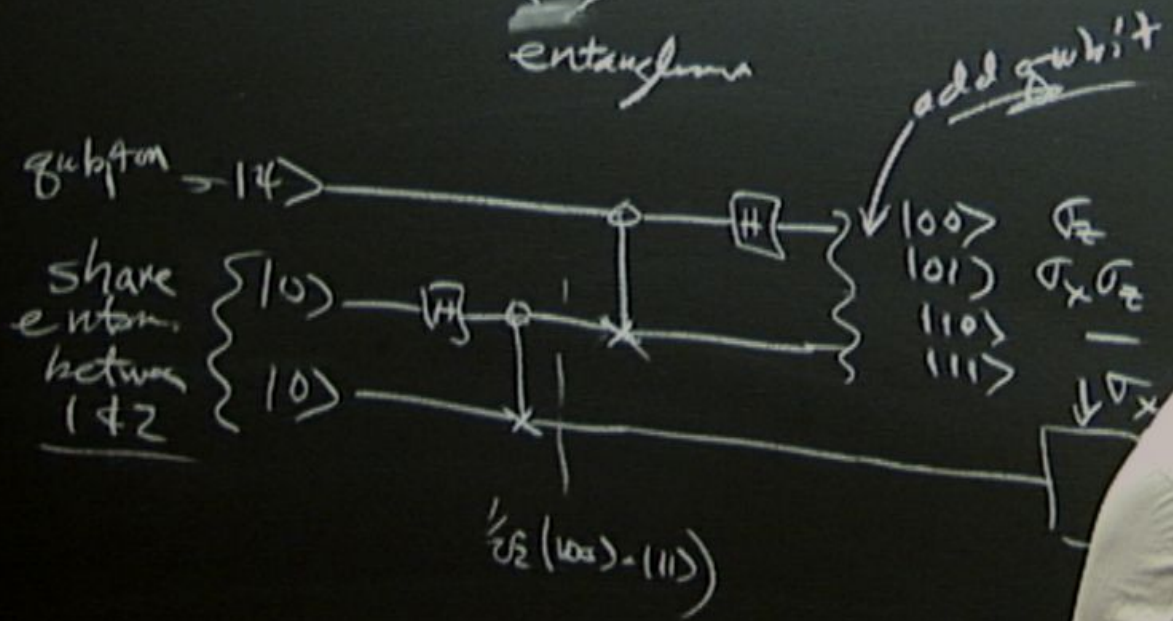
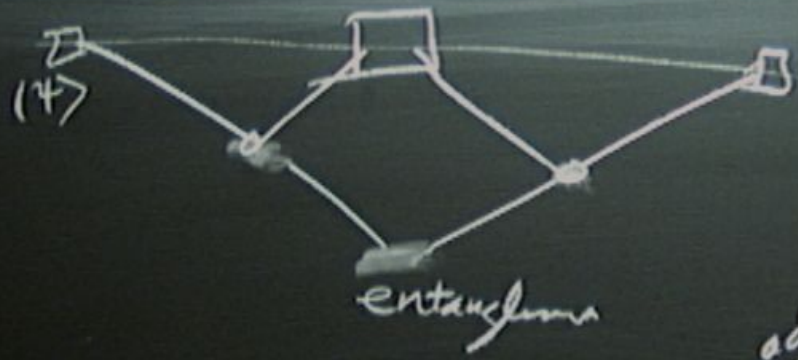
$$E = \frac{\mu}{r_{ij}^3} \left[(m_i \cdot r_{ij}) (m_j \cdot r_{ij}) - (m_i \cdot m_j) r_{ij}^2 \right]$$

$$\langle H_{int} \rangle = \frac{\mu}{r_{ij}^3} \left[(1 - 3 \cos^2 \theta) \sigma_z \sigma_z + 3(1 - 3 \cos^2 \theta) (\sigma_+ \sigma_- + \sigma_- \sigma_+) + 2 \cos \theta \sin \theta (i \sigma_+ \sigma_z + \sigma_z \sigma_+) + e^{-i\alpha} (\sigma_+ \sigma_+ + \sigma_- \sigma_-) + 2 \cos \theta \sin \theta (\sigma_+ \sigma_+ + \sigma_- \sigma_-) \right]$$

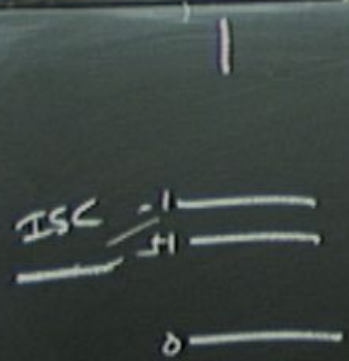




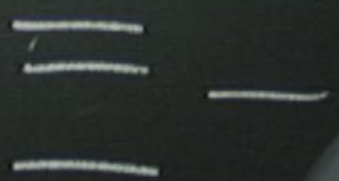




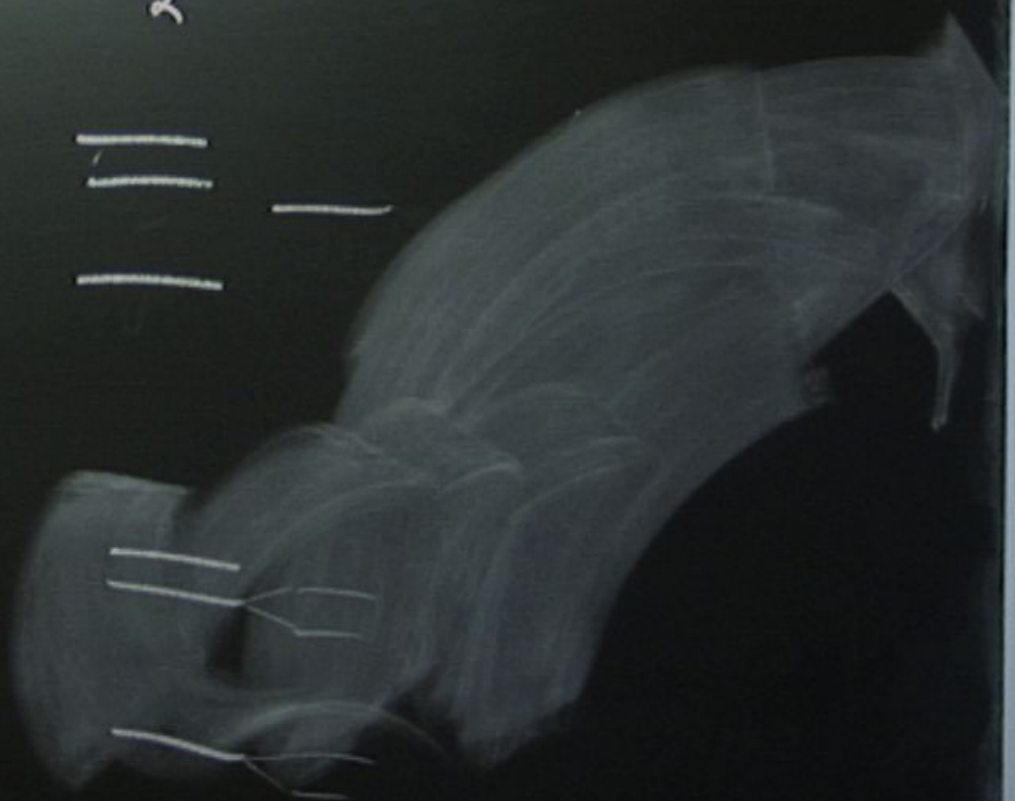
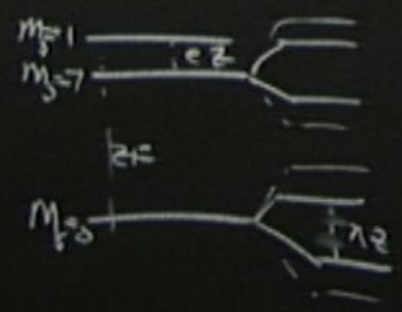
F



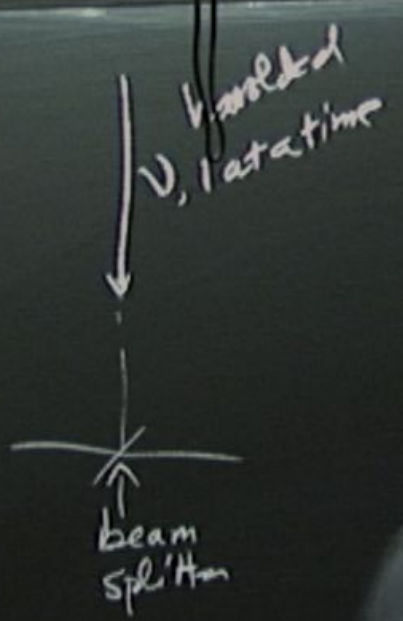
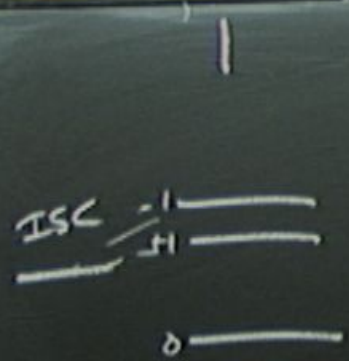
2



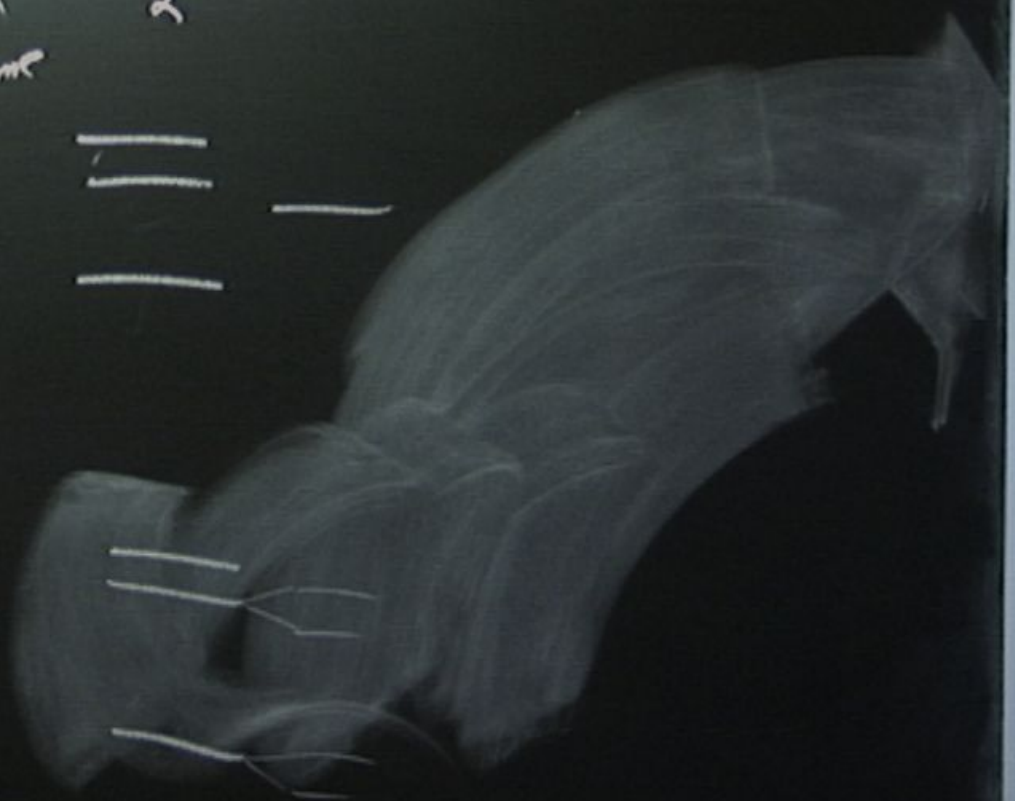
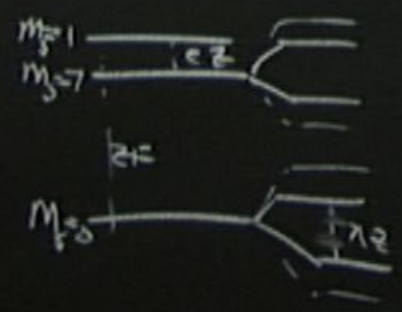
A

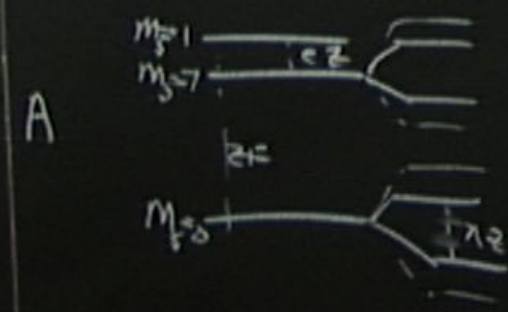
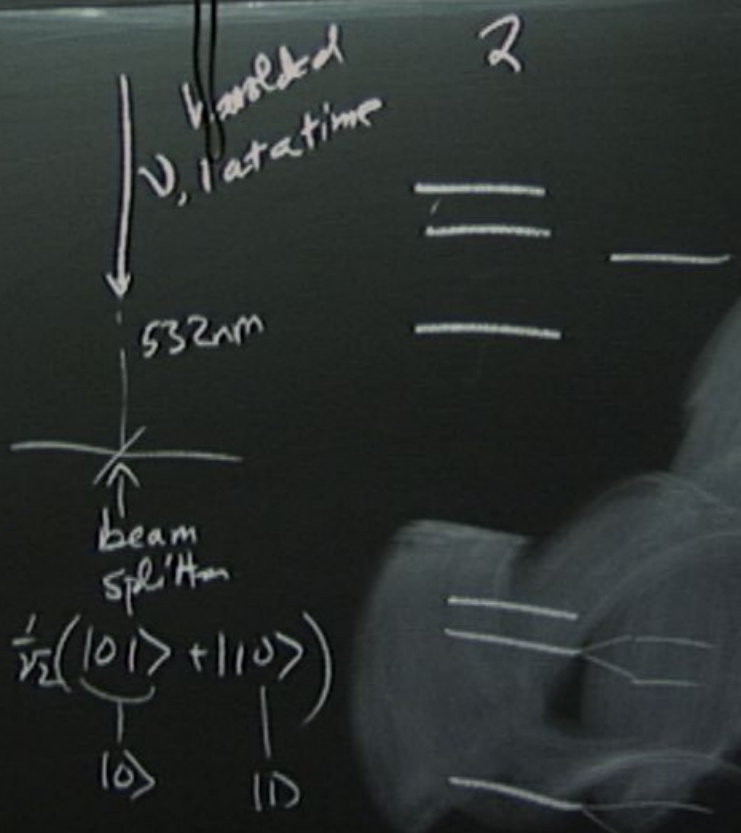
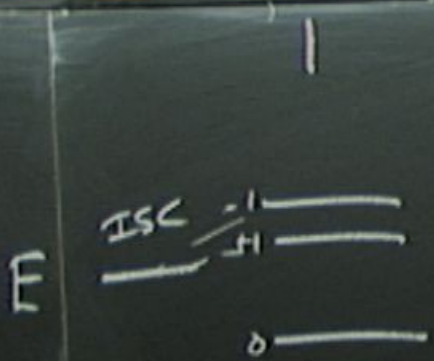


E

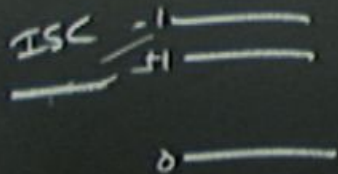


A





FF



1
V, 1 at a time
2

1, cool NV

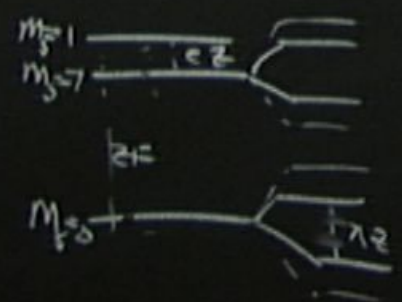
532nm

beam splitter

$$\frac{1}{\sqrt{2}}(|01\rangle + |10\rangle)$$

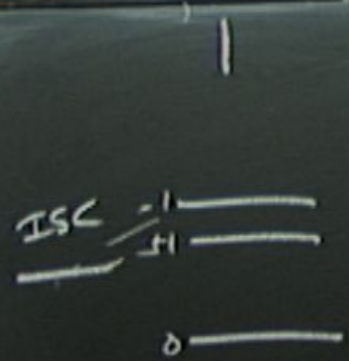
$$\left(\begin{array}{c} |0\rangle \\ |1\rangle \end{array} \right)$$

A



$$|A \underbrace{m_s^e m_s^A}_{1} \underbrace{m_s^e m_s^A}_{2}\rangle$$

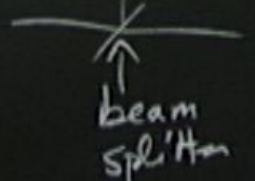
F



ν , 1 at a time
 ν , 1 at a time
 532nm



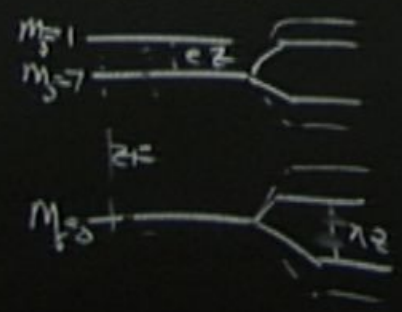
1, cool NV
 $|A+1, \uparrow, A+1 \uparrow\rangle \langle$



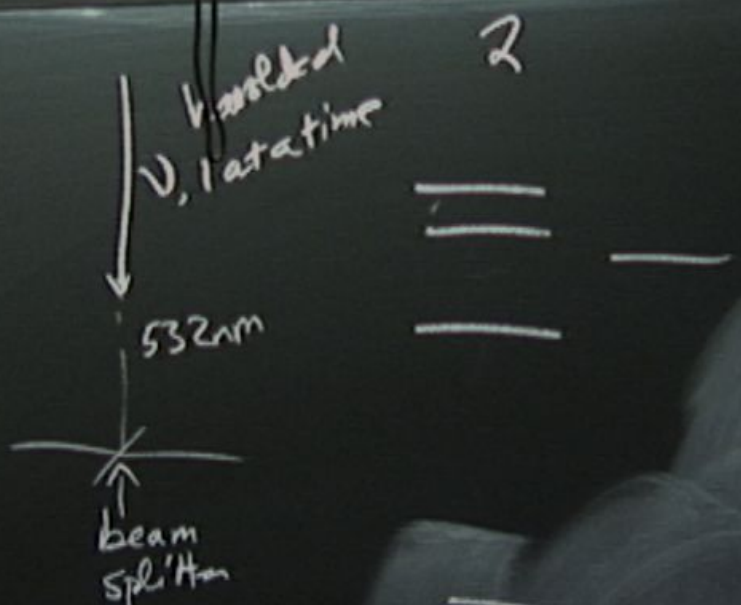
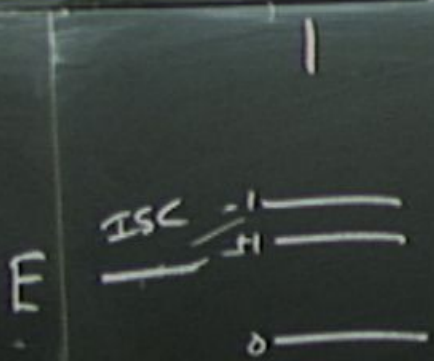
$$\frac{1}{\sqrt{2}}(|01\rangle + |10\rangle)$$

$|0\rangle$ $|1\rangle$

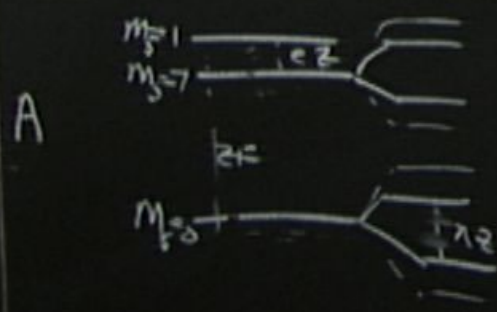
A



$$|A \underbrace{m_s^e m_s^A}_1 \underbrace{m_s^e m_s^A}_2\rangle$$



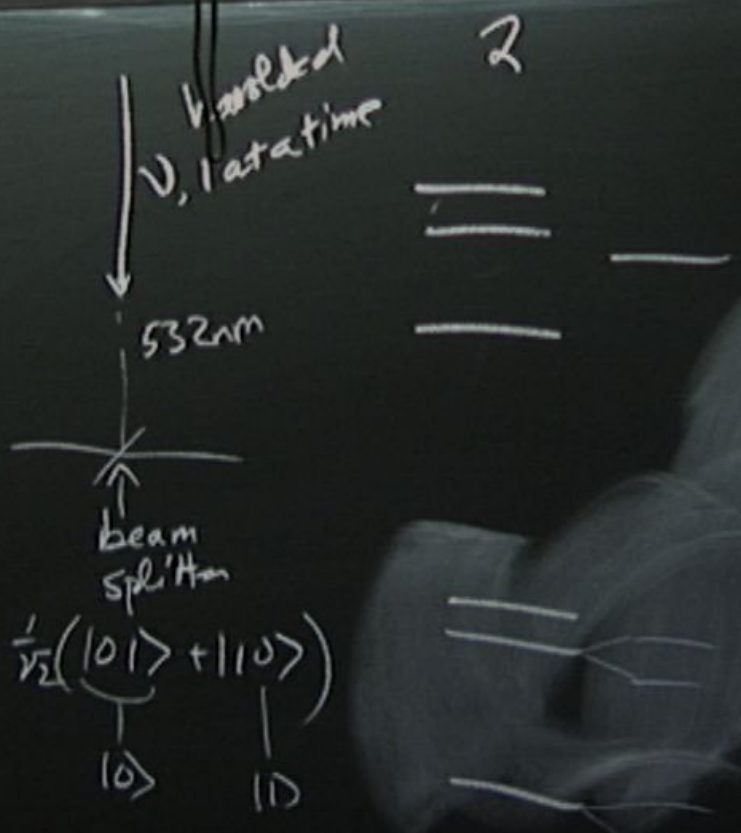
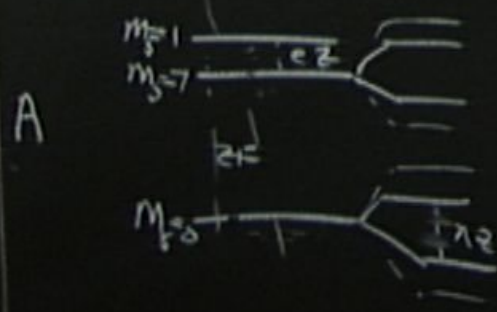
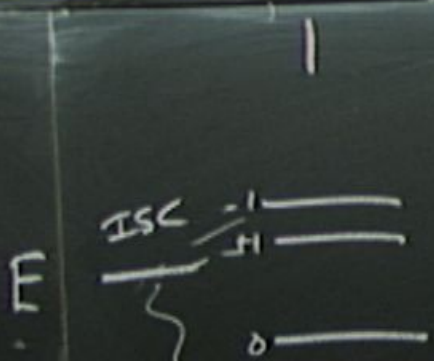
1, cool NV
 $|A+1, \uparrow, A+1 \uparrow\rangle \langle |$
 2. \downarrow



$$\frac{1}{\sqrt{2}}(|01\rangle + |10\rangle)$$

$|0\rangle$ $|1\rangle$

$$|A \underbrace{m_s^e m_s^h}_1 \underbrace{m_s^e m_s^h}_2 \rangle$$



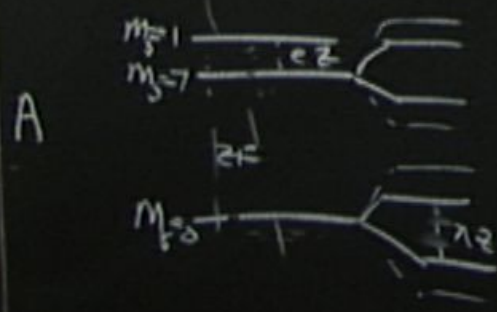
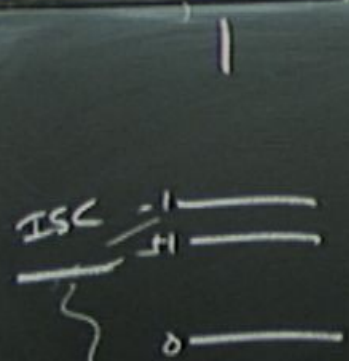
1, cool NV

$$\frac{|A+1, \uparrow, A+1 \uparrow\rangle \langle|}{2 \cdot \nu}$$

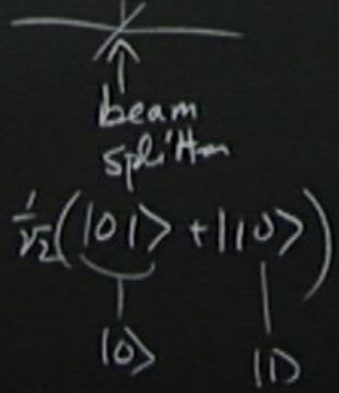
$$\frac{1}{\sqrt{2}} (|A0 \uparrow, A1 \uparrow\rangle + |A1 \uparrow, A0 \uparrow\rangle)$$

$$|A \underbrace{m_s^e m_s^h}_1 \underbrace{m_s^e m_s^h}_2\rangle$$

F



1
 ↓ ν , 1 at a time
 532nm



1, cool NV
 $|A+1, \uparrow, A+1 \uparrow\rangle \langle$
 $2, \downarrow$

$\frac{1}{\sqrt{2}}(|A0\uparrow, A1\uparrow\rangle + |A1\uparrow, A0\uparrow\rangle)$
 → test
 0- \hbar

$$|A \underbrace{m_s^e m_s^h}_1 \underbrace{m_s^e m_s^h}_2 \rangle$$

From
Grains of
Pollen to
Evidence
for Atoms

How
Big Is A
Molecule?

left

right

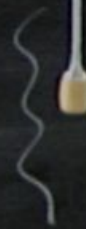
$$\sum_{i=1}^n \frac{1}{r_i^2} \rightarrow 19$$

$$\sum_{i=1}^n \frac{1}{r_i} \rightarrow 19$$

$$(m_{i,j})_{i,j} \rightarrow \times 10$$

$$m_{i,j} \rightarrow \times 10$$

$$\sum_{i=1}^n A_i$$



From
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How
Big Is A
Molecule?

left

right

ΣB 10

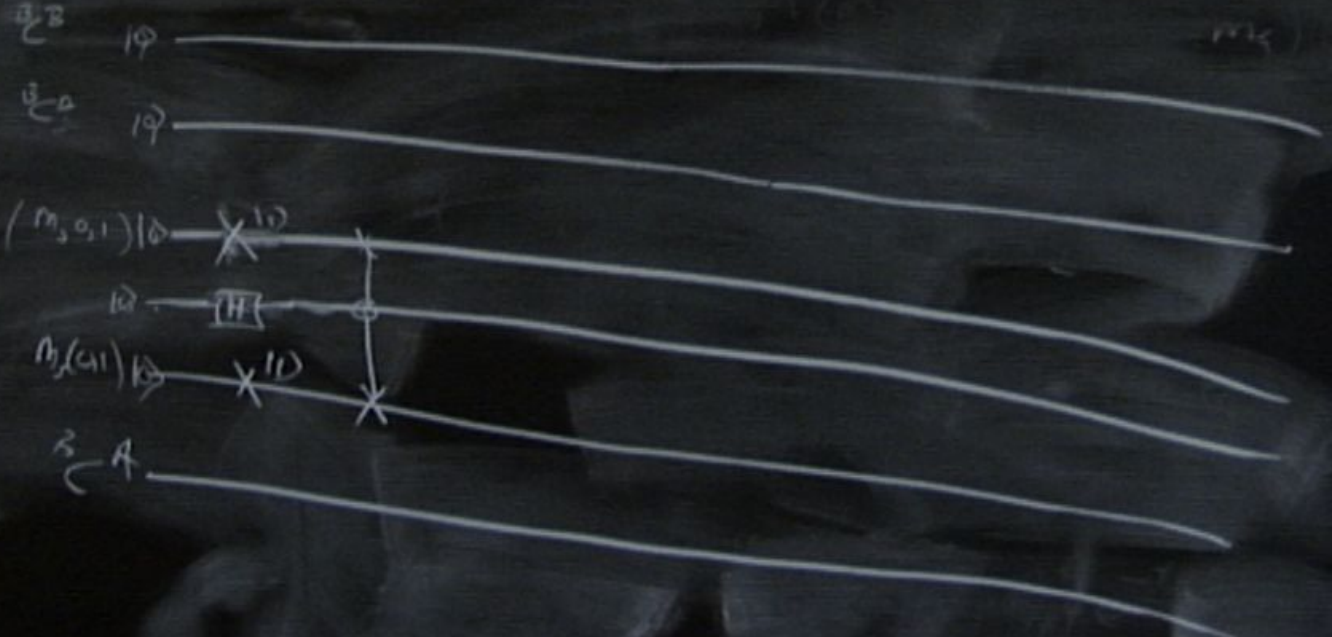
ΣC 10

$(m, s, i) 10$ X 10

10 III

$m, (c, i) 10$ X 10

ΣA



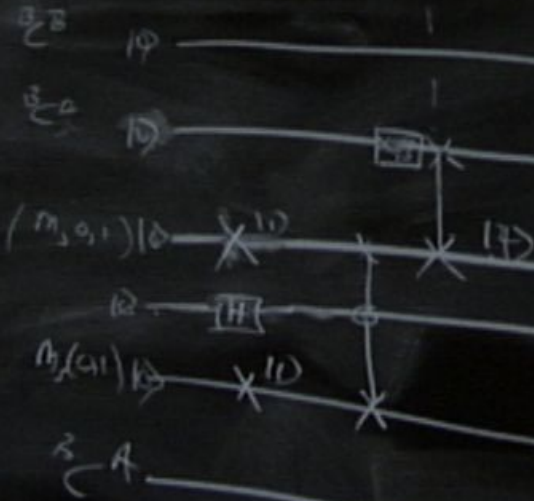
From
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for Atoms

How
Big Is A
Molecule?

$$|7\rangle = \sqrt{10}|0\rangle + \sqrt{2}|1\rangle$$

left

right



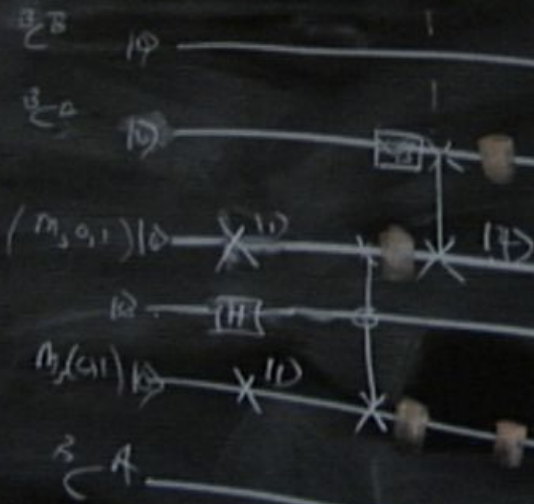
From
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$$|7\rangle = \sqrt{10}|0\rangle + \sqrt{2}|1\rangle$$

left

right



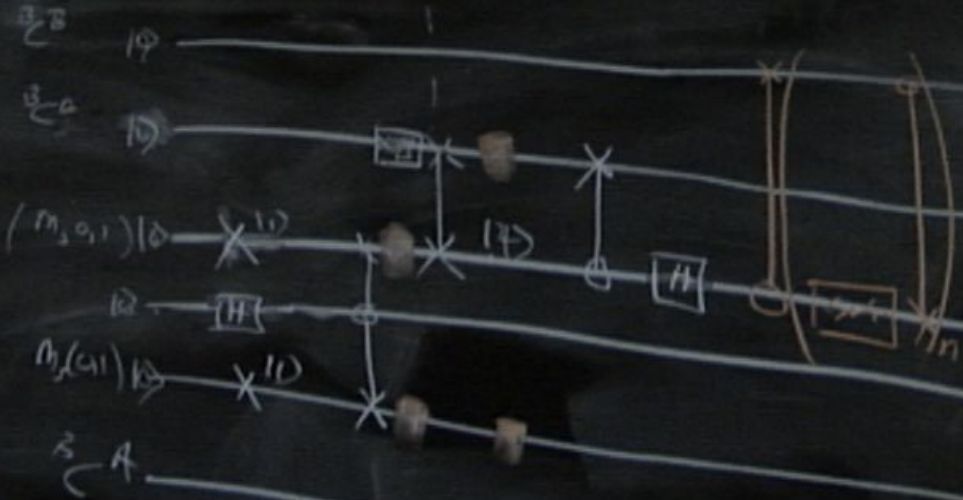
From
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How
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Molecule?

$$|7\rangle = \sqrt{10}|0\rangle + \sqrt{2}|1\rangle$$

left

right

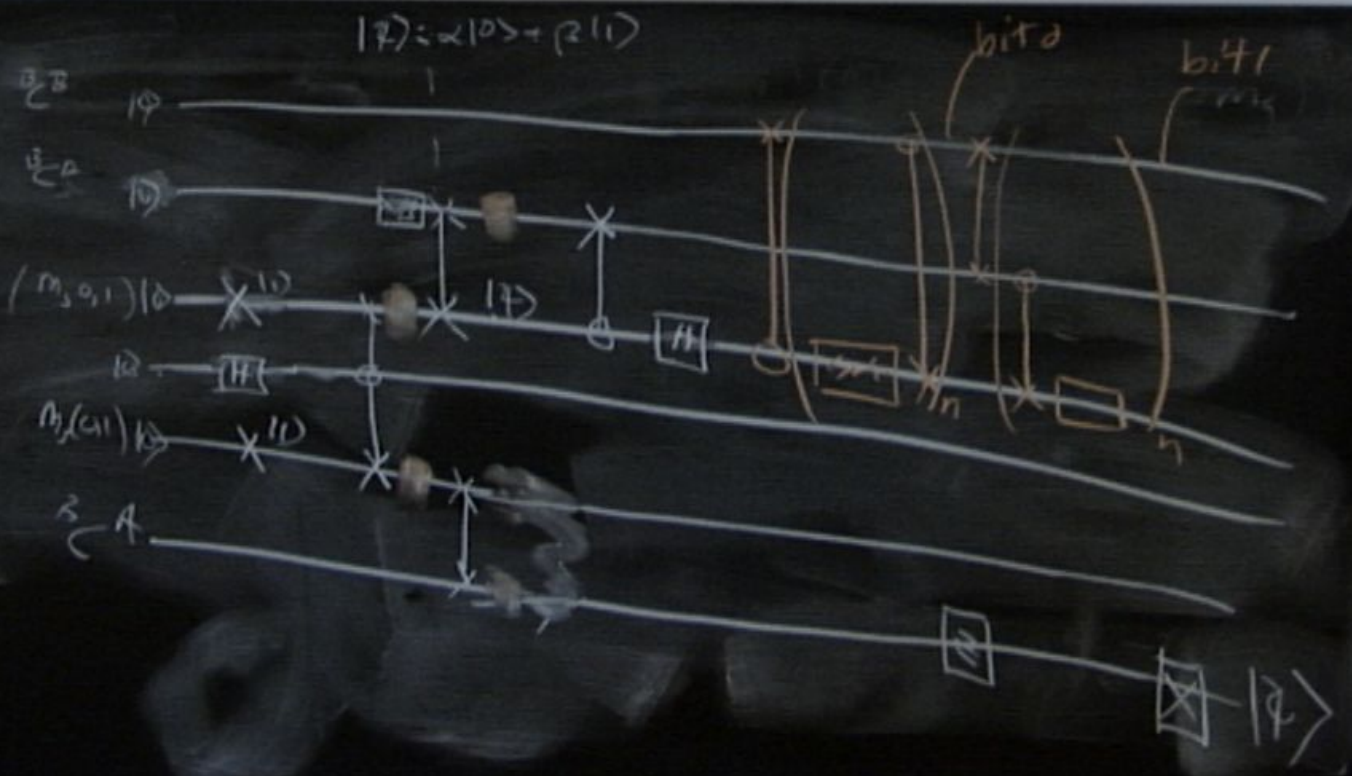


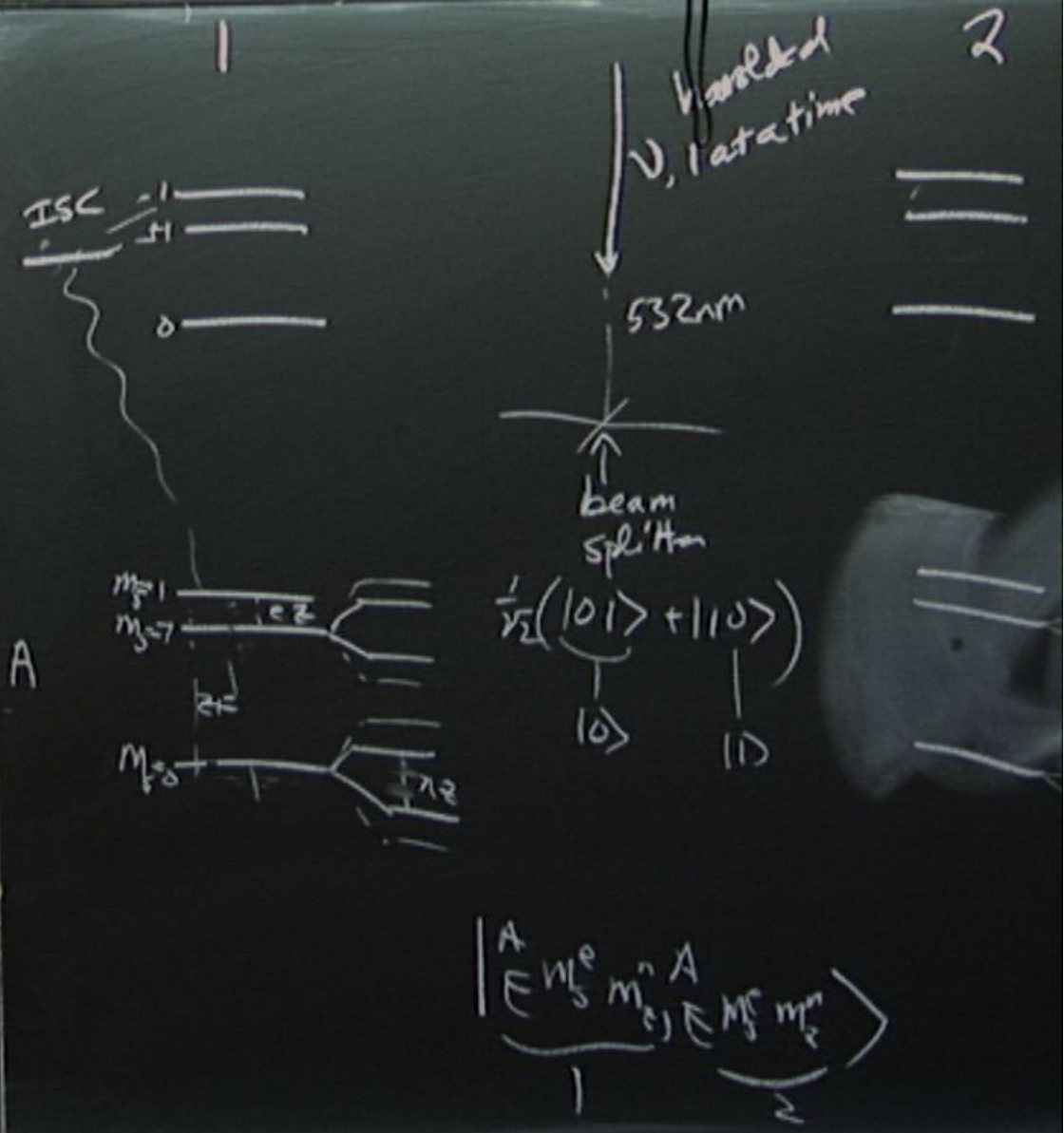
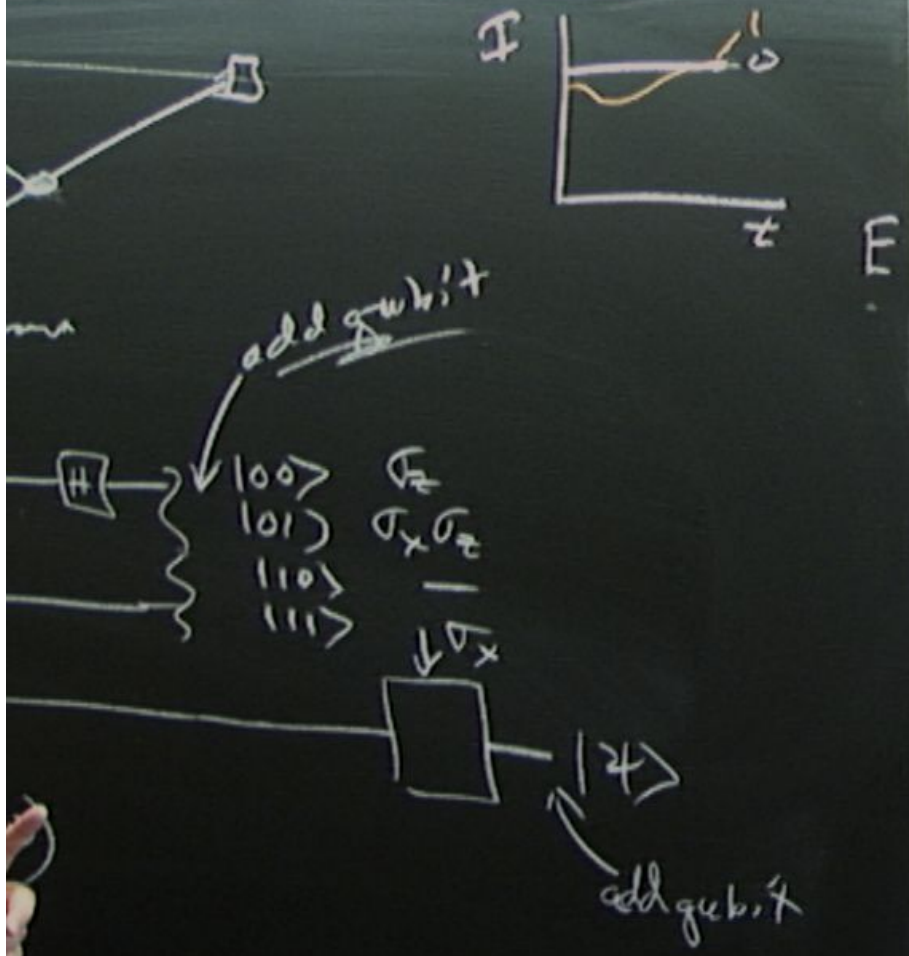
From
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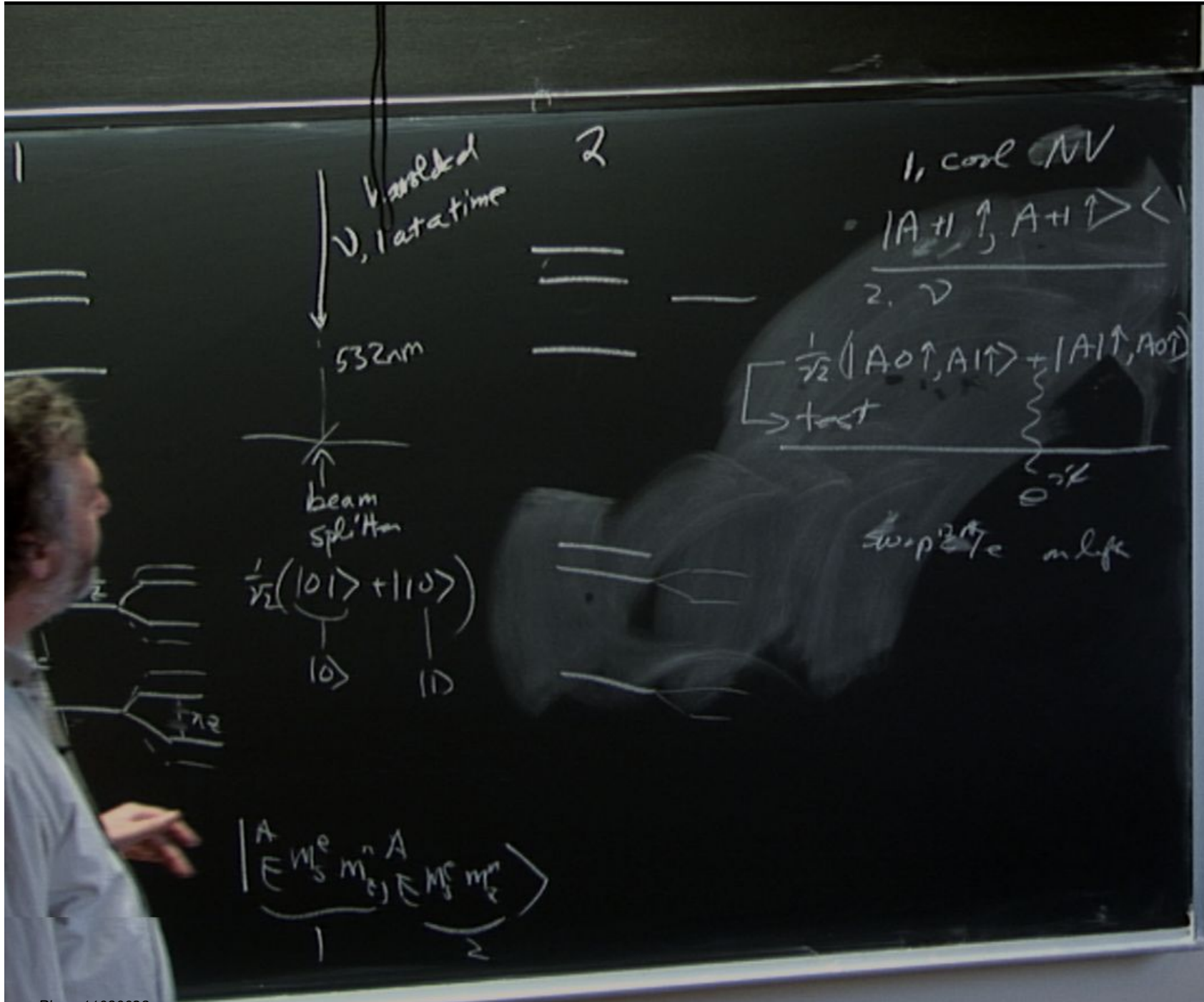
How
Big Is A
Molecule?

left

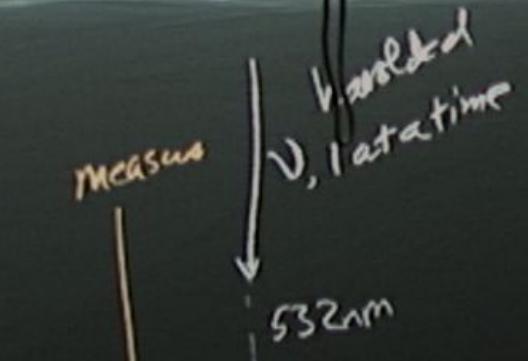
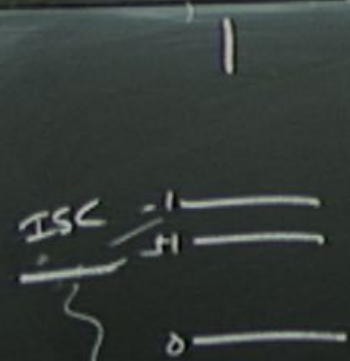
right



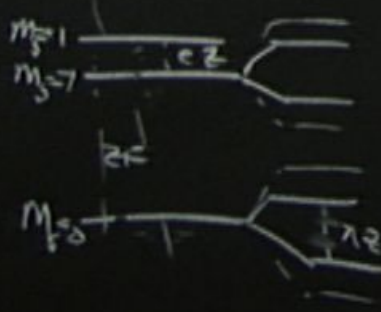




FF



A



$$\frac{1}{\sqrt{2}}(|01\rangle + |10\rangle)$$

$$\begin{array}{c} |0\rangle \quad |1\rangle \end{array}$$

$$|A \rangle = \frac{1}{\sqrt{2}} \left(|m_s^e m_s^A\rangle + |m_s^e m_s^A\rangle \right)$$

1, cool NV

$$|A+1 \uparrow, A+1 \uparrow\rangle$$

$$\frac{1}{\sqrt{2}} (|A0 \uparrow, A1 \uparrow\rangle + |A1 \uparrow, A0 \uparrow\rangle)$$

→ test

swap state in life

From
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for Atoms

How
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left

right

