

Title: Quantum Foundations Lecture - 230109

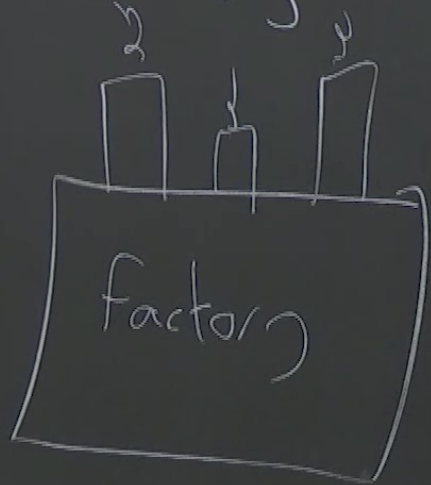
Speakers: Lucien Hardy

Collection: Quantum Foundations (2022/2023)

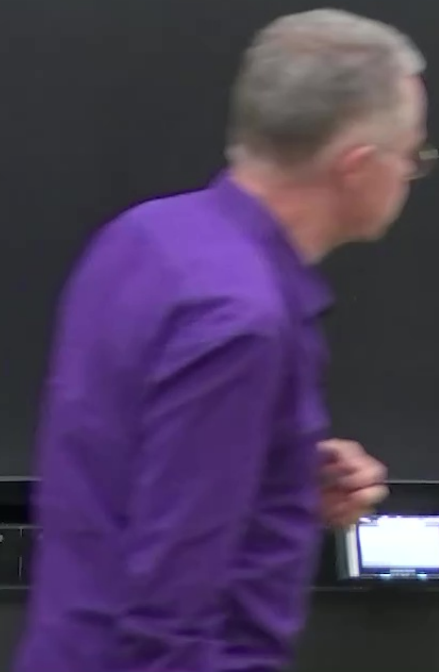
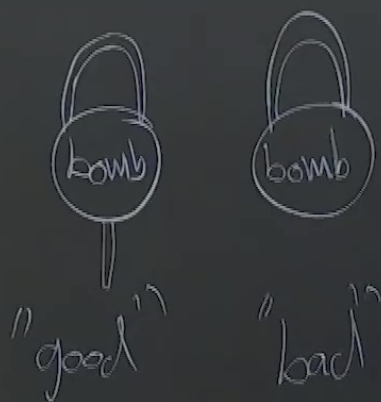
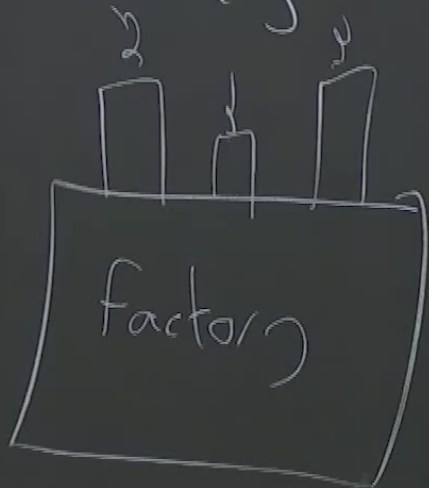
Date: January 09, 2023 - 10:15 AM

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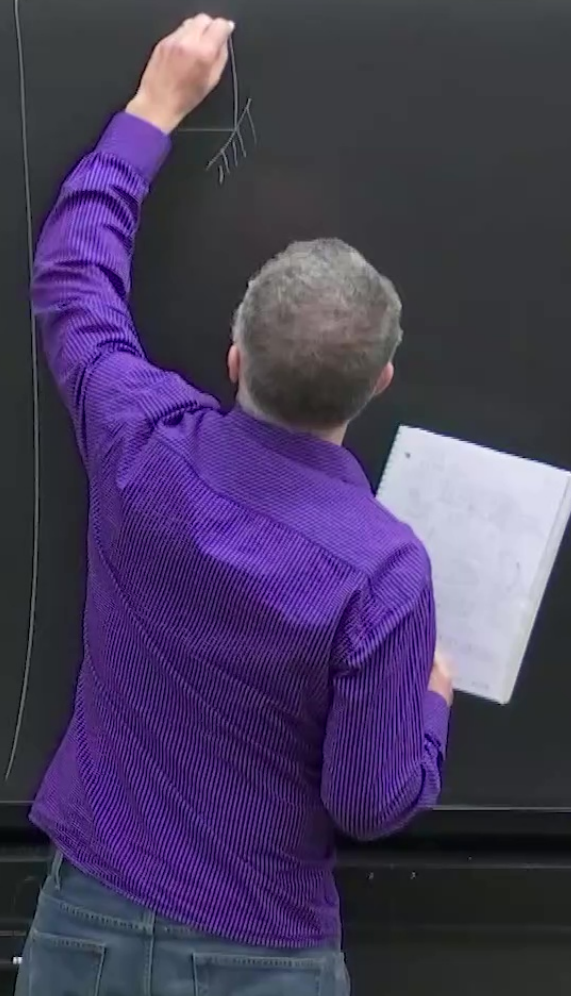
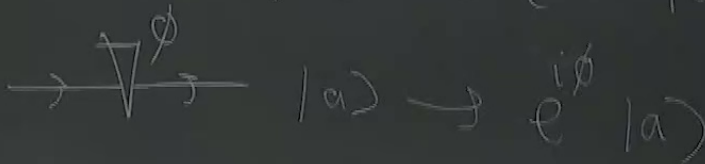
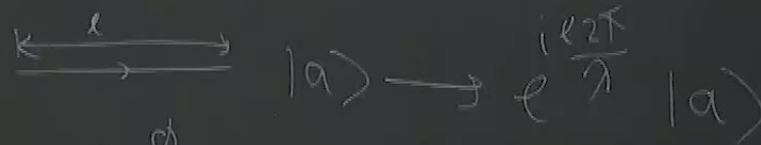
Elitzur Vaidman Bomb problem



Elitzur Vaidman Bomb problem



Interferometers
one particle.

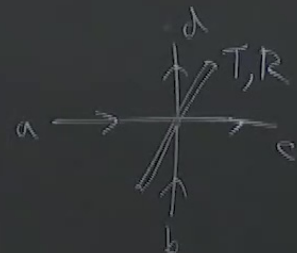


Interferometers one particle.

$|s\rangle$
 $|a\rangle \rightarrow e^{i\frac{k2\pi}{\lambda}x} |a\rangle$
 $|a\rangle \rightarrow e^{i\phi} |a\rangle$



$$|a\rangle \rightarrow i|a\rangle$$



$$|a\rangle \rightarrow \sqrt{T}|c\rangle + i\sqrt{R}|d\rangle$$

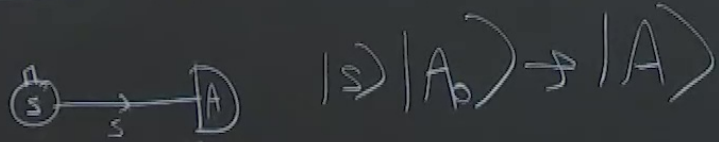
$$|b\rangle \rightarrow i\sqrt{R}|c\rangle + \sqrt{T}|d\rangle$$

$$\langle a|b\rangle = (\sqrt{R}(1-i\sqrt{R}|d\rangle)) (i\sqrt{R}|c\rangle + \sqrt{T}|d\rangle)$$

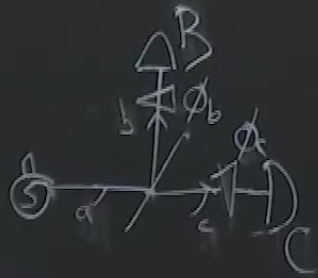
$$a \rightarrow D \quad |a\rangle|D_0\rangle \rightarrow |D\rangle$$

$$\rightarrow \boxed{D} \rightarrow |a\rangle|D_0\rangle \rightarrow |a\rangle|D\rangle$$

2nd example



First example



$$|a\rangle |B_0\rangle |C_0\rangle \rightarrow (i\sqrt{R} e^{i\phi_b} |b\rangle + \sqrt{T} e^{i\phi_c} |c\rangle) |B_0\rangle |C_0\rangle$$
$$\rightarrow i\sqrt{R} e^{i\phi_b} |B\rangle |C_0\rangle$$

$$\text{prob}(B_0 C) = T \quad (= |\sqrt{T} e^{i\phi_c}|^2)$$

$$\text{prob}(B C_0) = R$$

$$\text{prob}(B C) = 0 = \text{prob}(B_0 C_0)$$

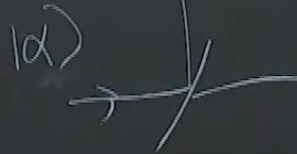
$$e^{i\phi_c} |C\rangle |B_0\rangle |C_0\rangle$$

$$e^{i\phi_c} |B_0\rangle |C\rangle$$



$$|D_0\rangle \rightarrow |D\rangle$$

$$|a\rangle |D_0\rangle \rightarrow |a\rangle |D\rangle$$

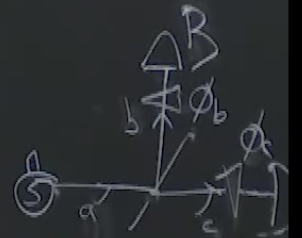


$$|\alpha\rangle \rightarrow \left| \frac{\alpha}{\sqrt{2}} \right\rangle \left| \frac{\alpha}{\sqrt{2}} \right\rangle$$

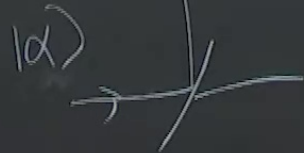
Zustände



First example

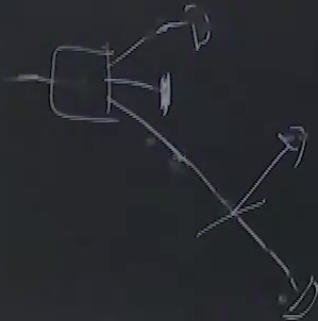


$|D\rangle$

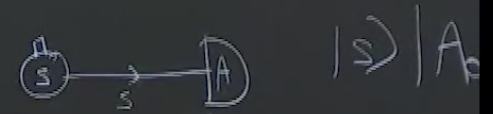


$\rightarrow |d\rangle |D\rangle$

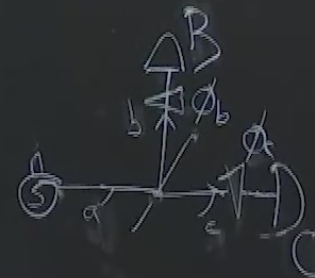
$|\alpha\rangle \rightarrow \left| \frac{\alpha}{\sqrt{2}} \right\rangle \left| \frac{\alpha}{\sqrt{2}} \right\rangle$



Zeroth example

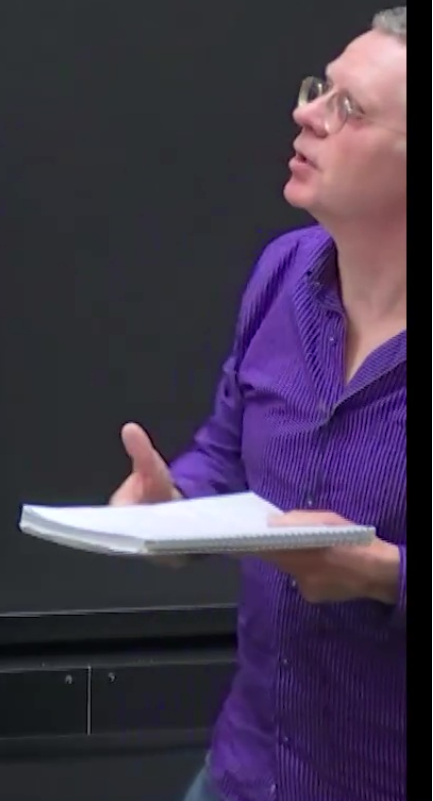
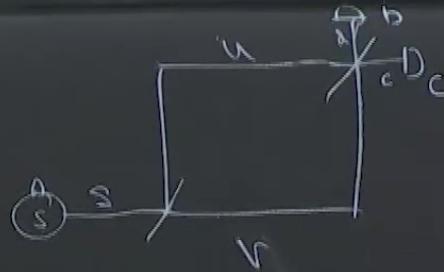
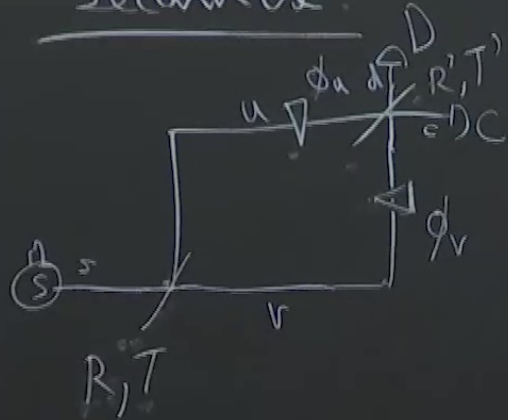


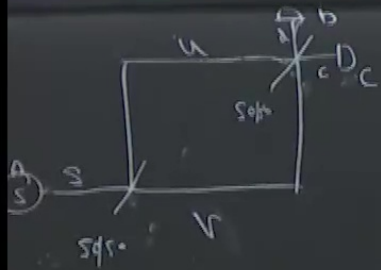
First example



$|\alpha\rangle |B_0\rangle$

Secundare





$$|s\rangle \rightarrow \frac{i}{\sqrt{2}}|u\rangle + \frac{1}{\sqrt{2}}|v\rangle \rightarrow \frac{i}{\sqrt{2}}\left(\frac{i}{\sqrt{2}}|a\rangle + \frac{1}{\sqrt{2}}|c\rangle\right) + \frac{1}{\sqrt{2}}\left(\frac{1}{\sqrt{2}}|a\rangle + \frac{i}{\sqrt{2}}|c\rangle\right)$$

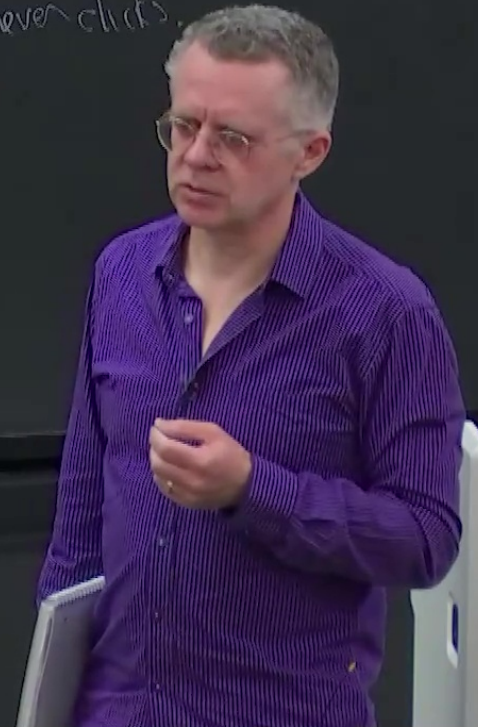
$$= |c\rangle$$

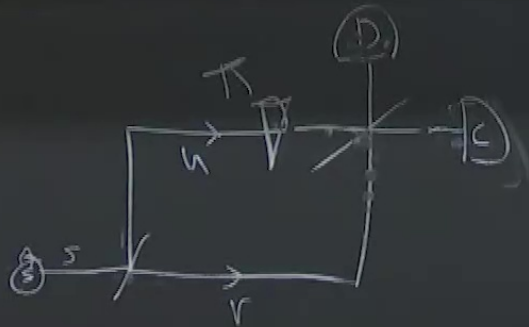
the C detector ^{always} clicks.
D never clicks.

$$\frac{1}{4} + \frac{1}{4} = 1$$

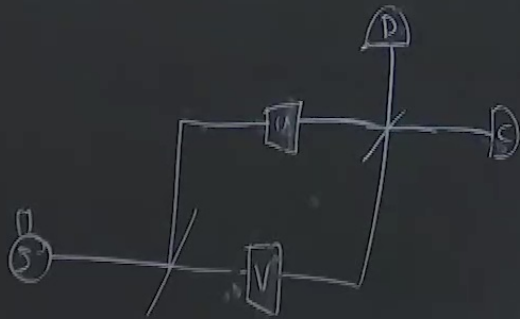
$$p + p = 2p$$

$$(\sqrt{p} + \sqrt{p})^2 = 4p$$

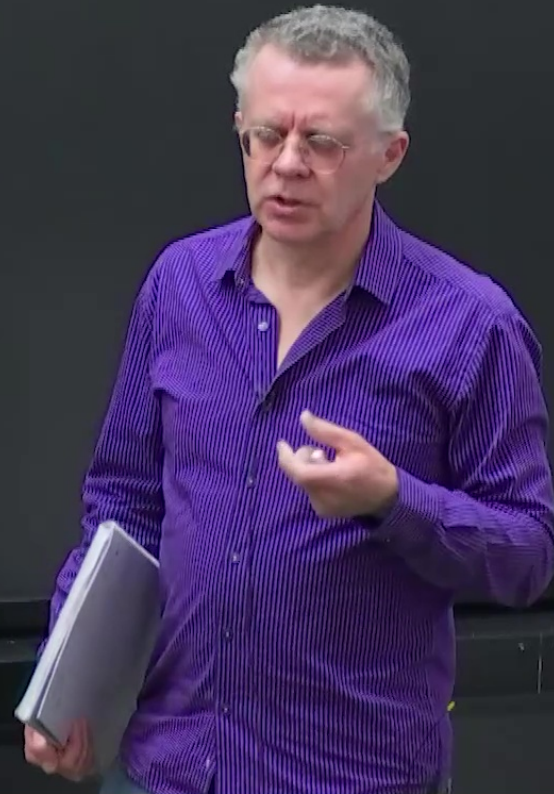


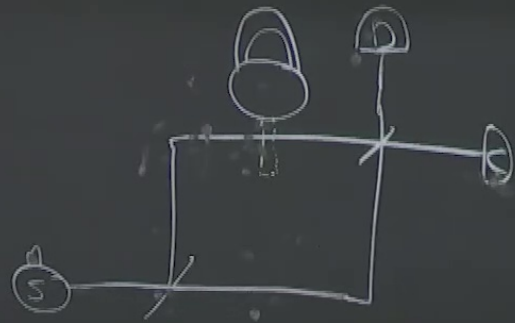


$$|s\rangle \rightarrow \dots \rightarrow |d\rangle$$



(Quantum Eraser)





- 1) Bomb explodes
- 2) C fires. learn nothing.
- 3) D fires. have a "good" bomb but haven't exploded it

$|S\rangle |bomb_0\rangle |C_0\rangle |D_0\rangle$

nothing.

o bomb
exploded it.

$$|c_0\rangle + \frac{1}{\sqrt{2}} |v\rangle |bomb_0\rangle |c_0\rangle |D_0\rangle \rightarrow \frac{i}{\sqrt{2}} |bomb_{bang}\rangle + \frac{1}{2} (|d\rangle + i|c\rangle) |c_0\rangle |D_0\rangle$$