

Title: Quantum Network Engineering

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URL: <http://pirsa.org/07060027>

Abstract:

# Quantum Network Engineering

*(and some random things I want to say)*

Man-Hong Yung

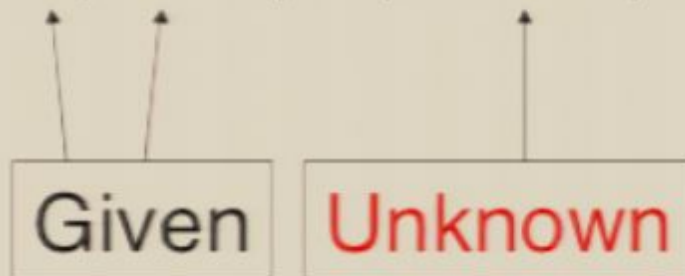
*Physics, University of Illinois at Urbana-Champaign*

4th Canadian Quantum Information Students' Conference  
@ Perimeter Institute, 4<sup>th</sup> June 2007

# Quantum Mechanics & Computation: Grand Unification Theory

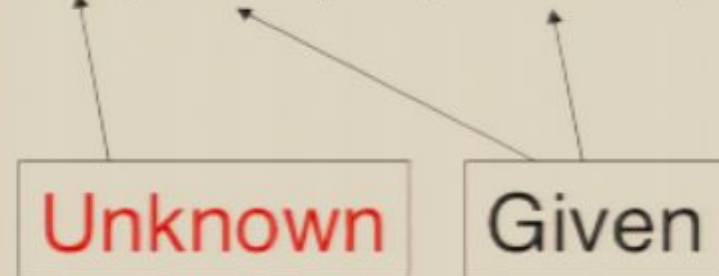
- ABC of Quantum Mechanics:

$$U |\text{Input}\rangle = |\text{Output}\rangle$$



- ABC of Quantum Computation:

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$$U = \exp(-iHt) \Rightarrow \text{product of discrete gates}$$

# Open question

- We **really** understand the power of a quantum computer?
- Open question:

$$\exp(-iH_1t) \equiv \underbrace{U_1 U_2 U_3 \dots}_{\sim O(2^N) \text{ terms}}$$

$$\exp(-iH_2t) \equiv \underbrace{V_1 V_2 V_3 \dots}_{\sim O(N) \text{ terms}}$$

- Difference between  $H_1$  and  $H_2$ ?

# Energy-Time Argument

- Seth Lloyd 2000: computation rate limited by energy.

- For each gate, minimal execution time

$$\Delta t \sim \frac{\hbar}{E}, \quad E = mc^2$$

- True?
  - QED: zero-point vacuum energy = infinity
  - Energy conserved for quantum computation
  - Can't speed up with a single Hamiltonian evolution?

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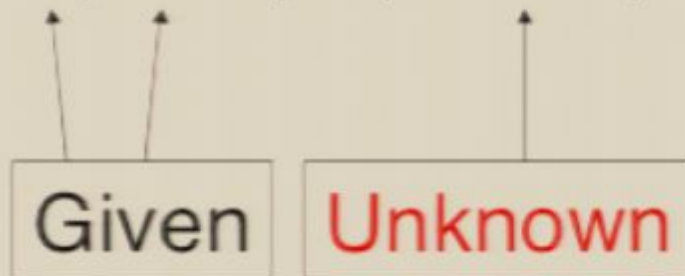
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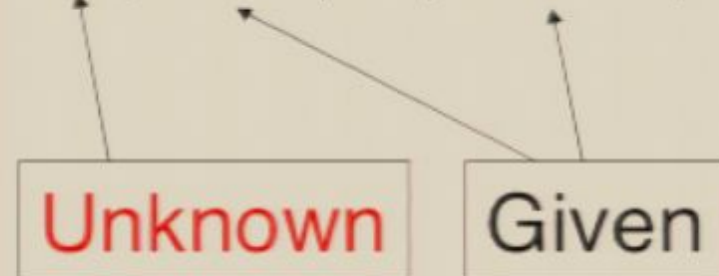
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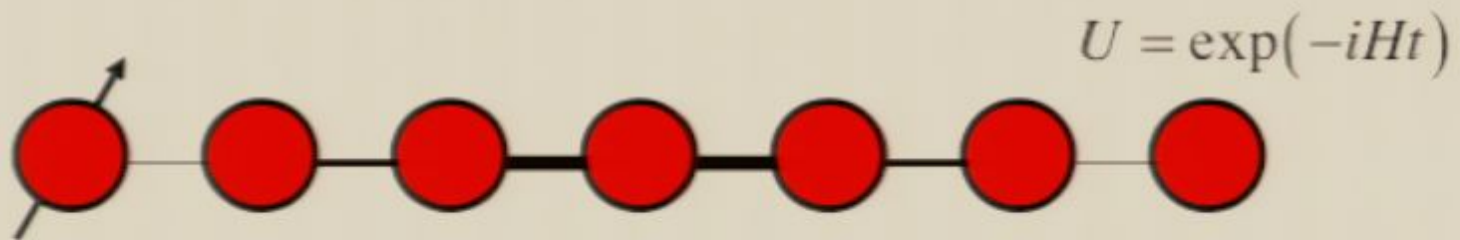
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# Quantum State Transfer

- Spin-chain QST [Yung2006]



- Which one is faster? (answer: almost the same)

# QST, how?

$$H = \omega_1 (\sigma_1^+ \sigma_2^- + \sigma_1^- \sigma_2^+) + \omega_2 (\sigma_2^+ \sigma_3^- + \sigma_2^- \sigma_3^+) + \dots$$

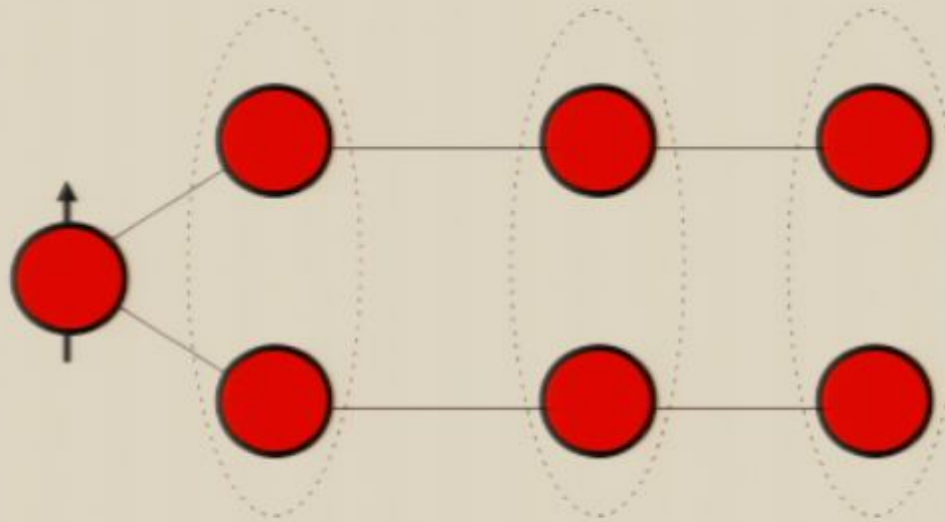
$$[H, \sigma_1^z + \sigma_2^z + \dots] = 0 \Rightarrow \text{Hilbert space: } 2^N \rightarrow N$$

$$H = \begin{pmatrix} 0 & \omega_1 & 0 & \dots & 0 \\ \omega_1 & 0 & \omega_2 & \dots & 0 \\ 0 & \omega_2 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \omega_N & 0 \end{pmatrix} \Rightarrow \frac{d}{dt} \vec{J} = \vec{B} \times \vec{J}$$

- Map to the spin precession problem [Christandl *et al.* 2004]

# Entanglement Generation

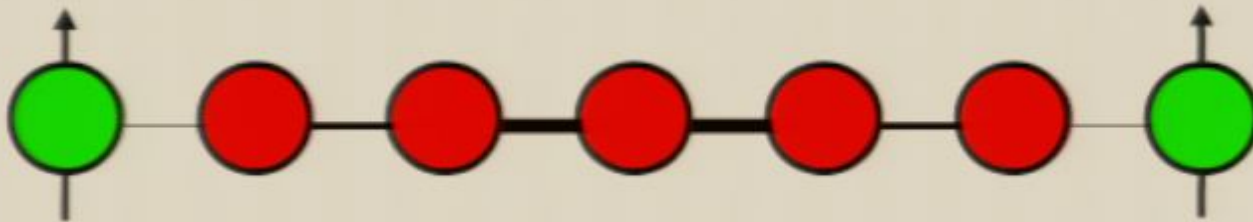
- Further reduction:



- QST by teleportation

# Quantum Gate Construction

- Jordan & Wigner 1928:
  - spin chain = spinless fermions hopping



Identical fermions :  $\psi(1,2) = (-1)\psi(2,1)$

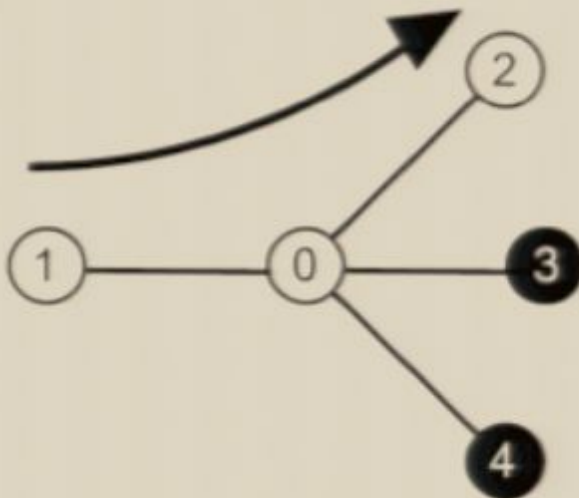
$\Rightarrow$  Controlled-phase gate

- Universal quantum computing [Yung *et al.*, 2006]

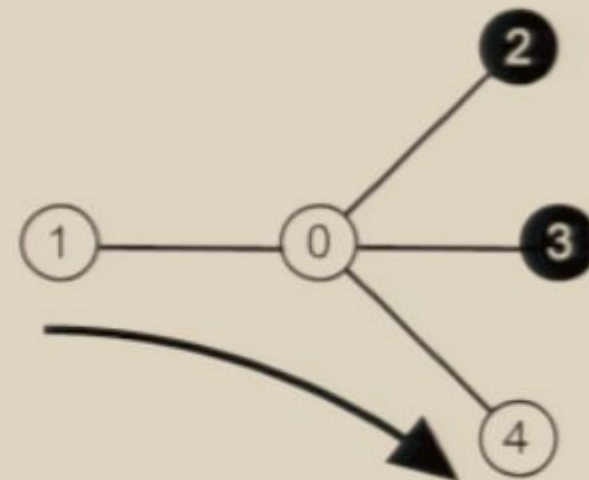
# Spin-Star as Network Switch [Yung2007]

$$U = \exp(-iHt)$$

a)



b)





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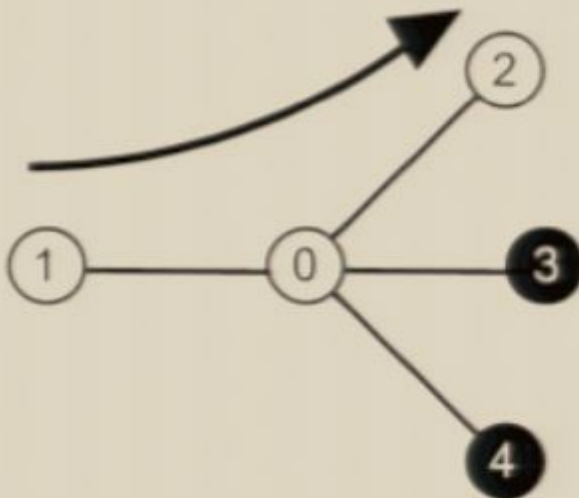
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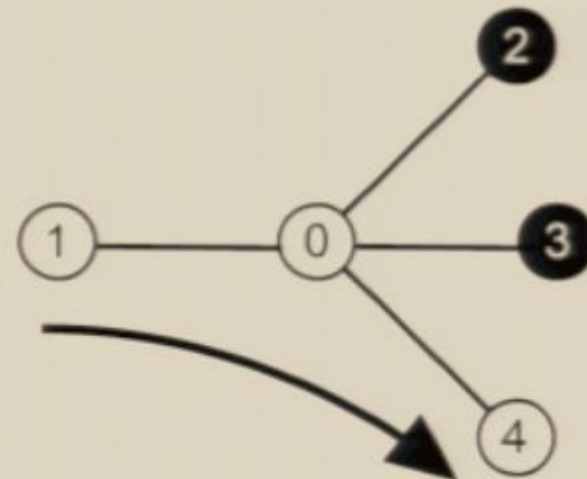
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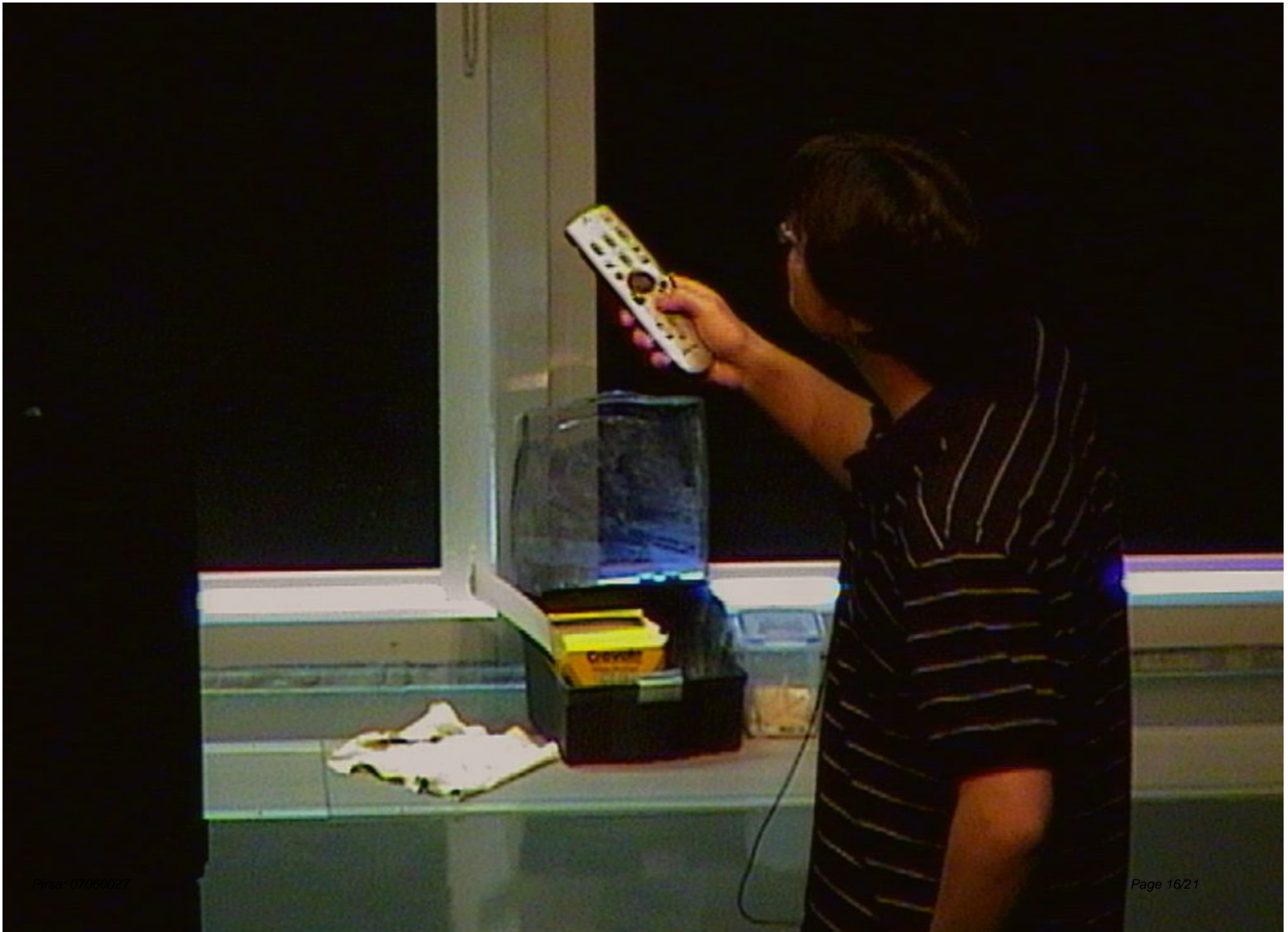
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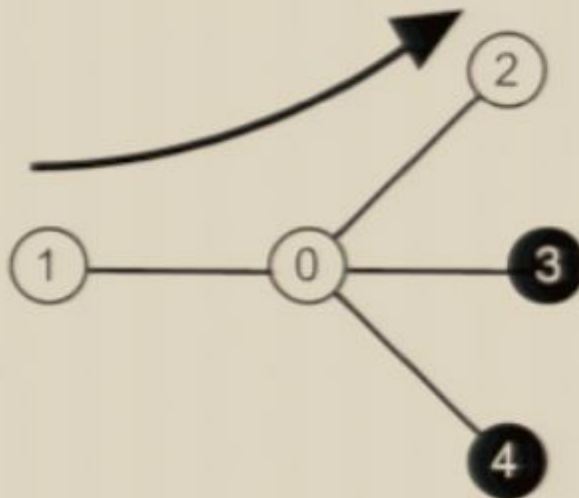




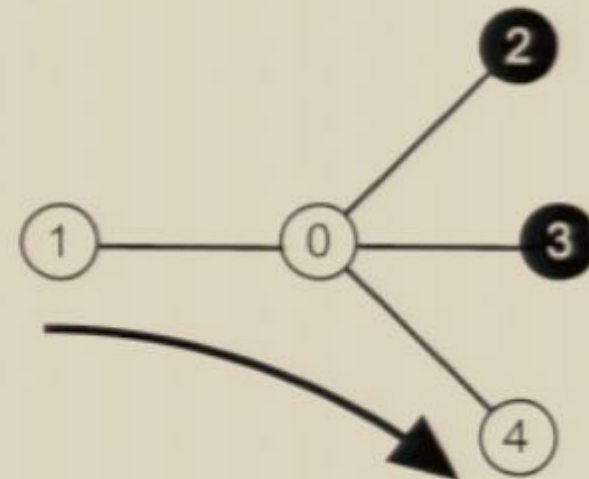
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# Conclusion

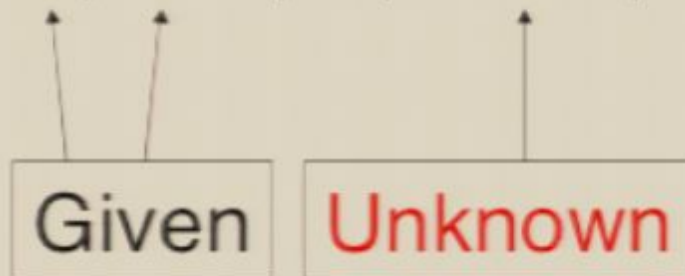
- I still can't unify the theories,  
– but I've developed some interesting devices
- Q&A



# Quantum Mechanics & Computation: Grand Unification Theory

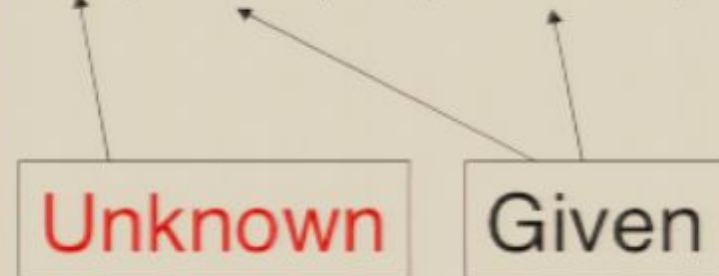
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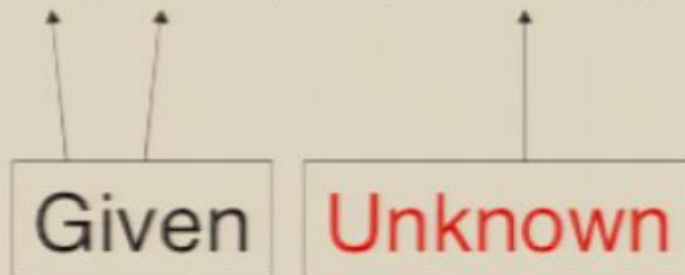
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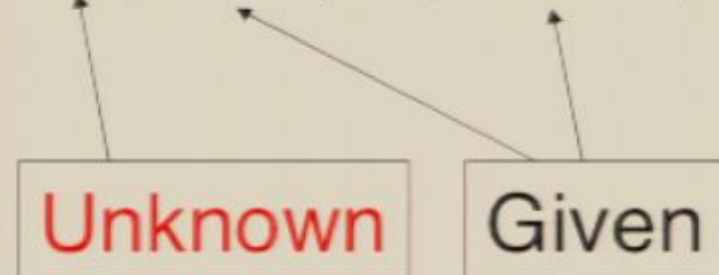
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