Quantum Walks: Speed Limits on Mixing and Fast-Forwarding Classical Walks

a presentation for the public defense of

Simon Apers

Ghent University
January 29, 2019

- Coins and Quantum
- Speed Limits on Mixing
- Fast-Forwarding Classical Walks

Coins and Quantum

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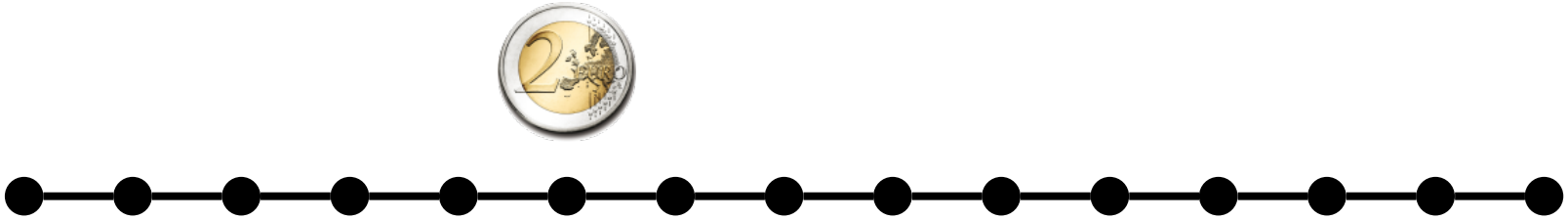

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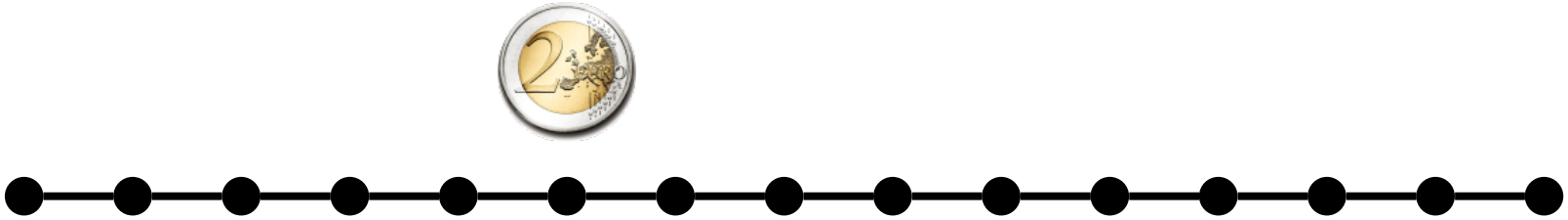

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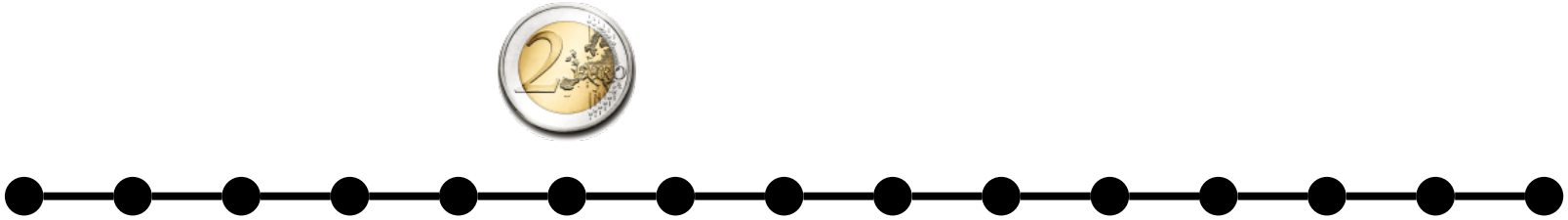

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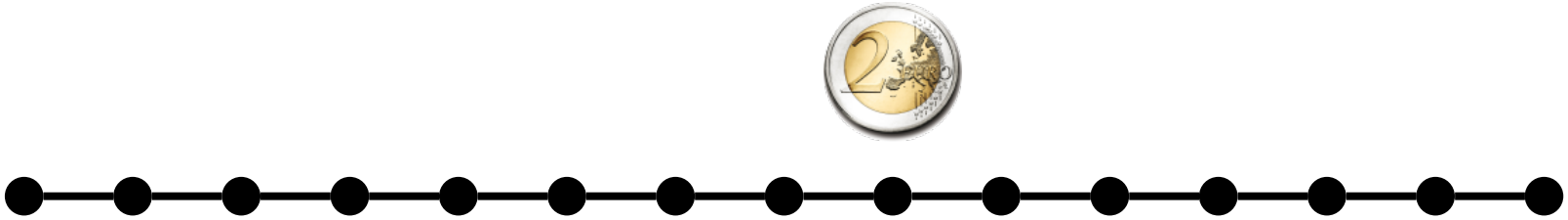

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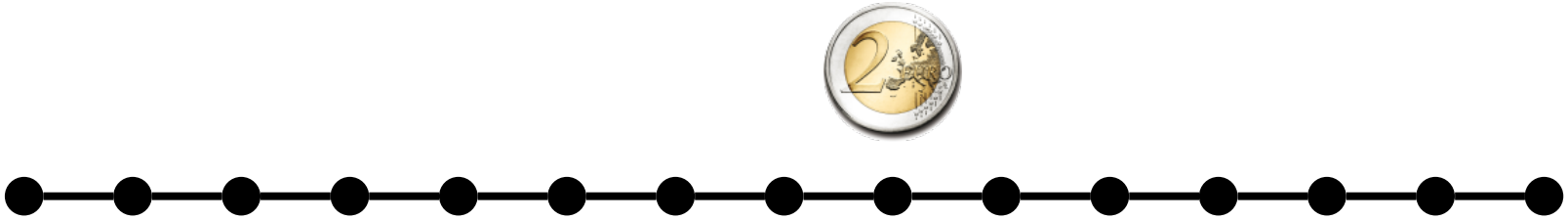

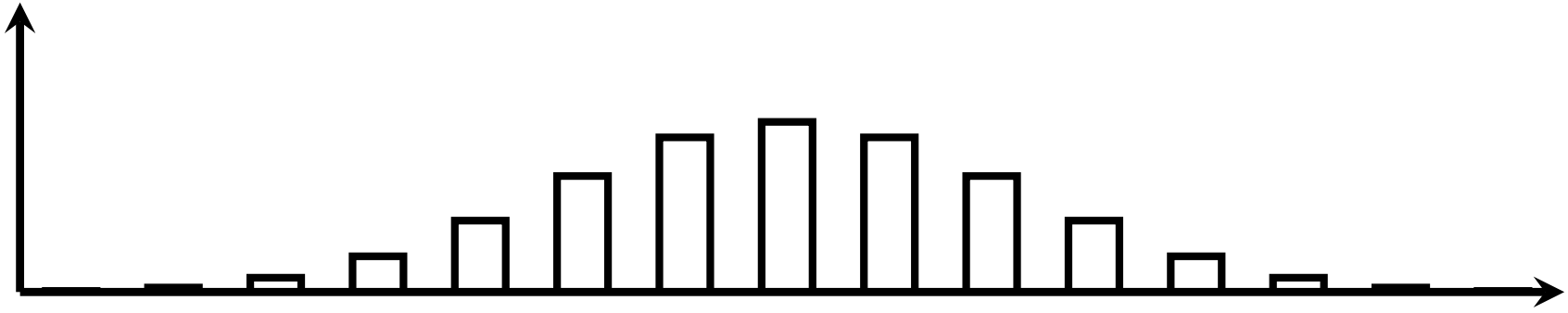

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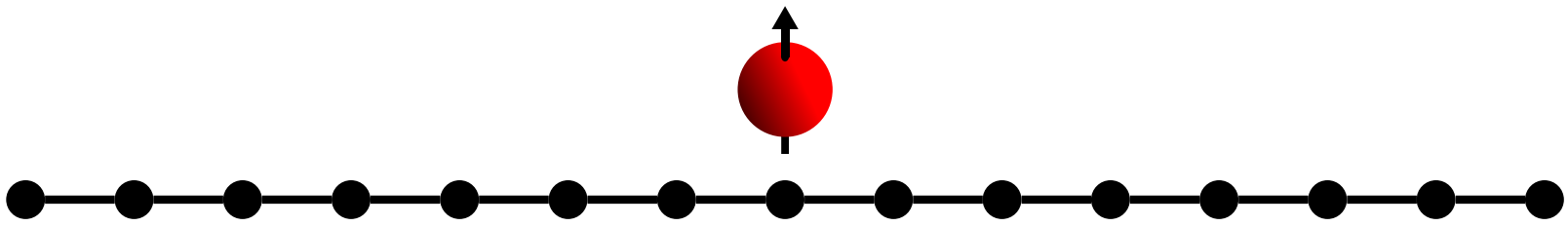

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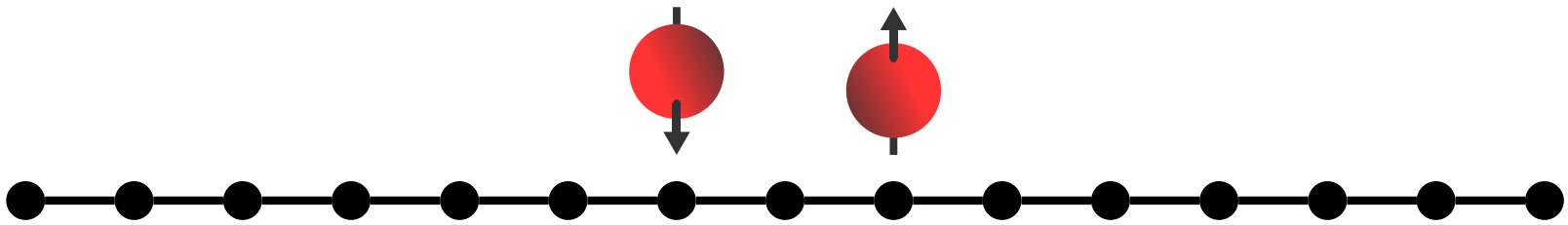

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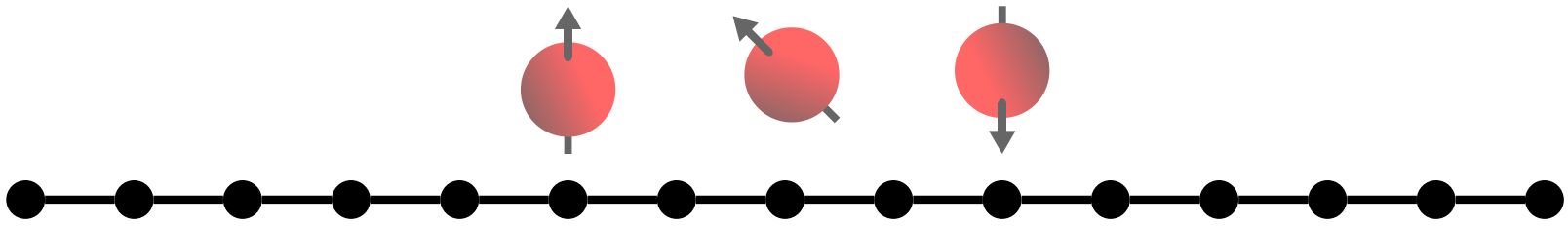

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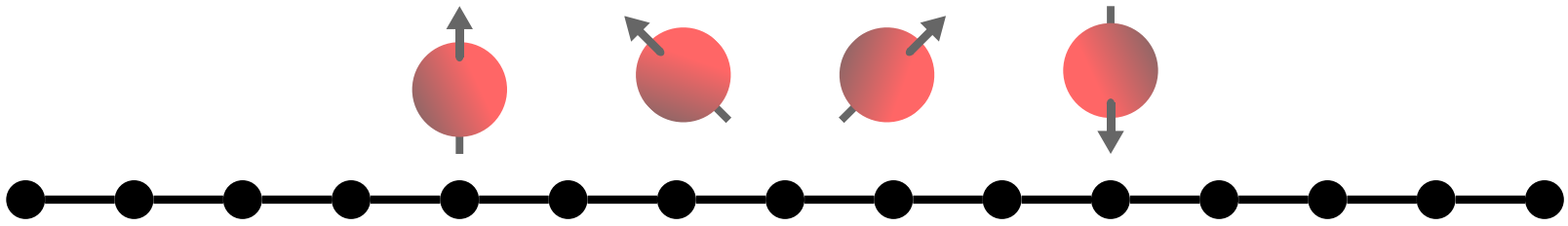

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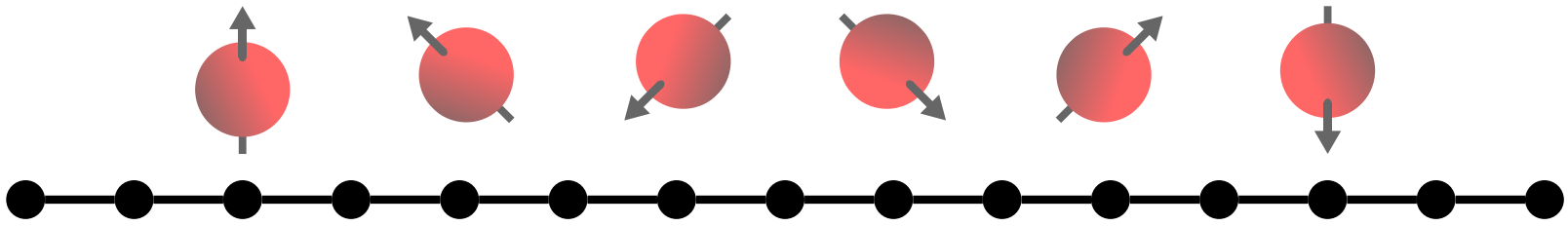

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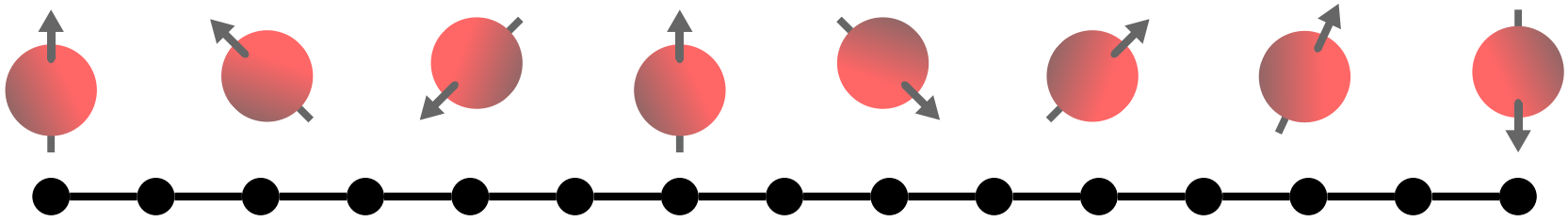

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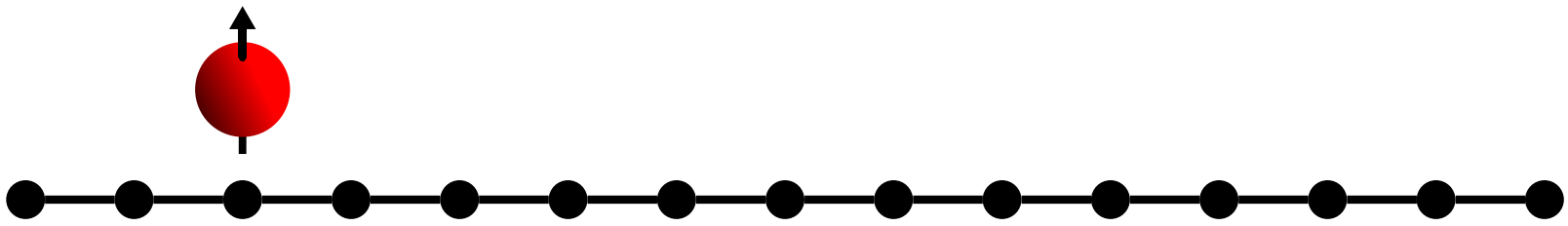

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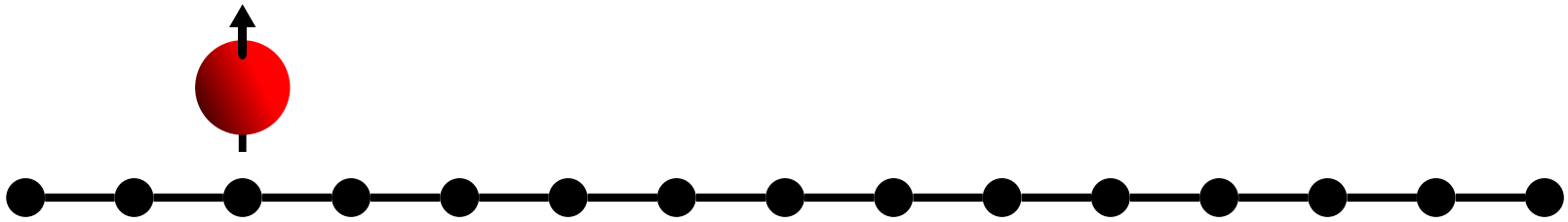
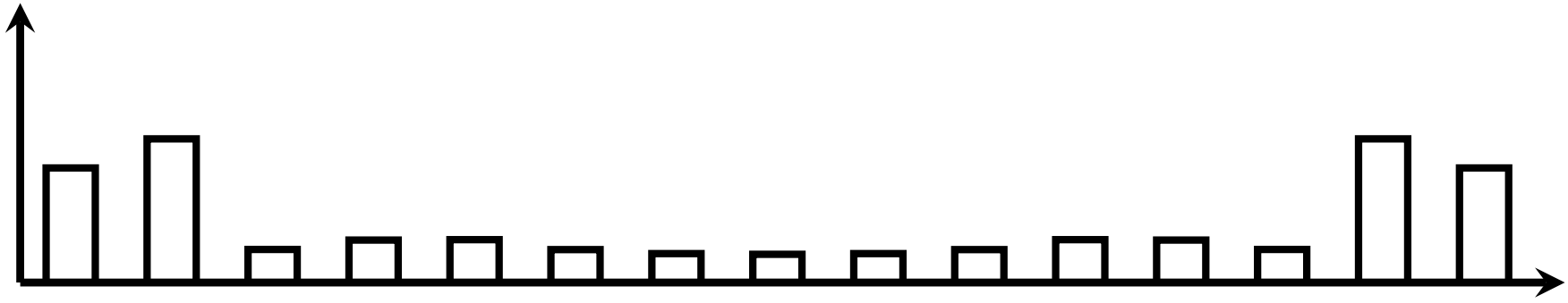
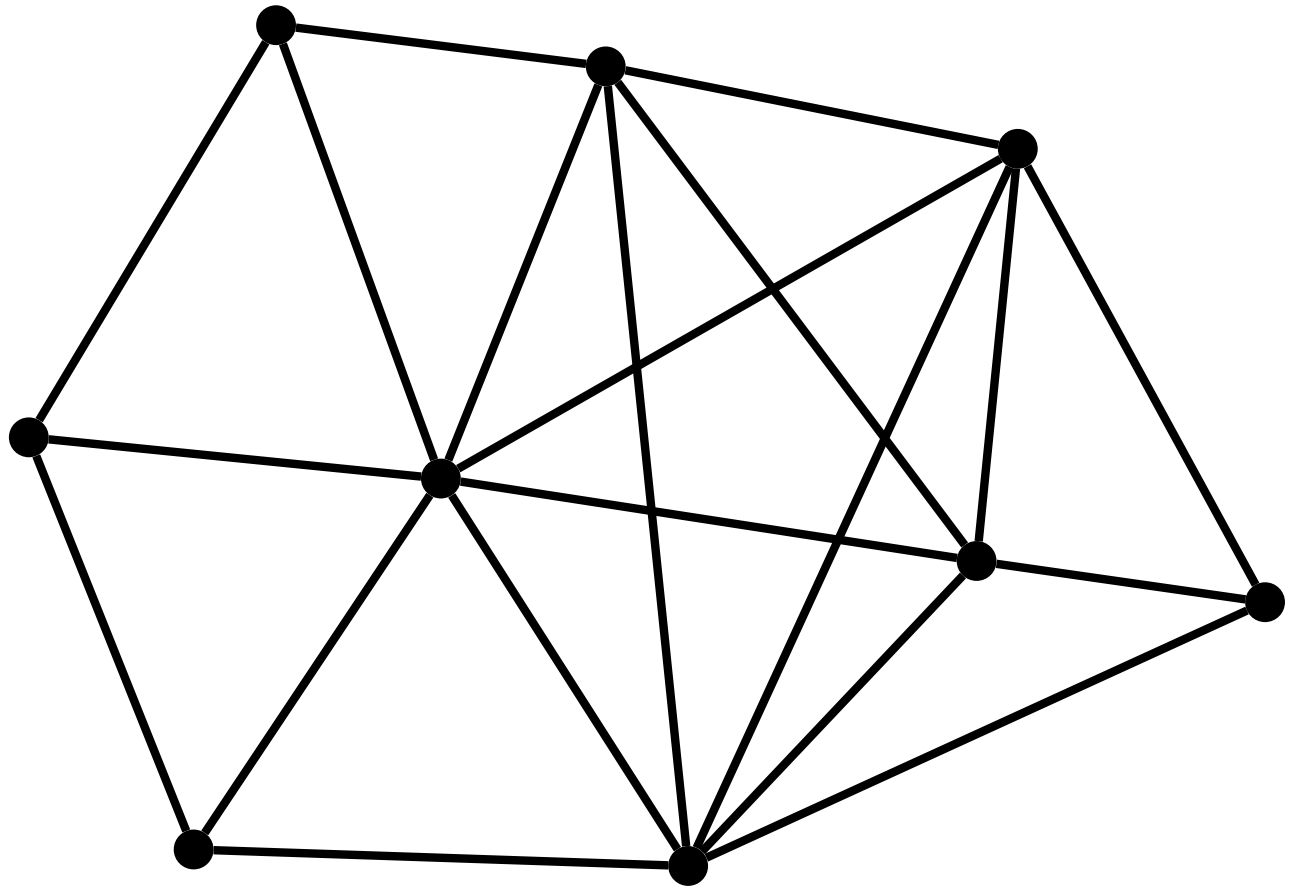




Walks on Graphs



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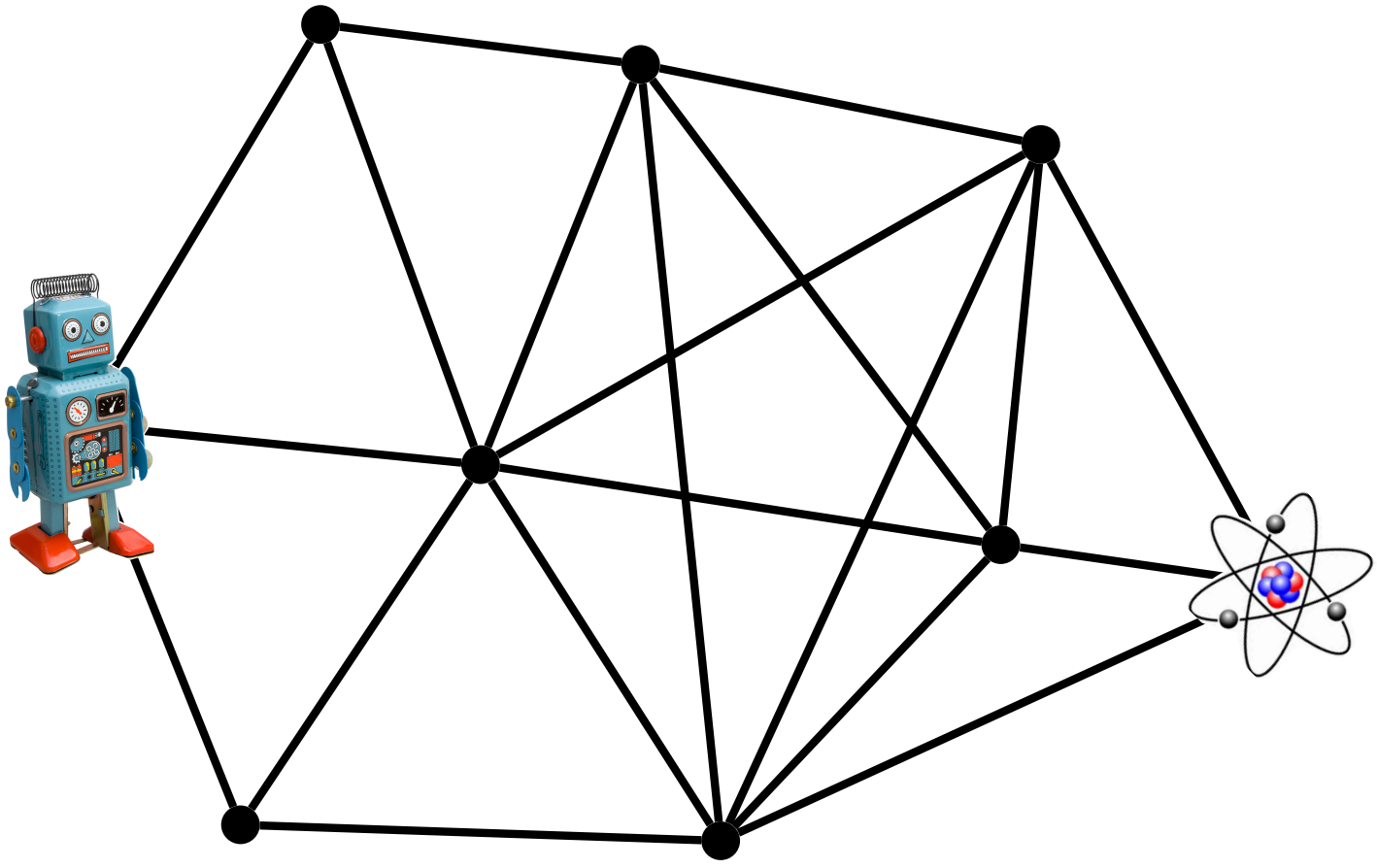

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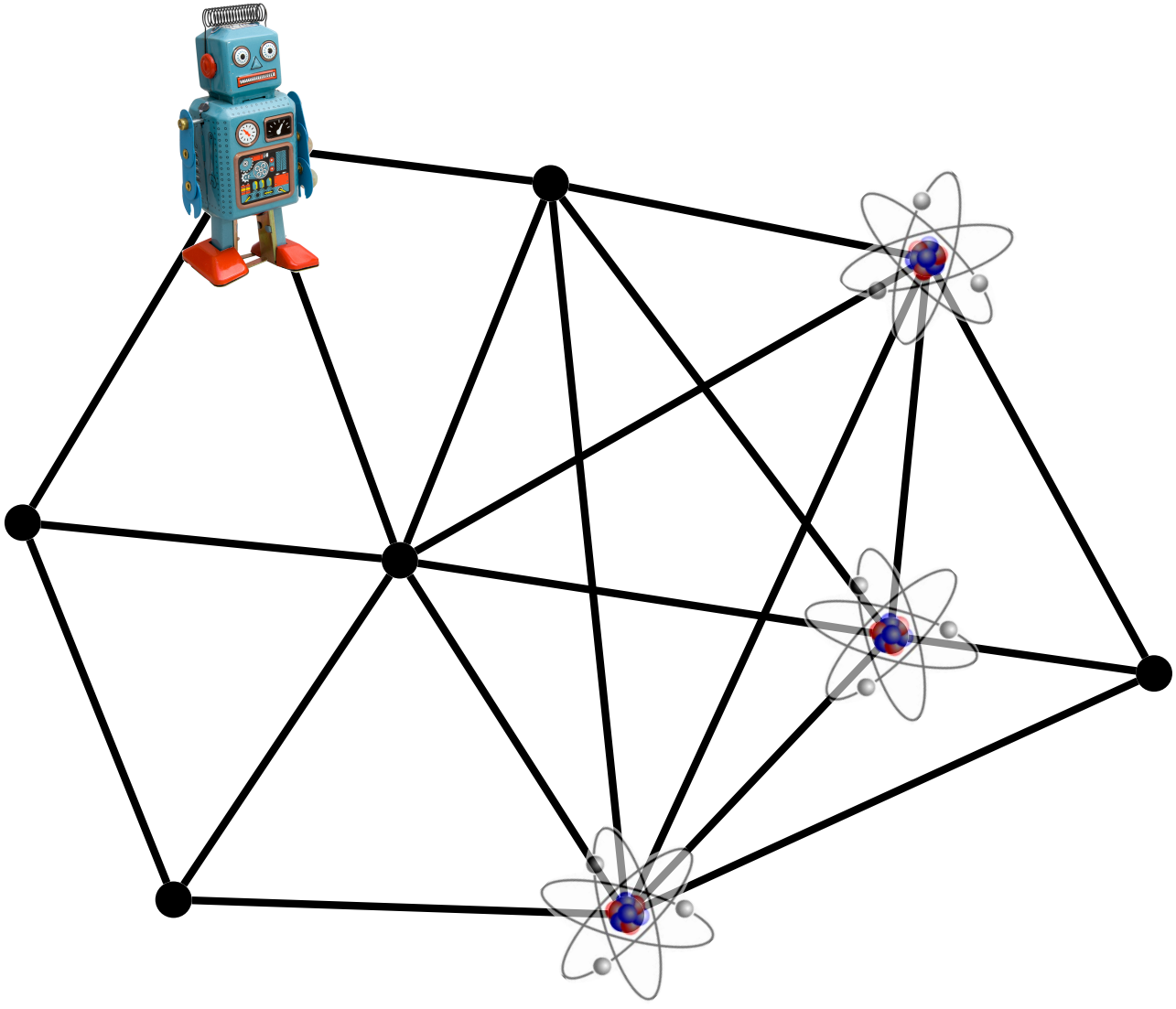

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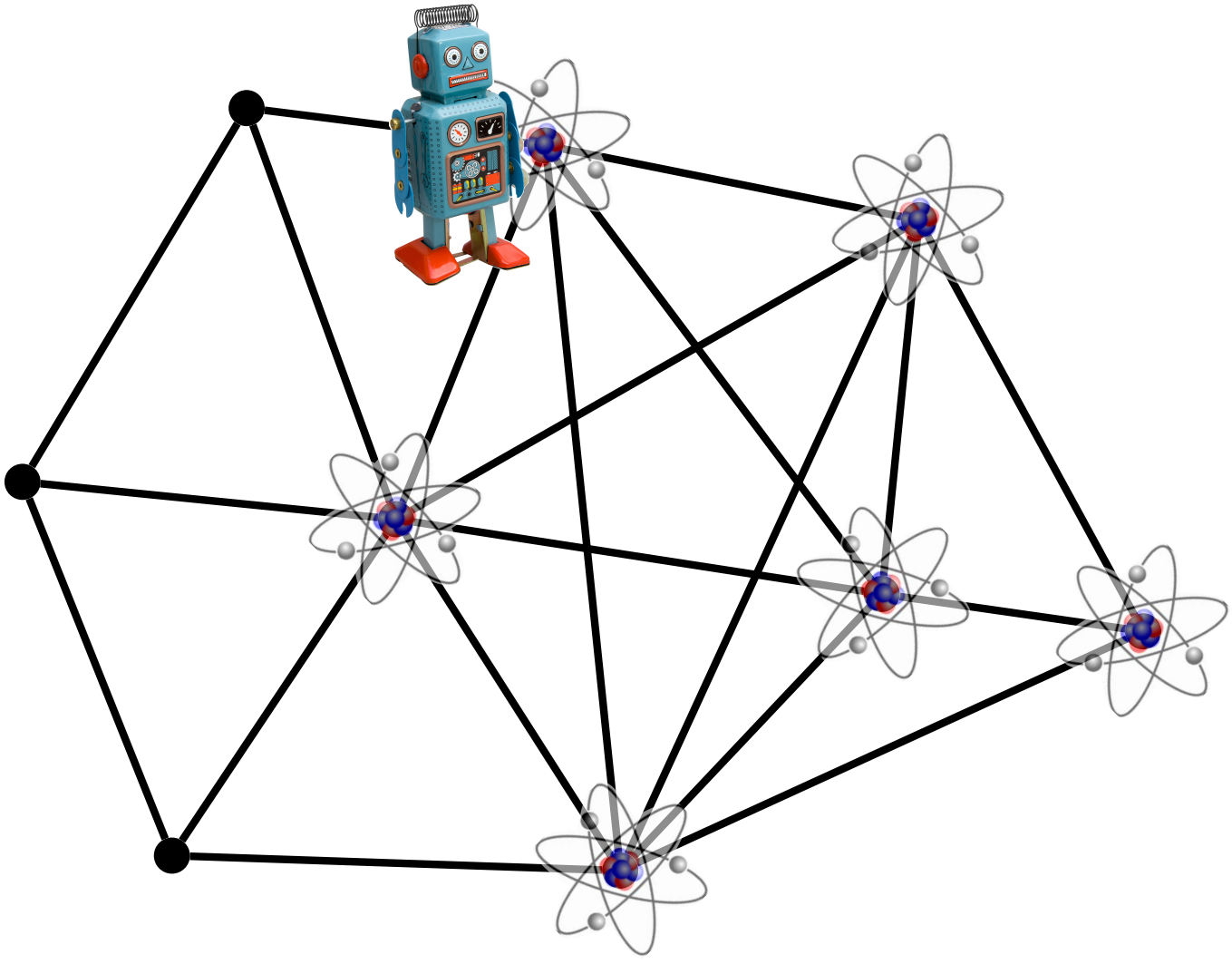

Classical Walks Can Simulate Quantum Walks

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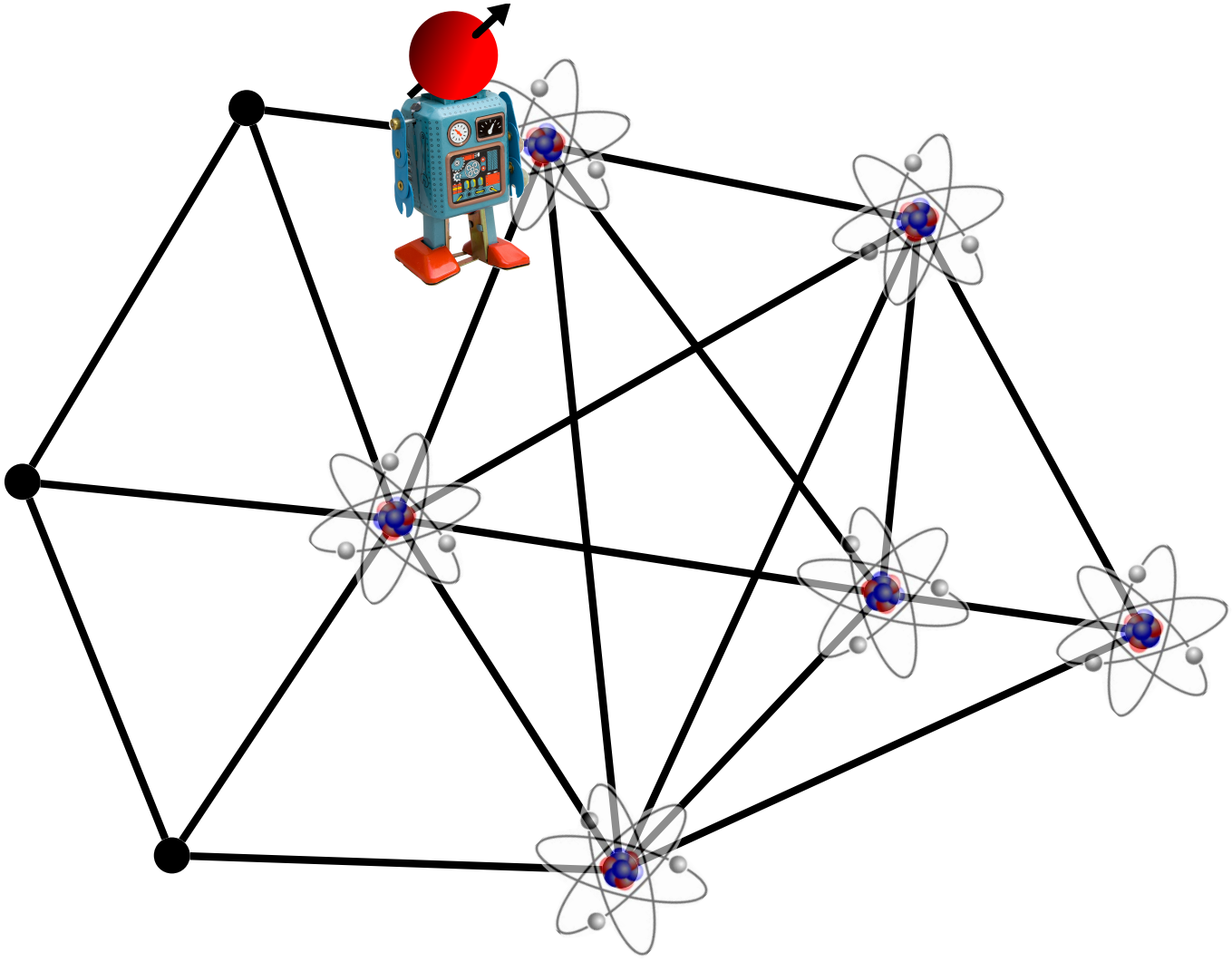

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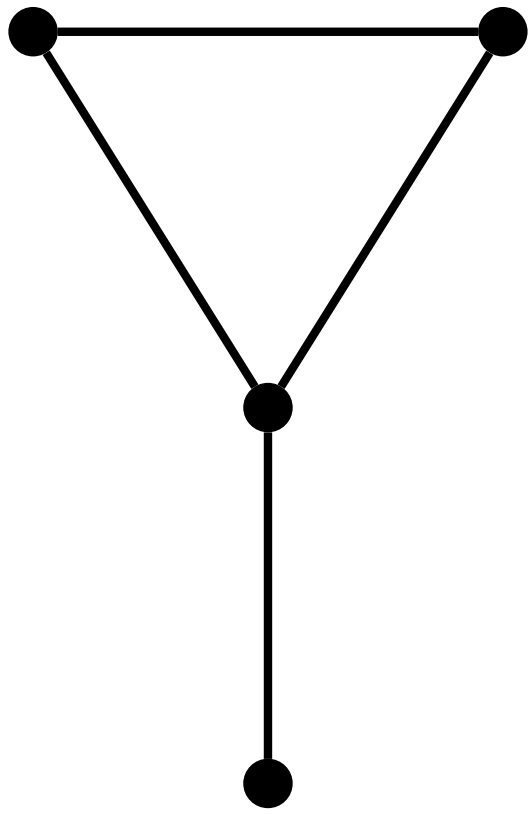

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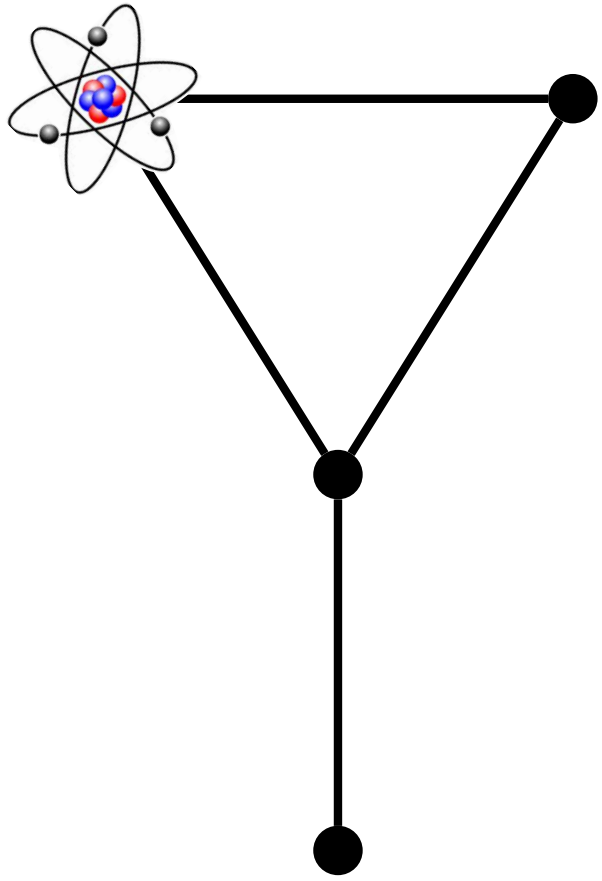
$|\psi_t\rangle$



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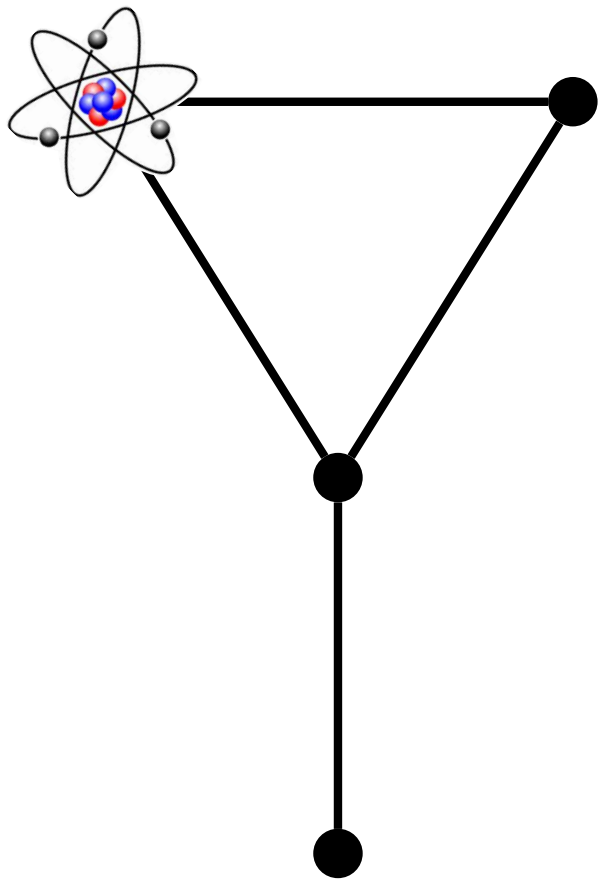


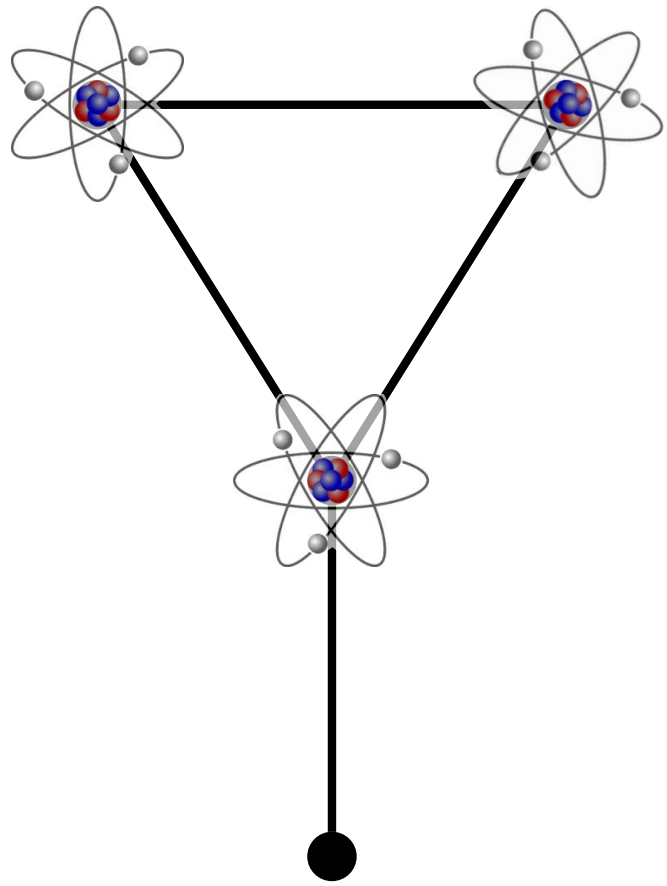
$|\psi_t\rangle$

$\downarrow$

p_t

Classical Walks Can Simulate Quantum Walks

$|\psi_{t+1}\rangle$

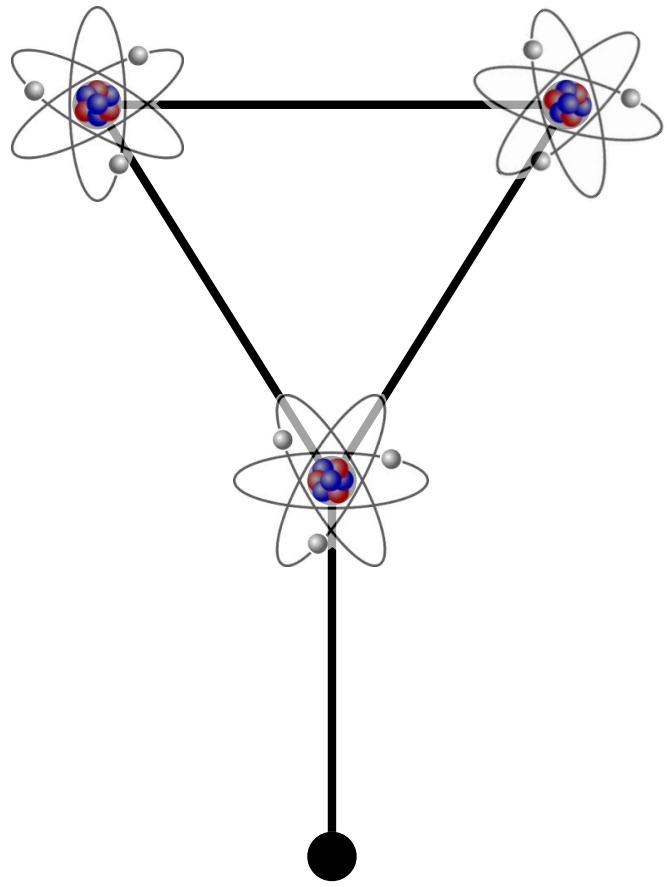


Classical Walks Can Simulate Quantum Walks

$|\psi_{t+1}\rangle$

$\downarrow$

p_{t+1}



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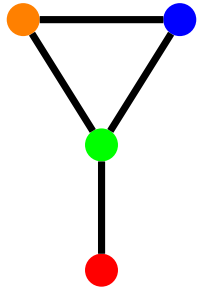

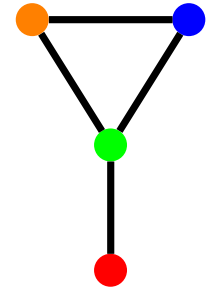

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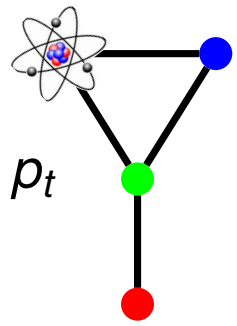

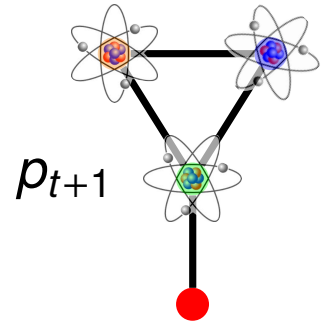

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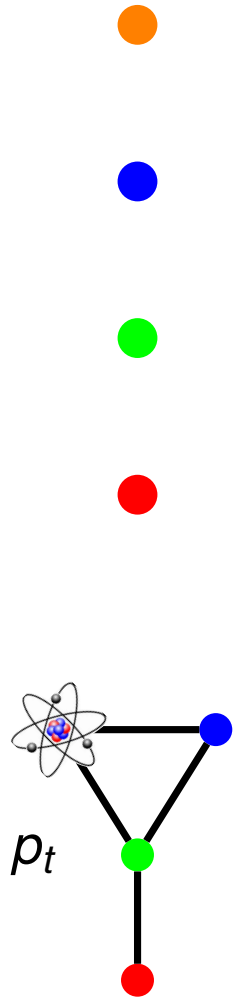
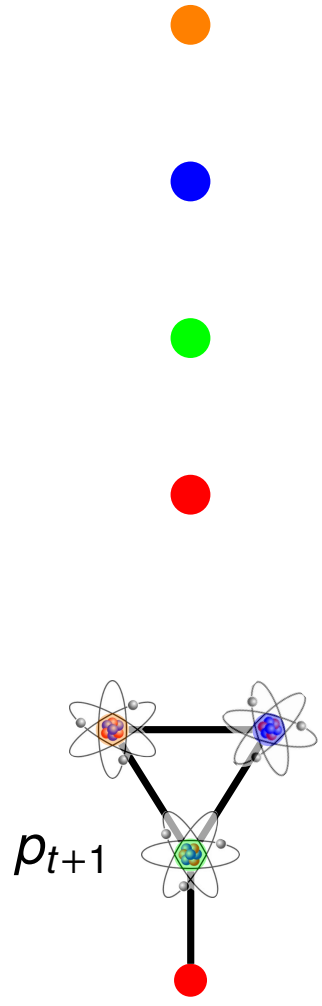


p_t



p_{t+1}

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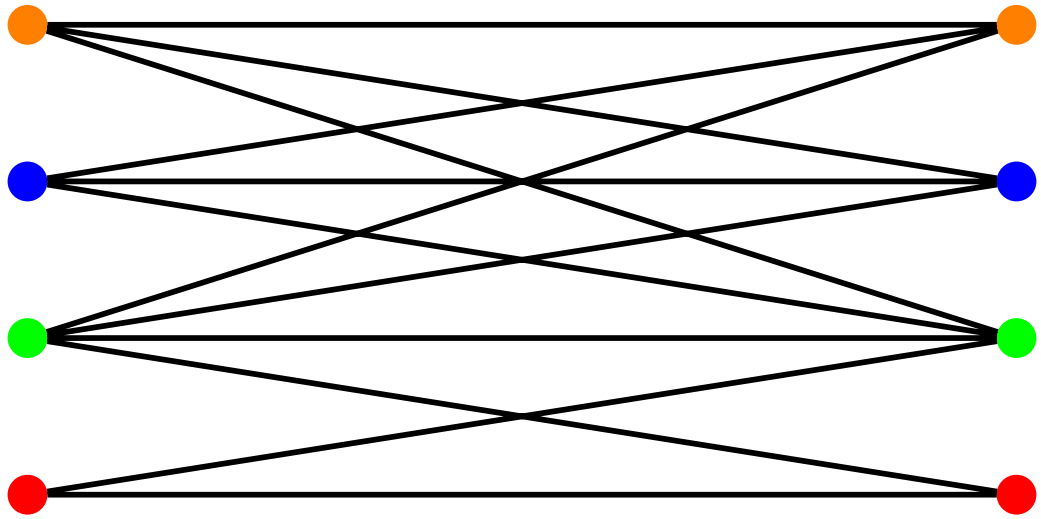

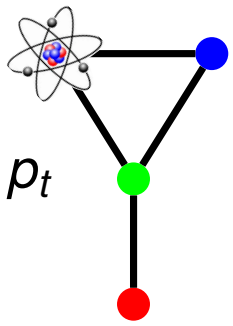

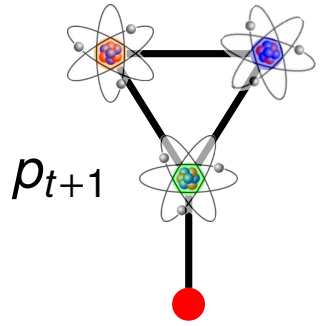

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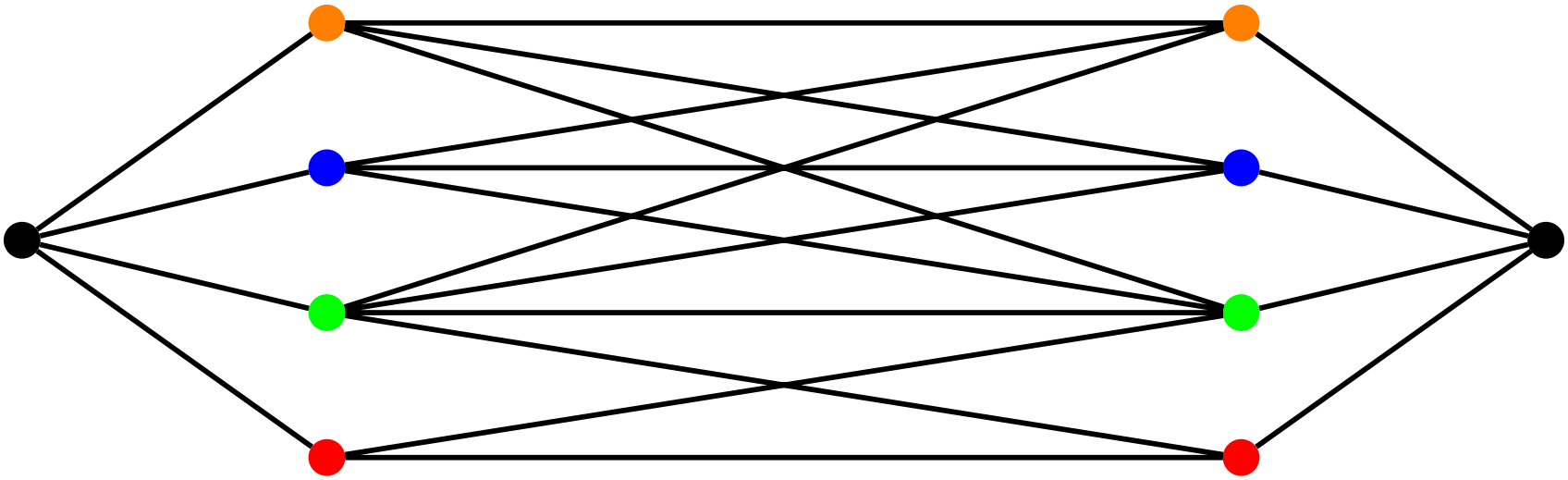

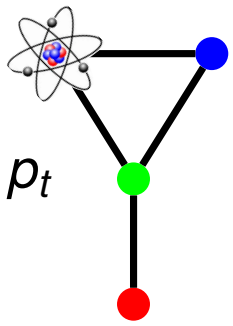

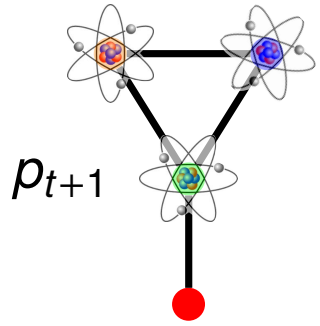

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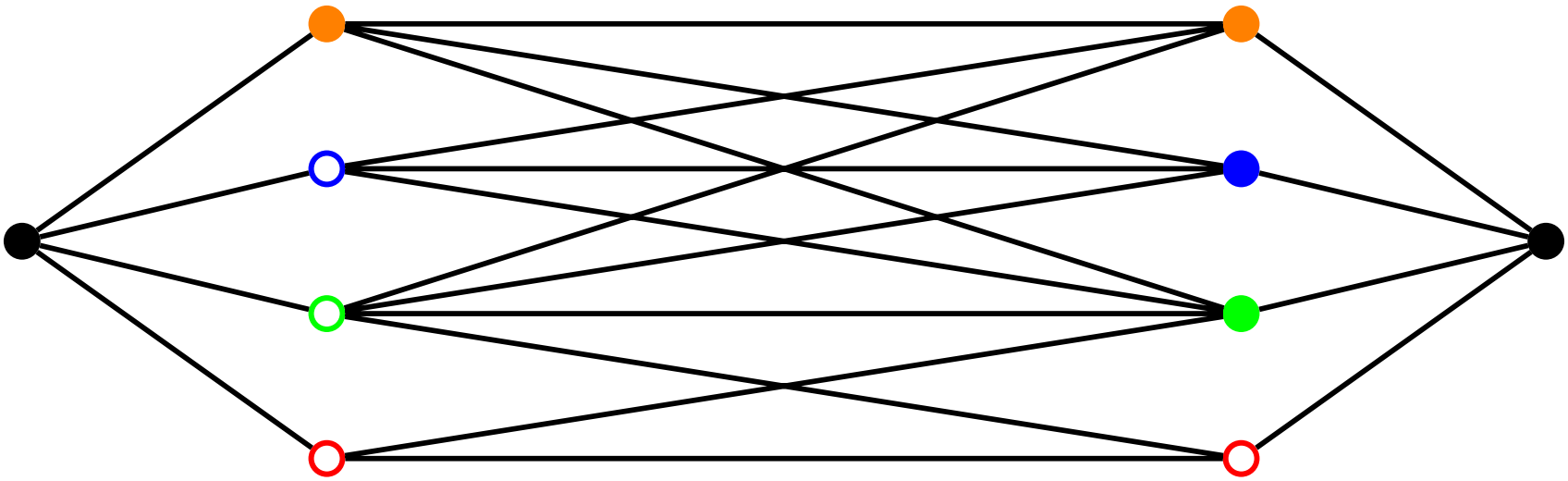

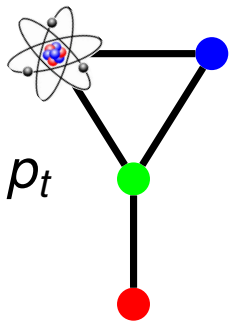

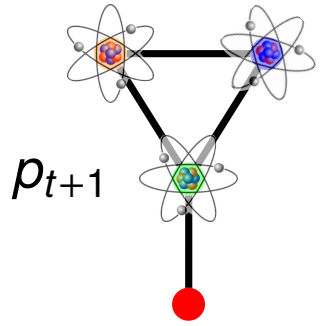

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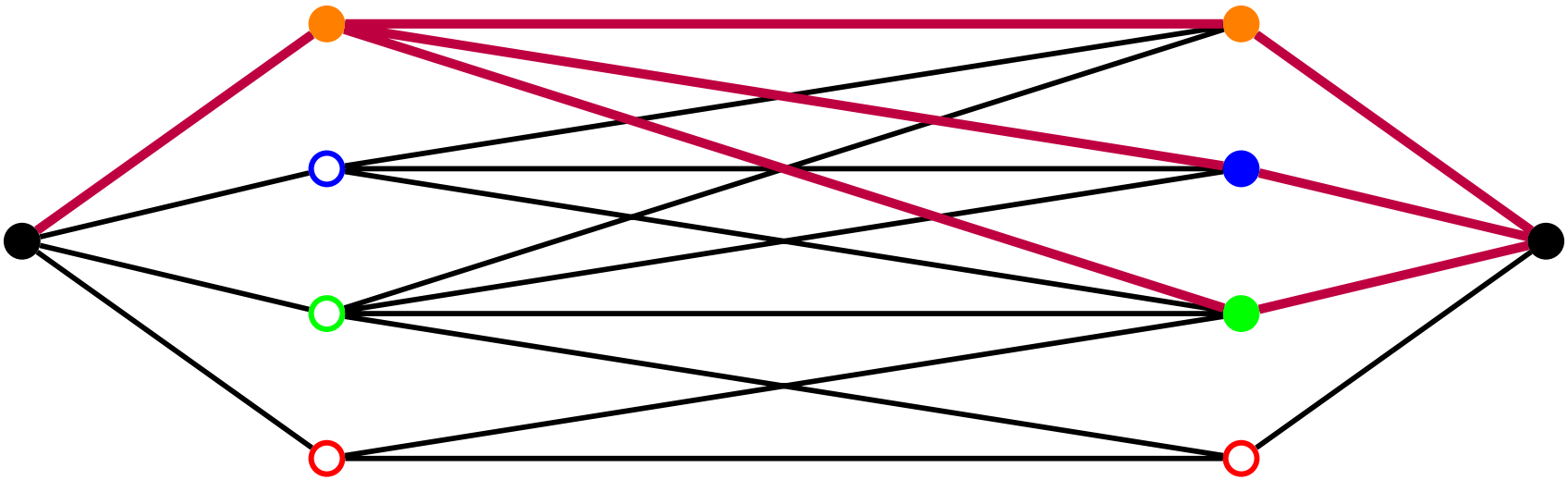

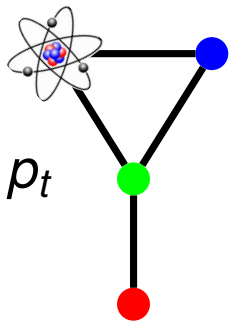

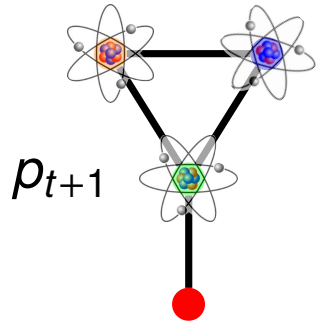

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- **Speed Limits on Mixing**

  Can quantum walks speed up mixing?

- Fast-Forwarding Classical Walks

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- **Speed Limits on Mixing**

  Can quantum walks speed up mixing?

  - Classical walks can simulate quantum walks

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- **Speed Limits on Mixing**

  Can quantum walks speed up mixing?

  - Classical walks can simulate quantum walks
  - In principle: no quantum speedup possible

- Fast-Forwarding Classical Walks

“In principle”

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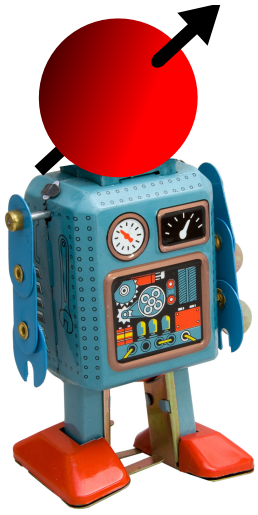

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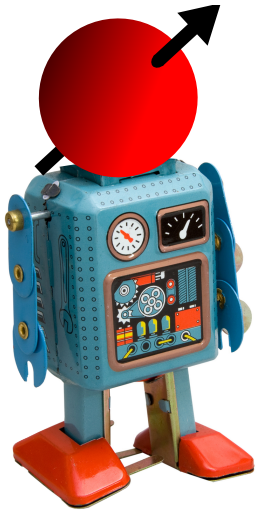

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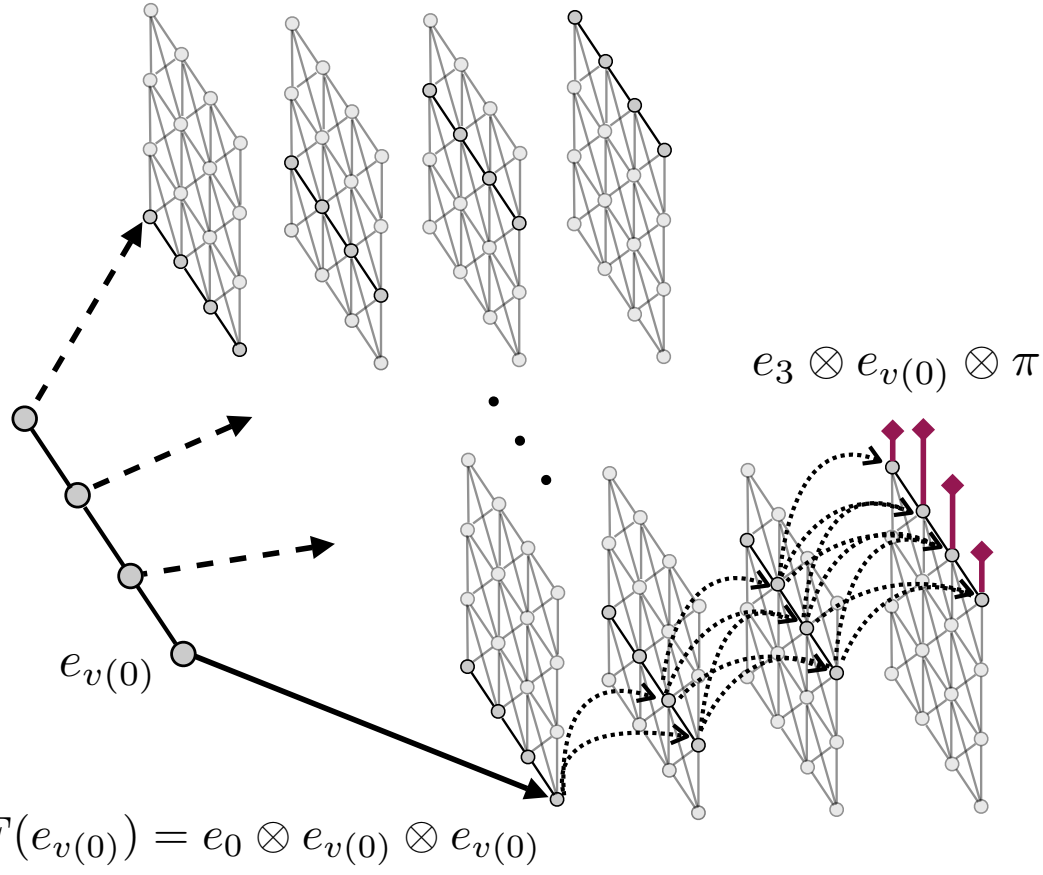
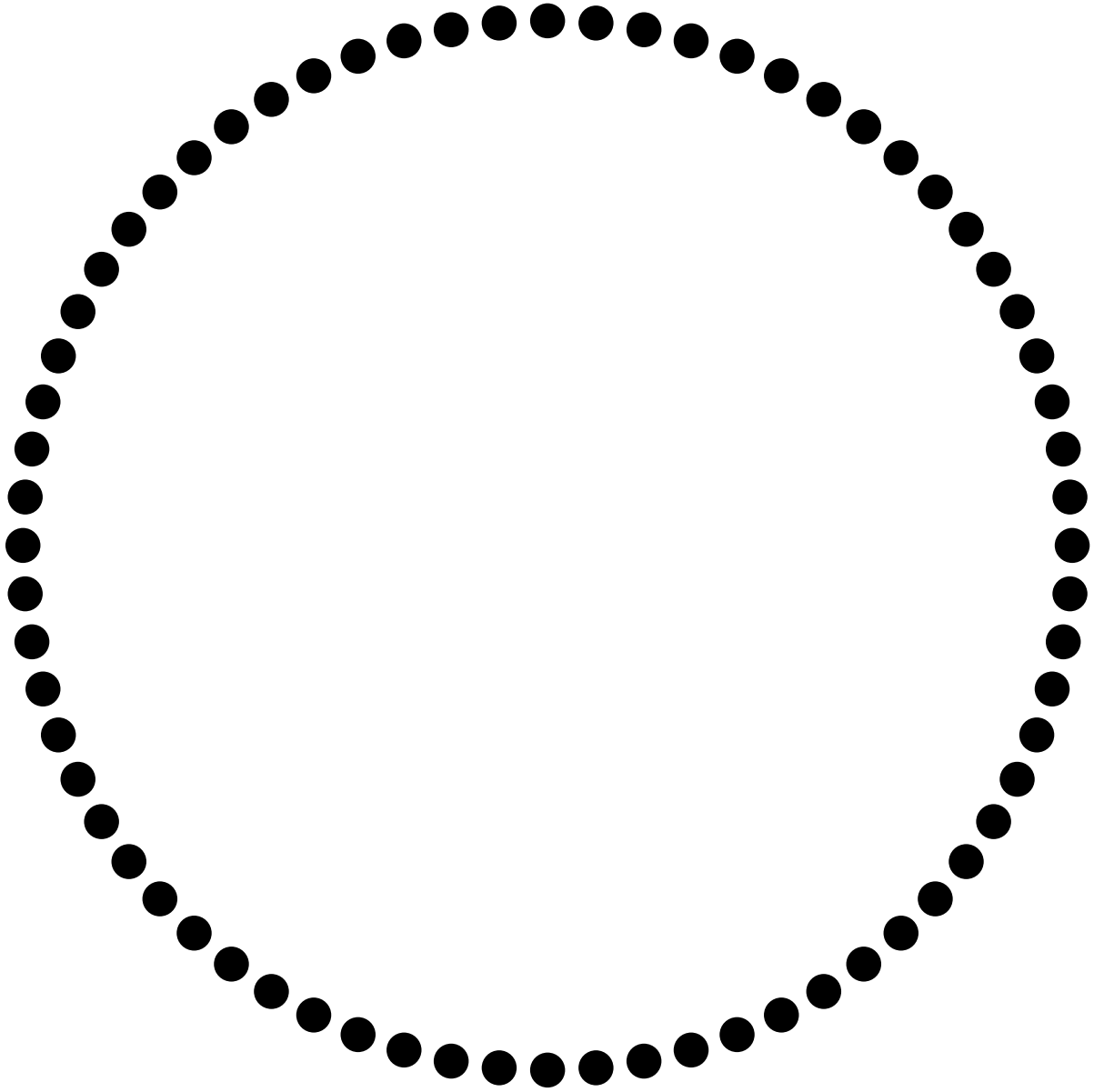


$$A = \sum_{s=1}^{T-1} \sum_{i \in \mathcal{V}} e_t e_{t-1}^\dagger \otimes \Pi_i^\dagger \otimes P^{(i)}(s) + \sum_{i \in \mathcal{V}} e_T e_{T-1}^\dagger \otimes \bar{p}\, e_i^\dagger \otimes P^{(i)}(T) + \Pi_T^\dagger \otimes I_{\mathcal{V}} \otimes I_{\mathcal{V}}$$

Friend Zone



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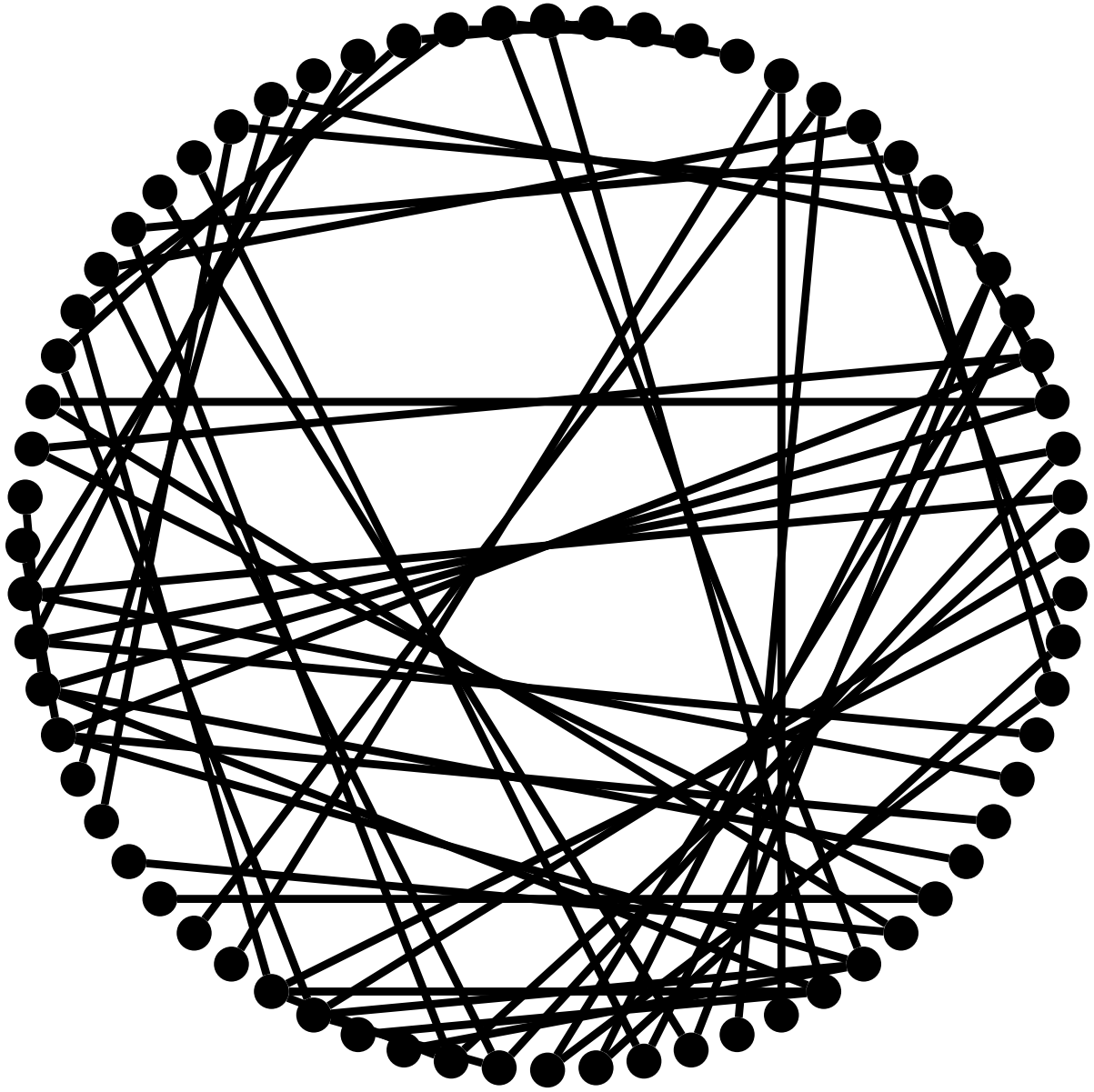

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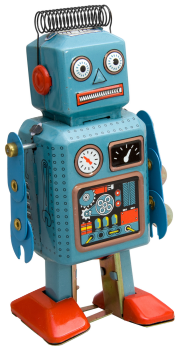

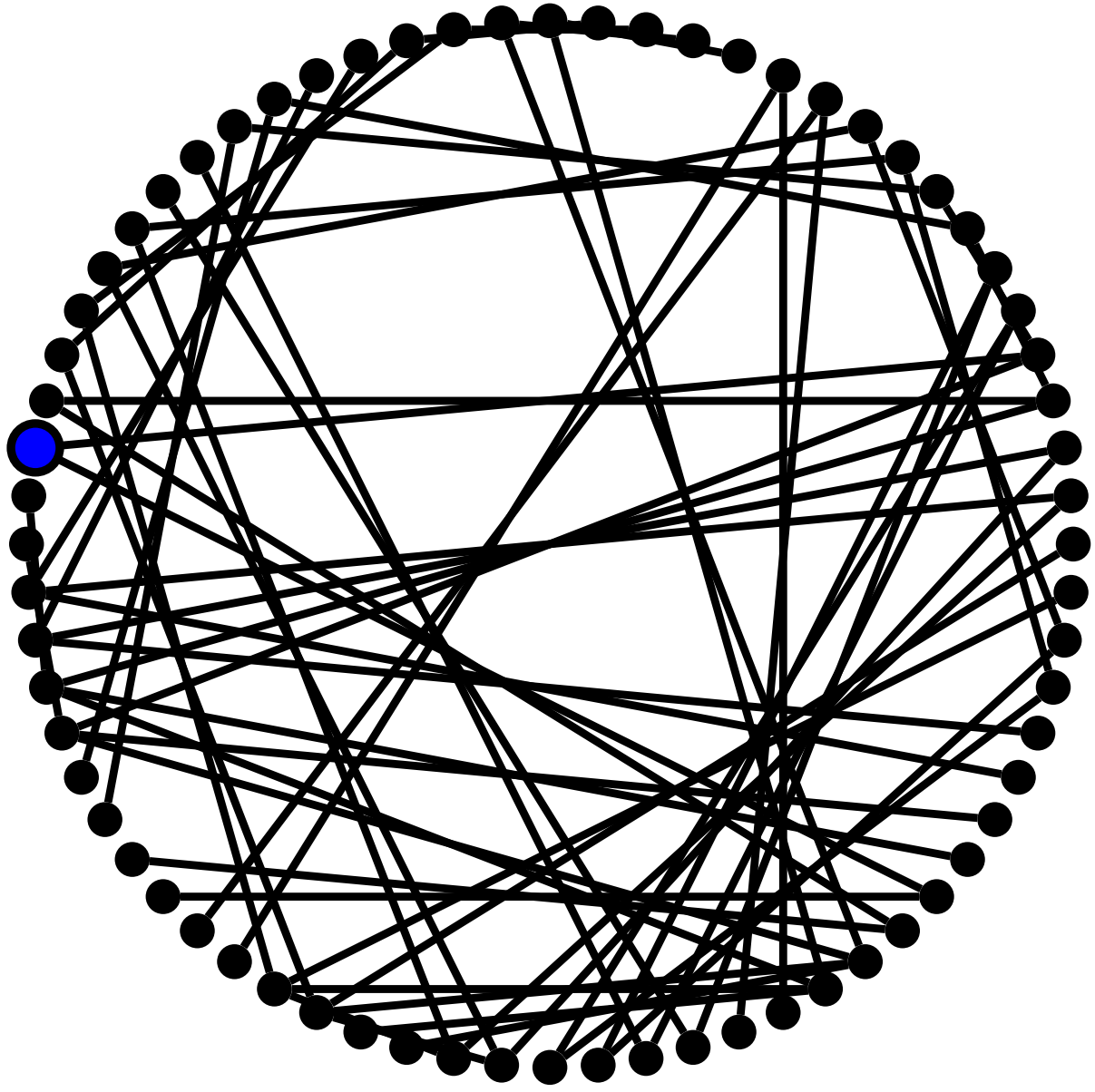

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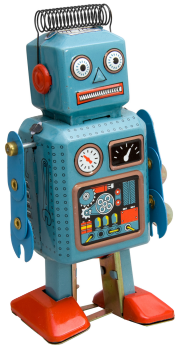
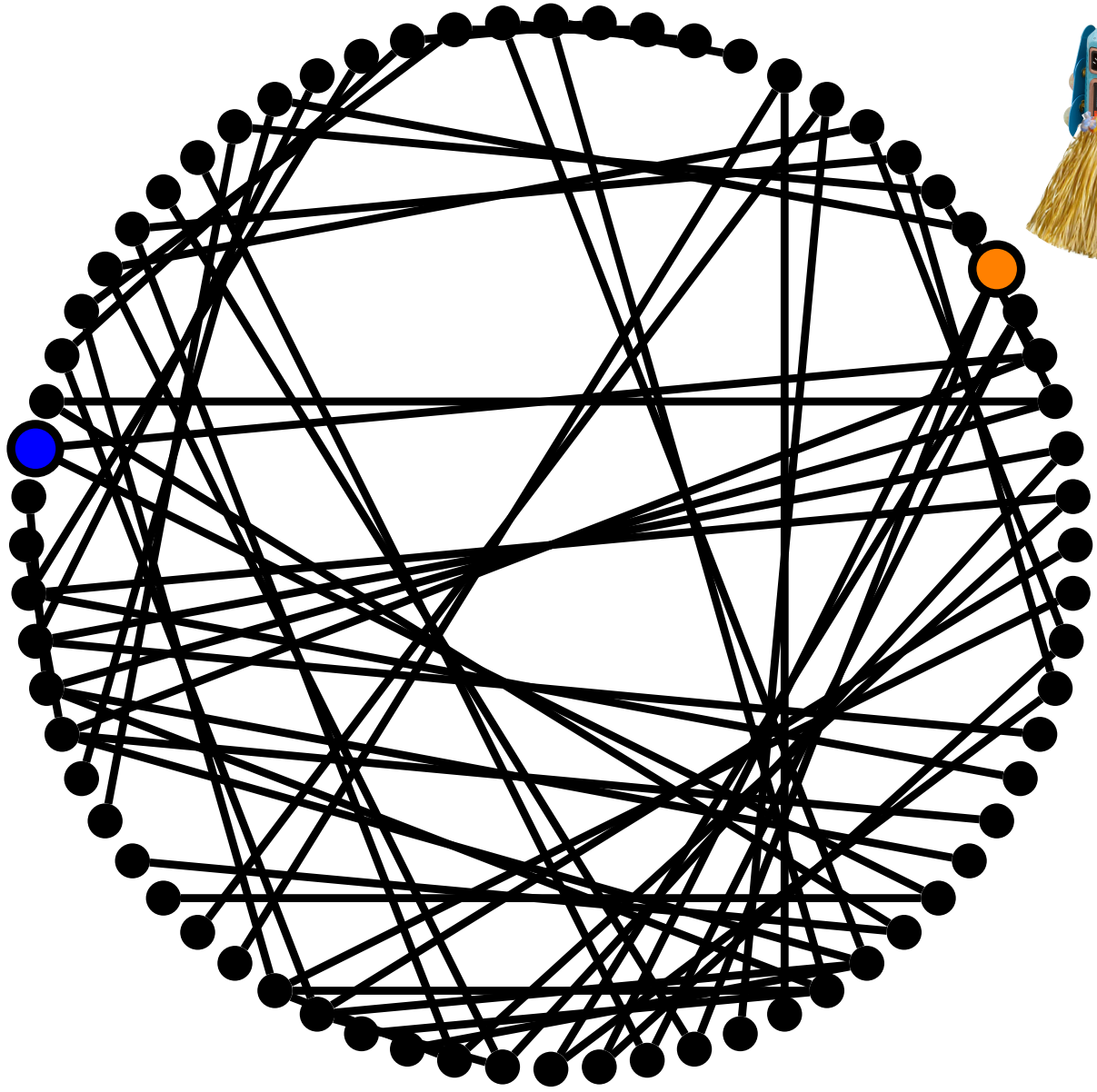
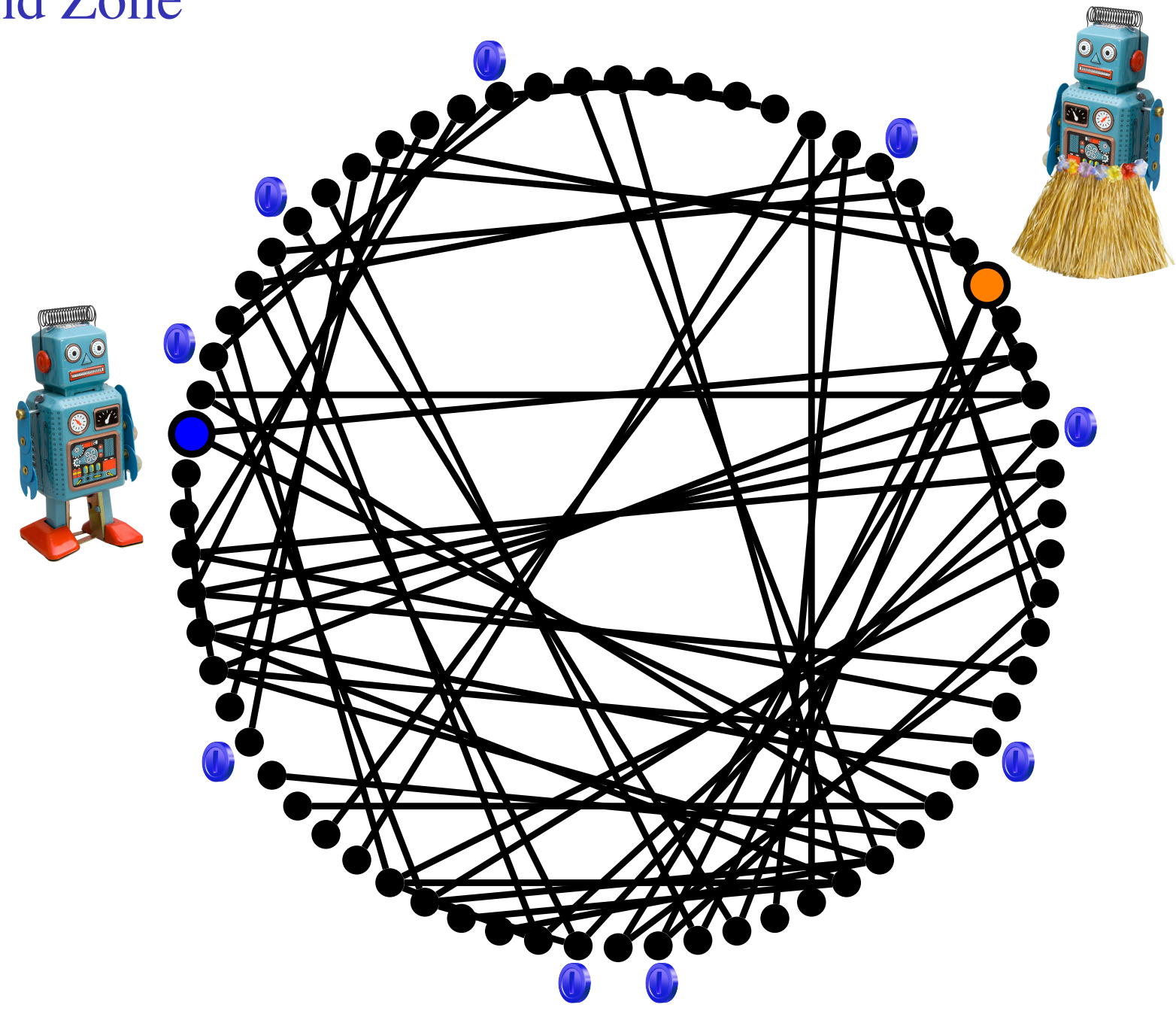




Friend Zone



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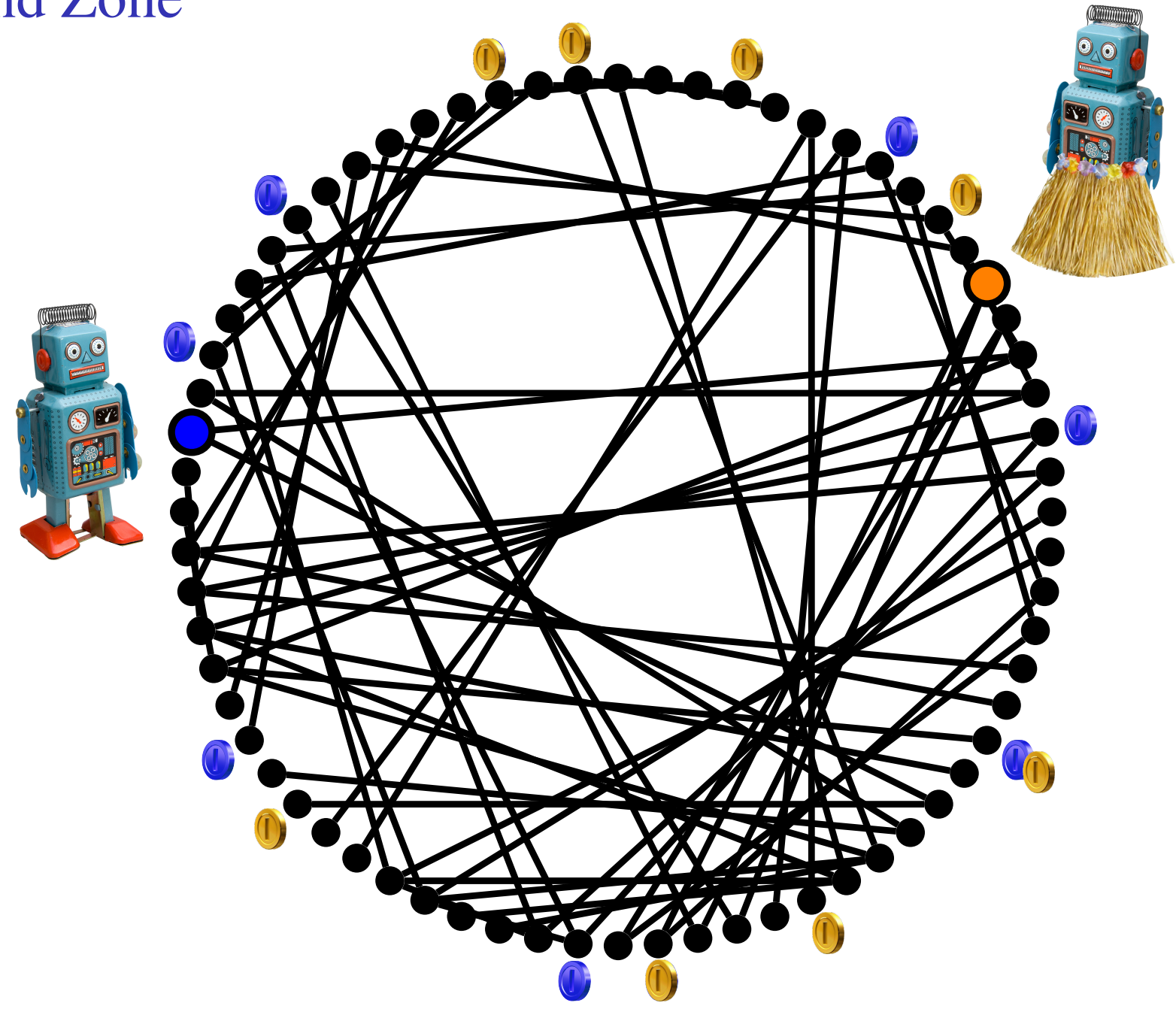
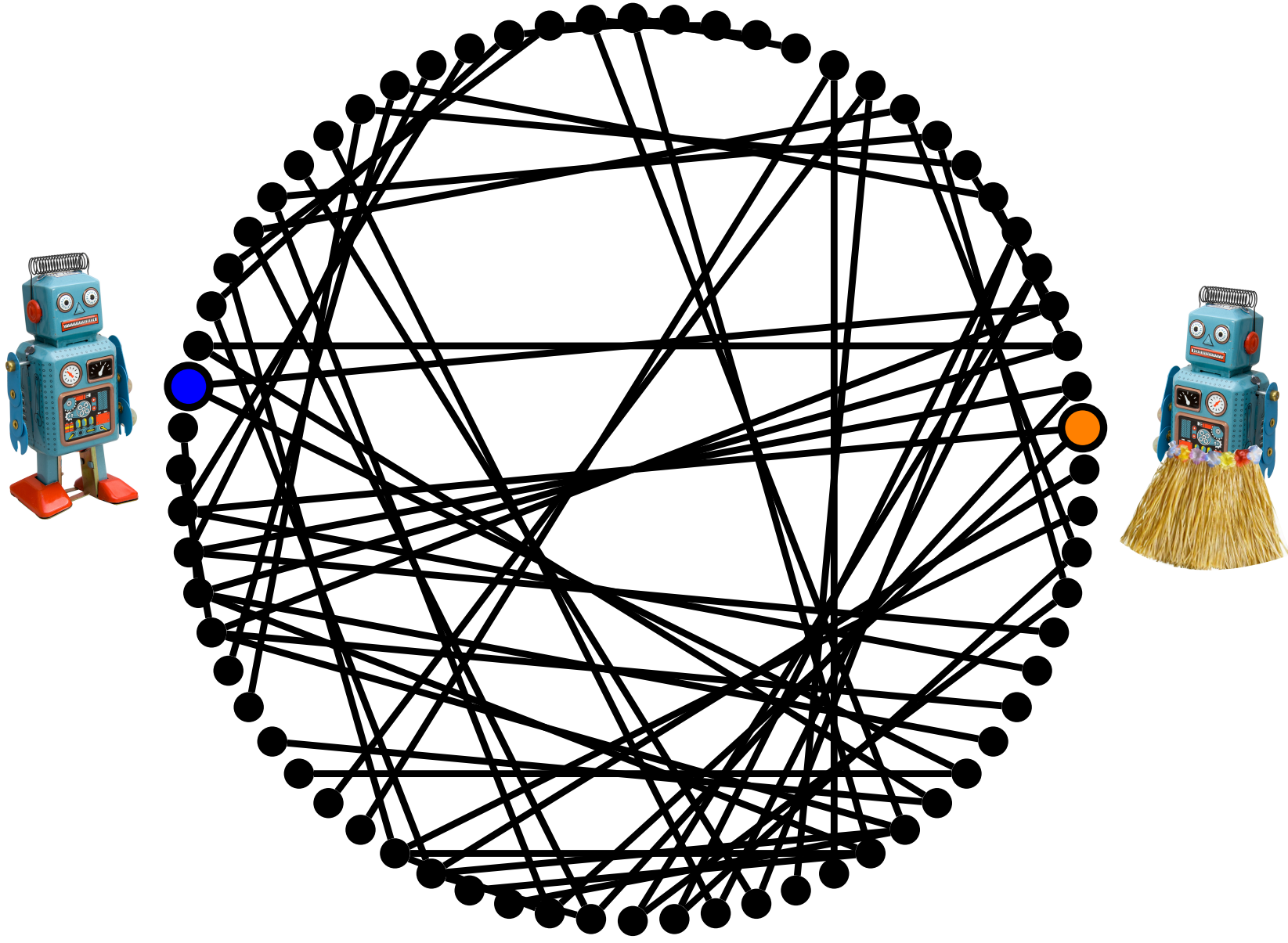


Friend Zone



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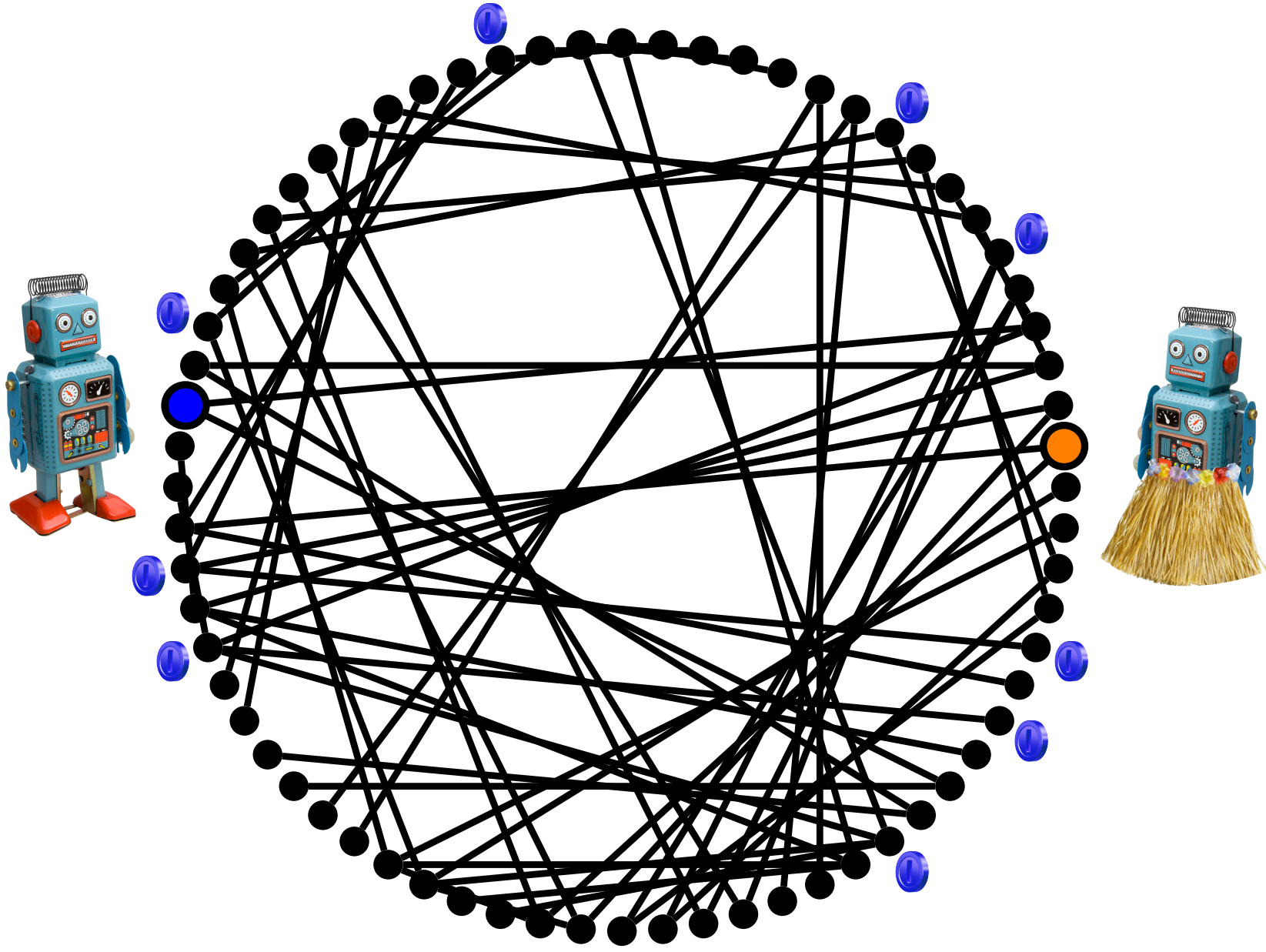
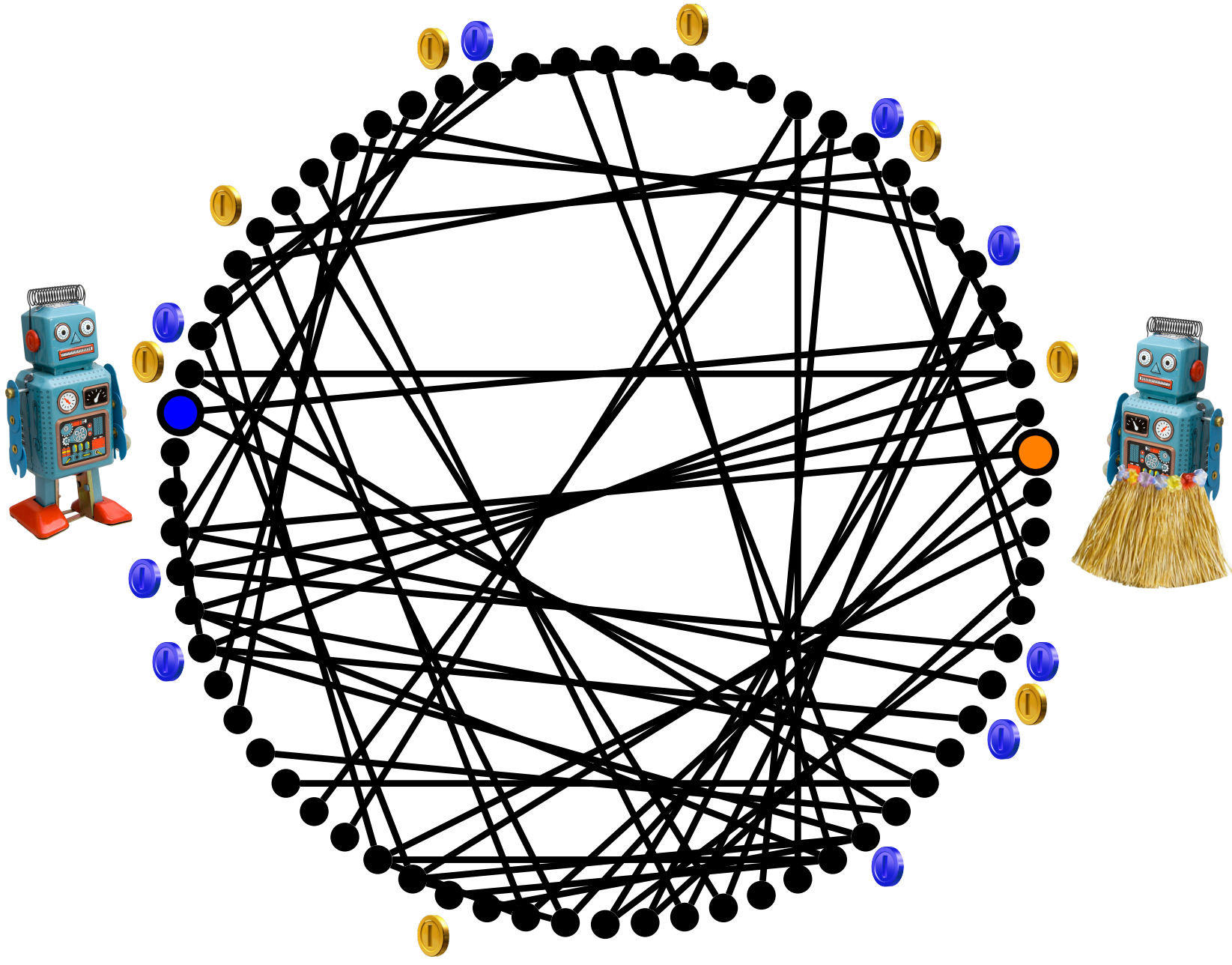
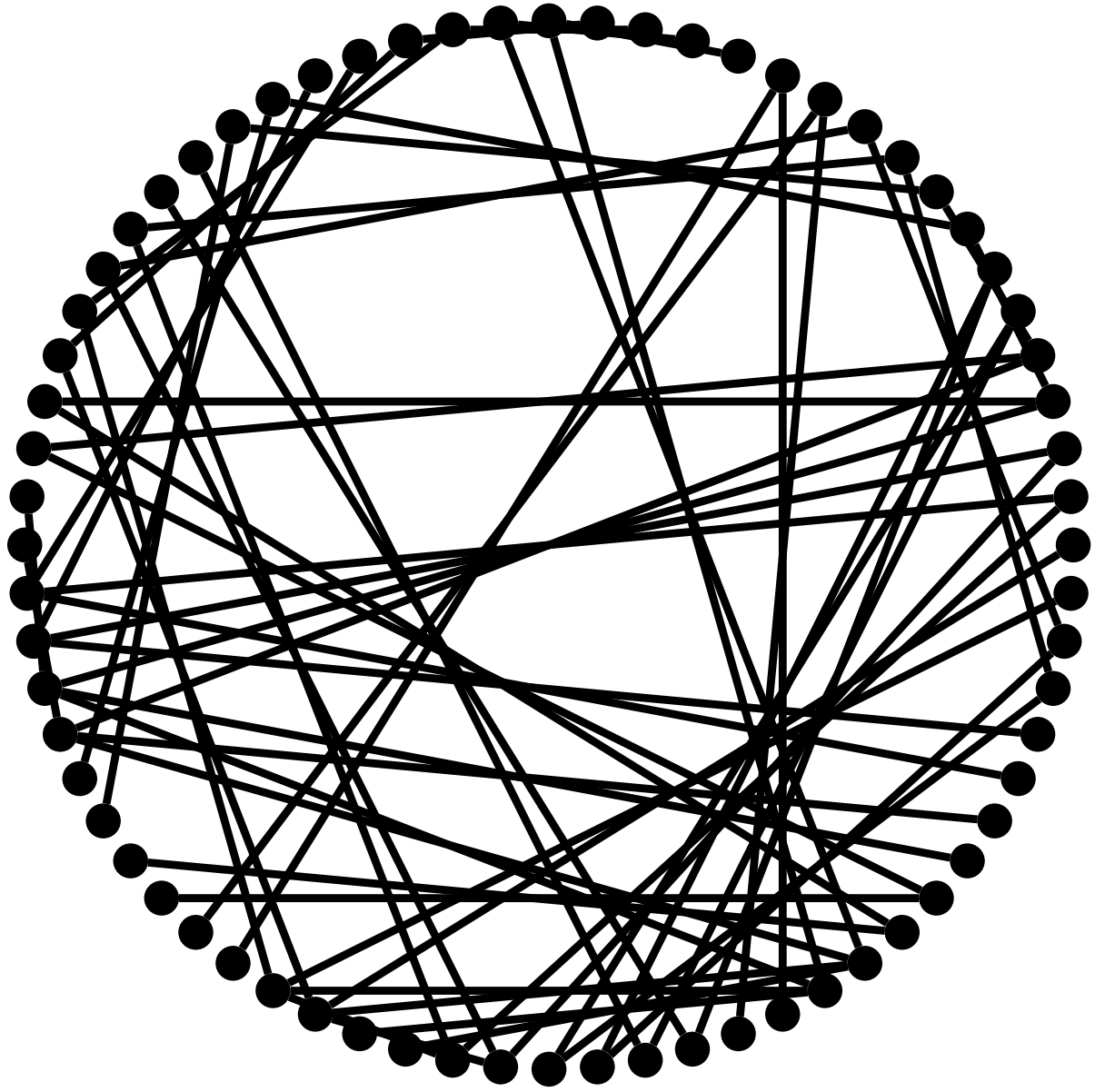


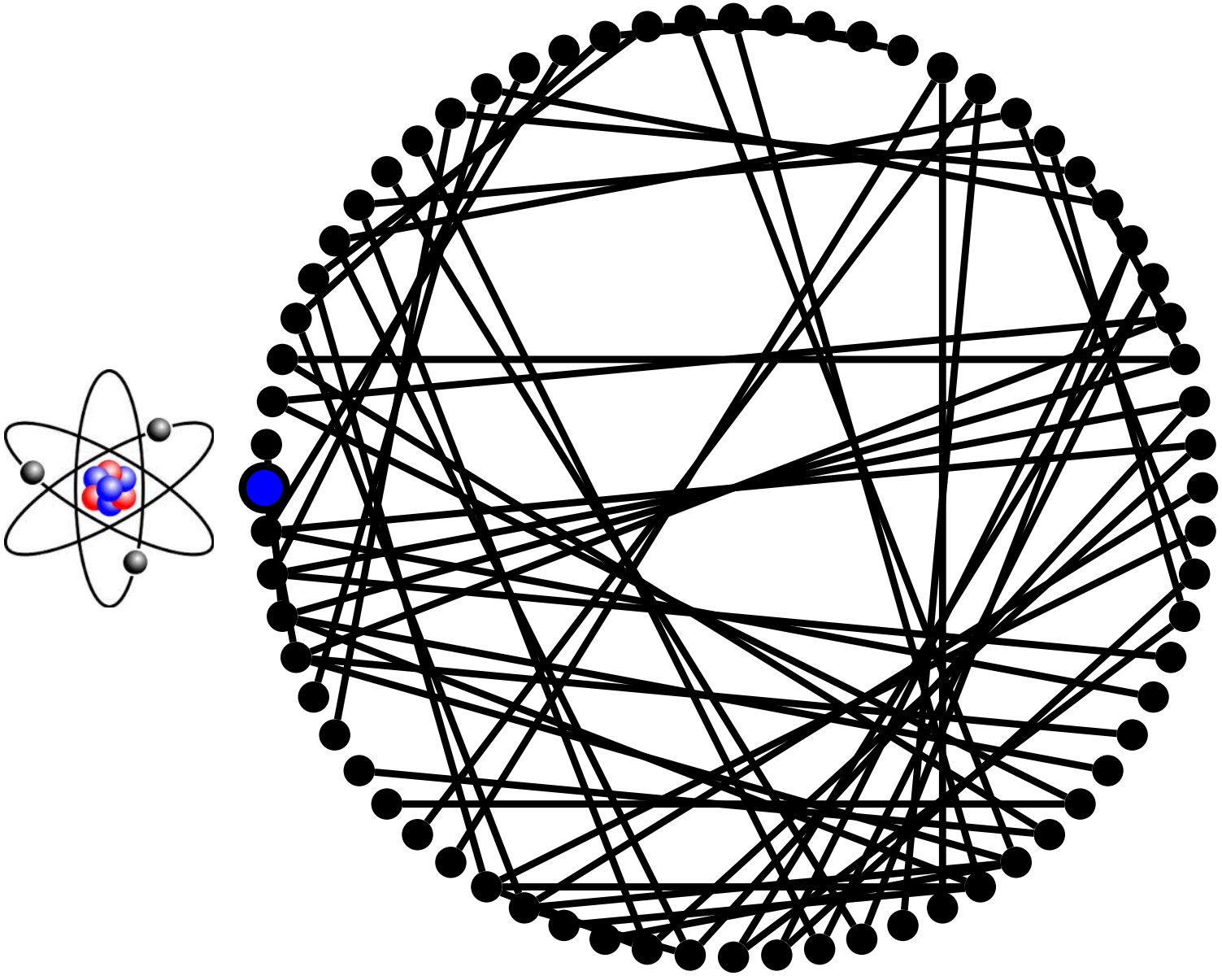
Friend Zone



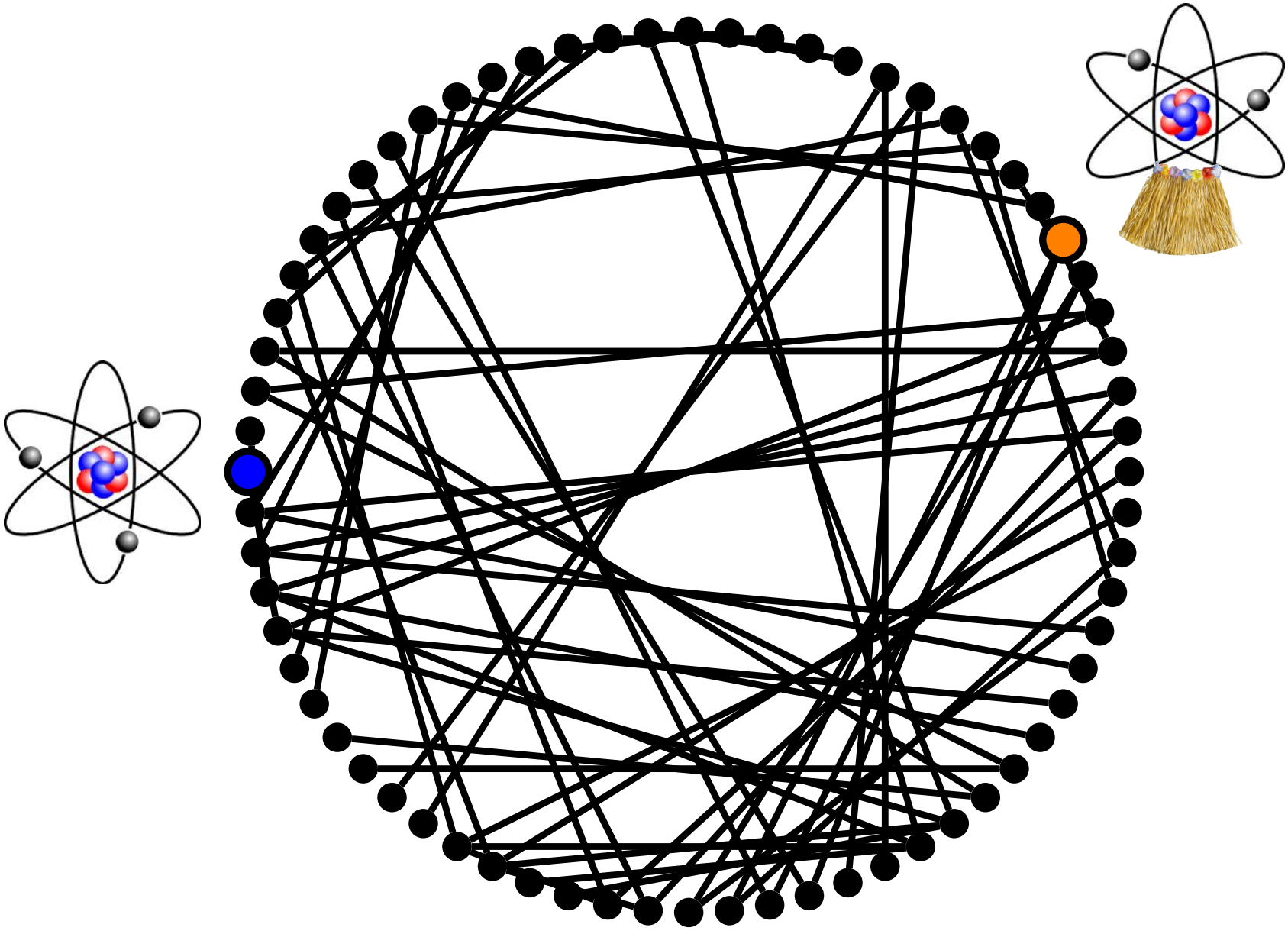
Quantum Algorithm



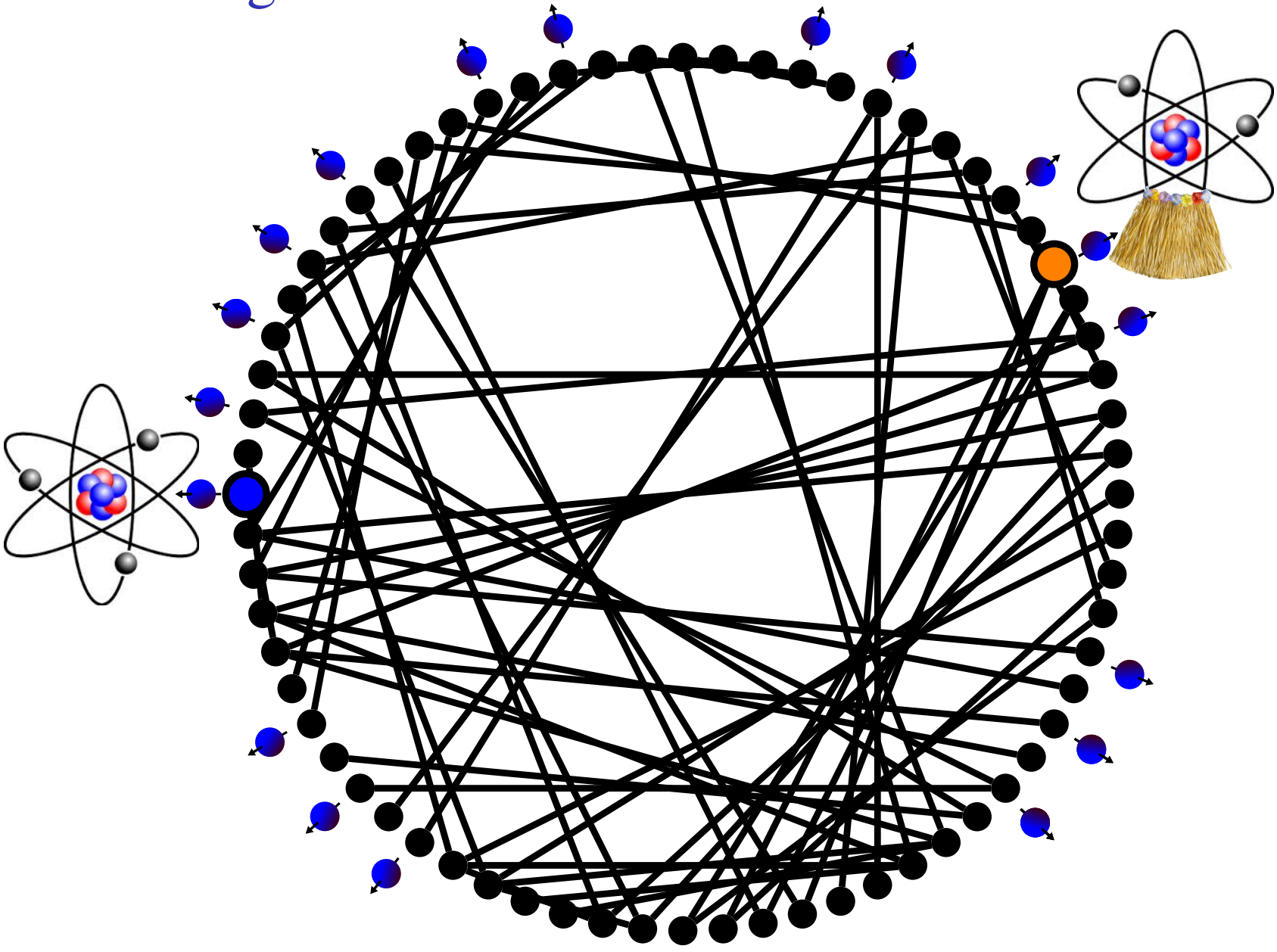
Quantum Algorithm



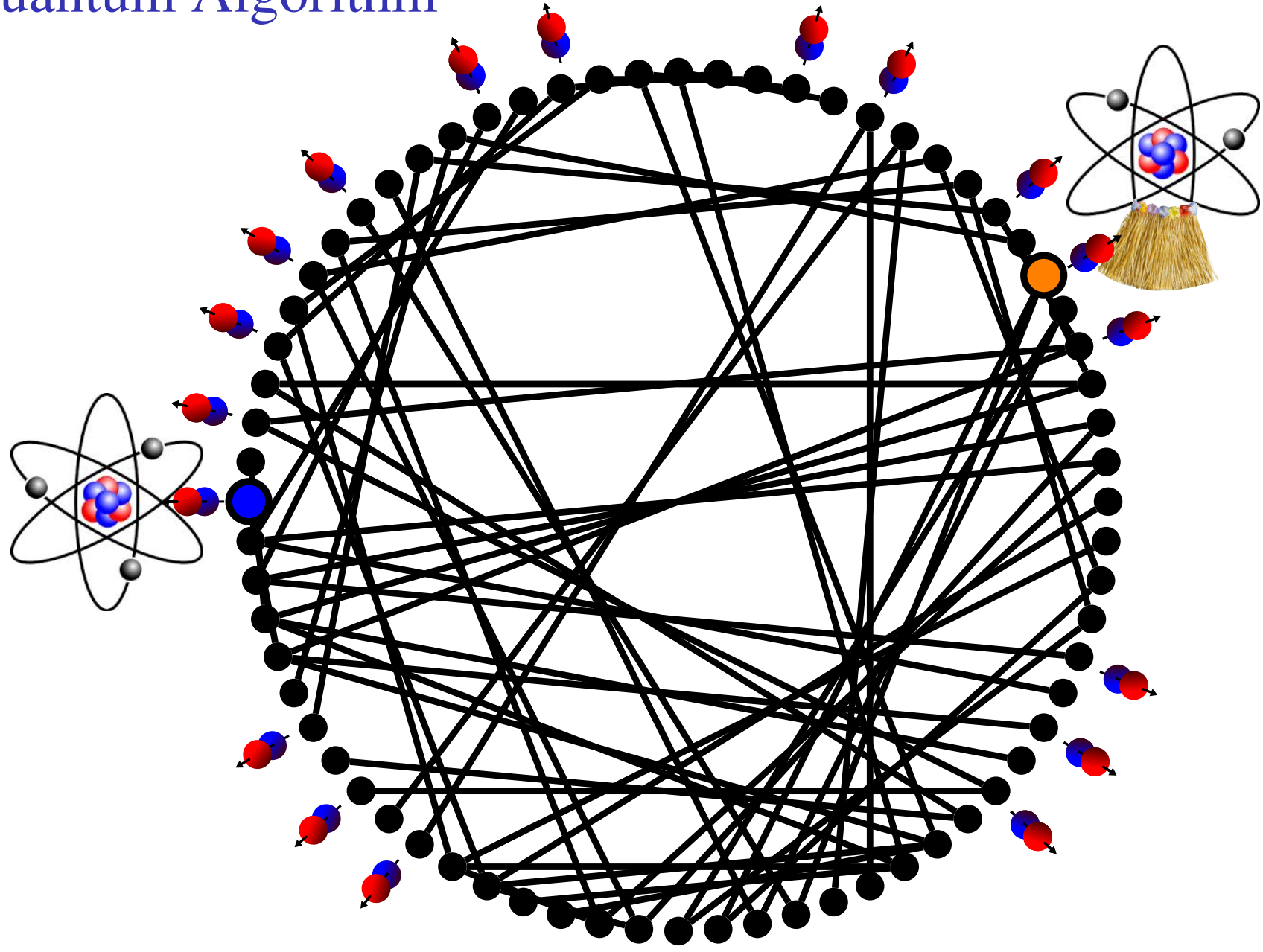
Quantum Algorithm



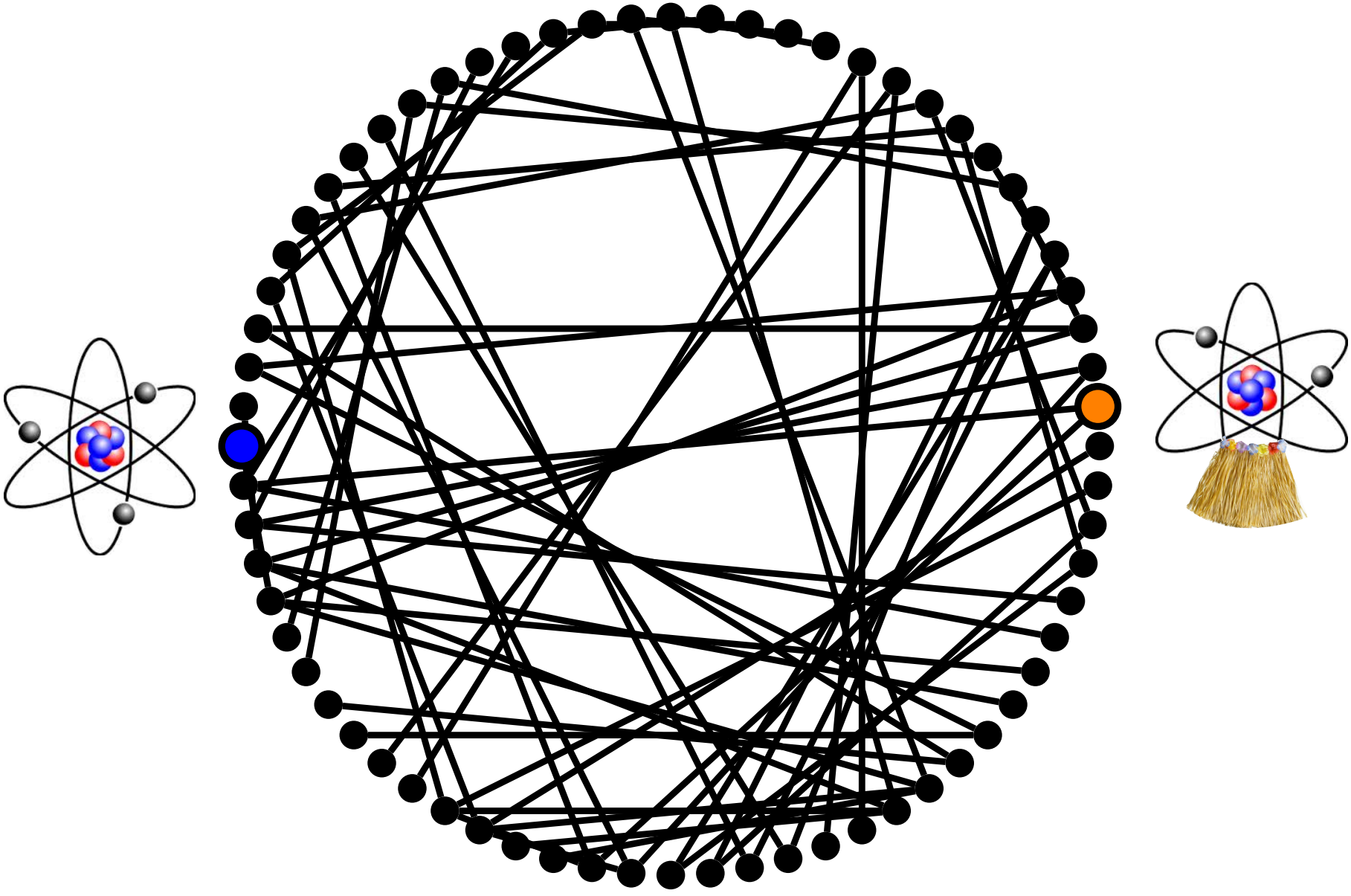
Quantum Algorithm



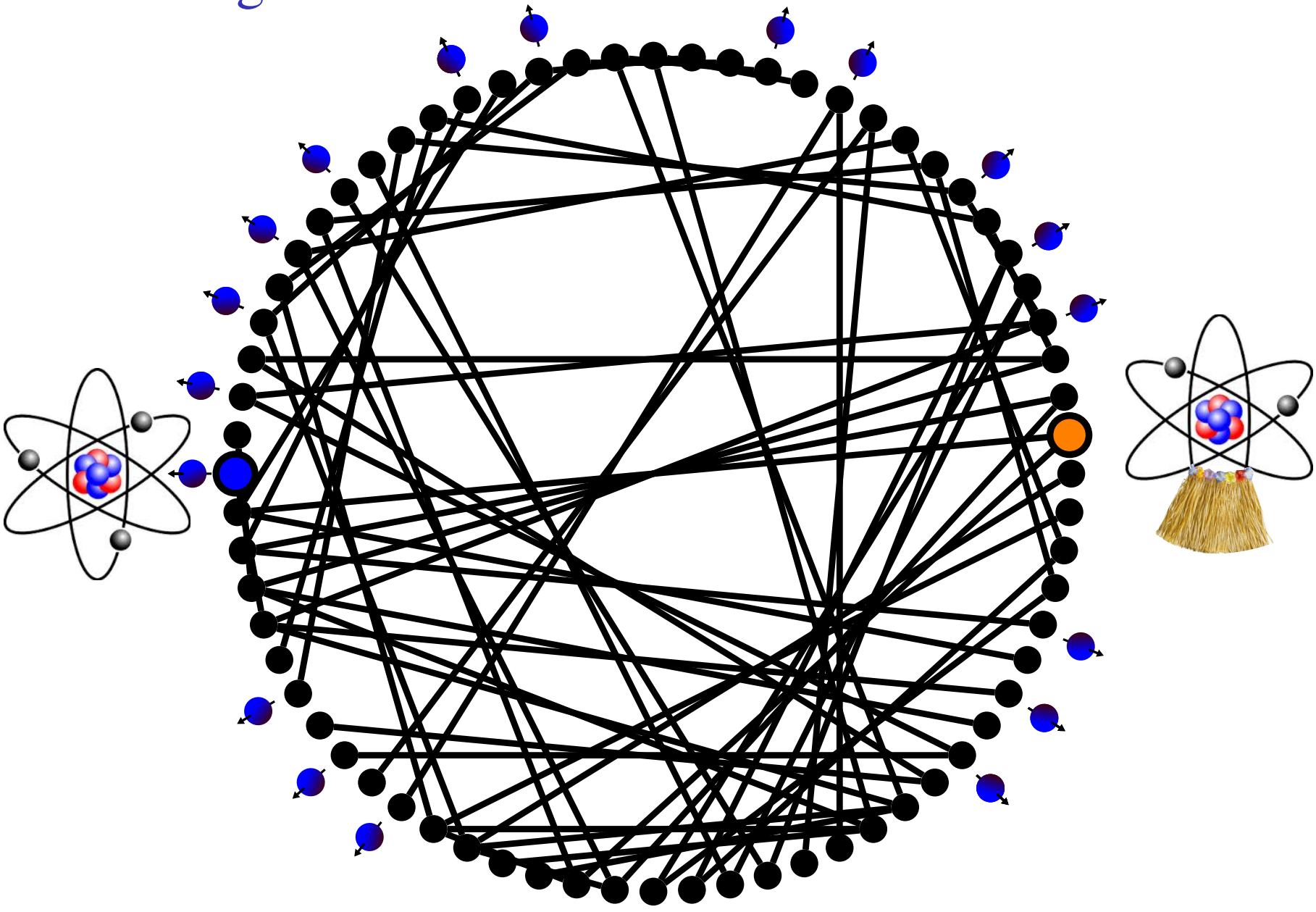
Quantum Algorithm



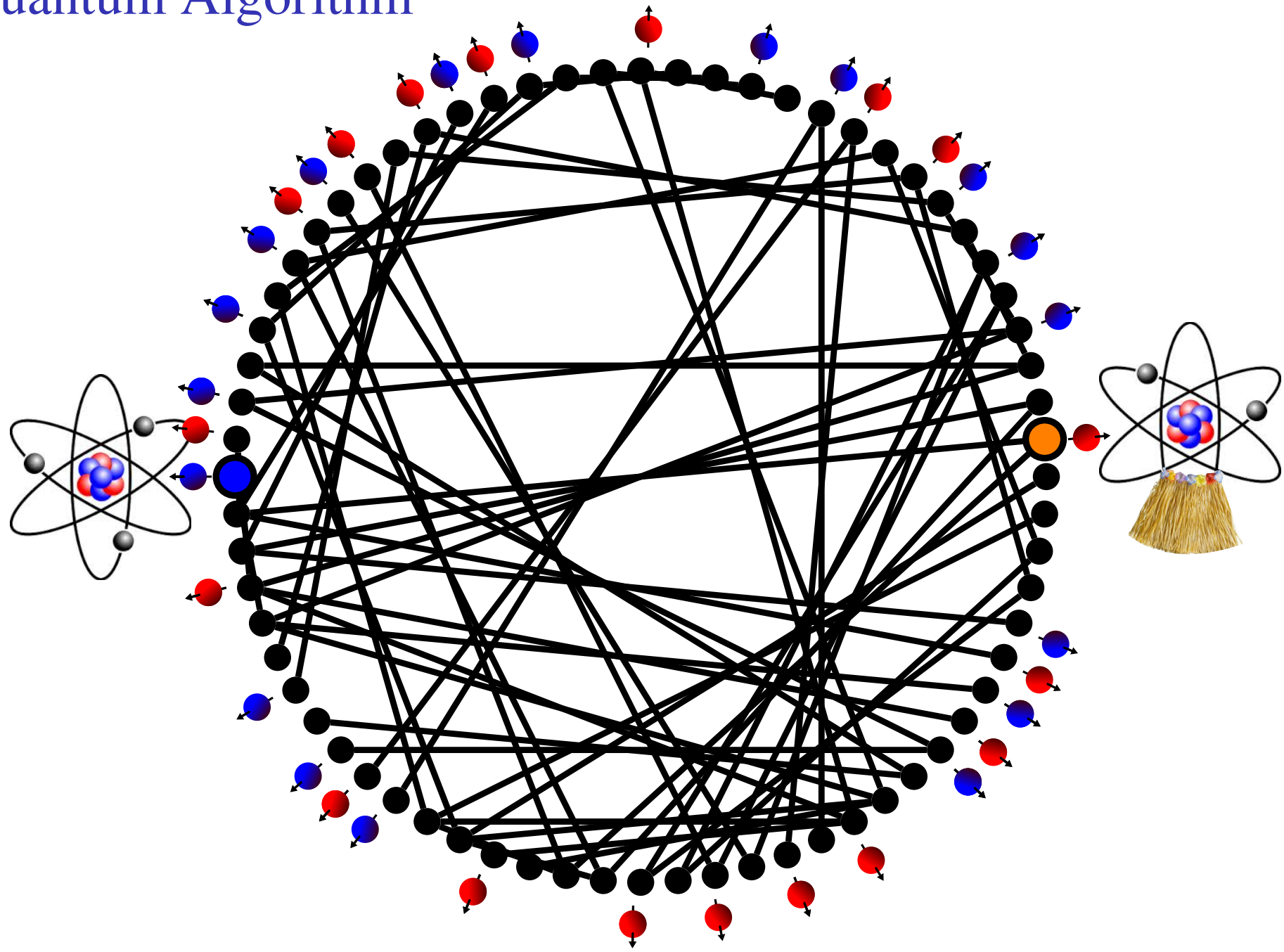
Quantum Algorithm



Quantum Algorithm

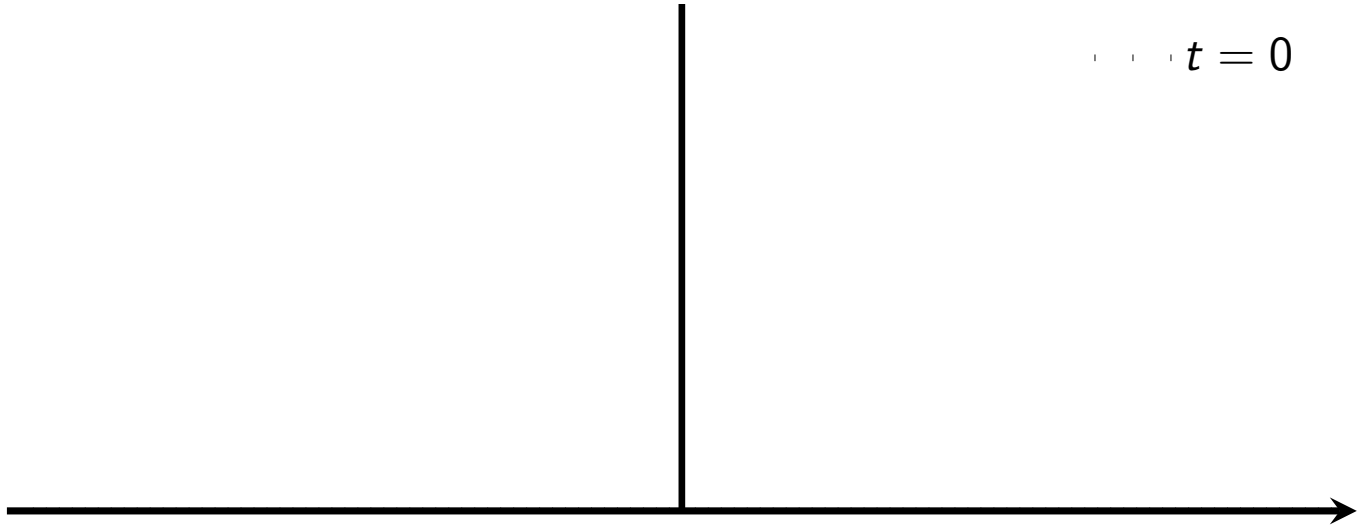


Quantum Algorithm

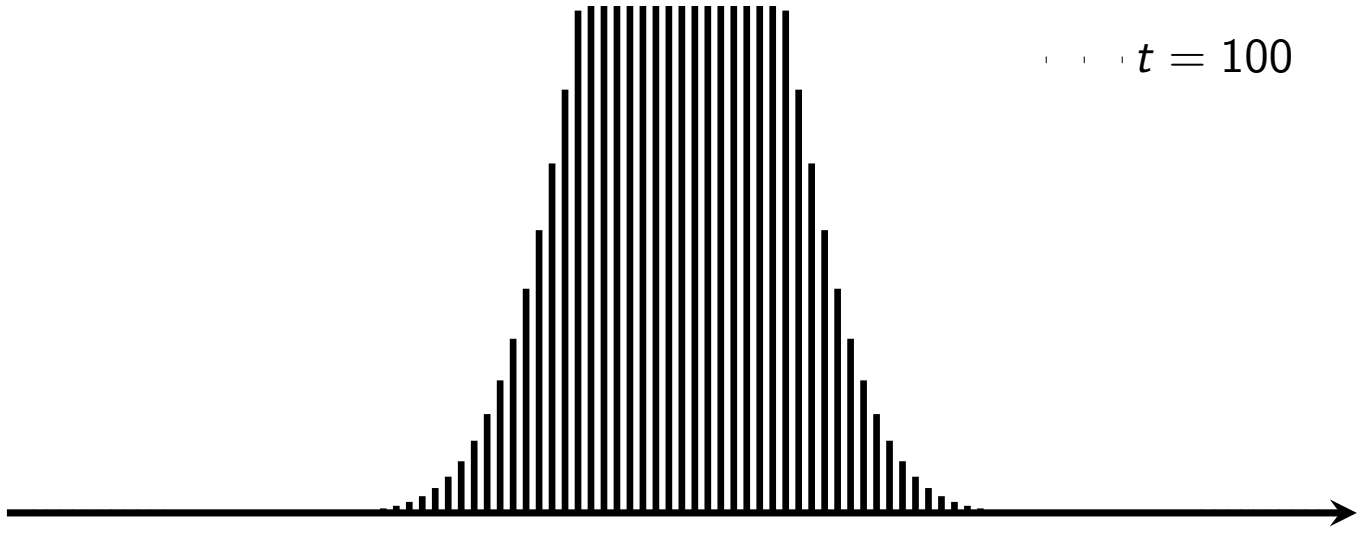


Quantum Fast-Forwarding *(or How to Tame a Quantum)*

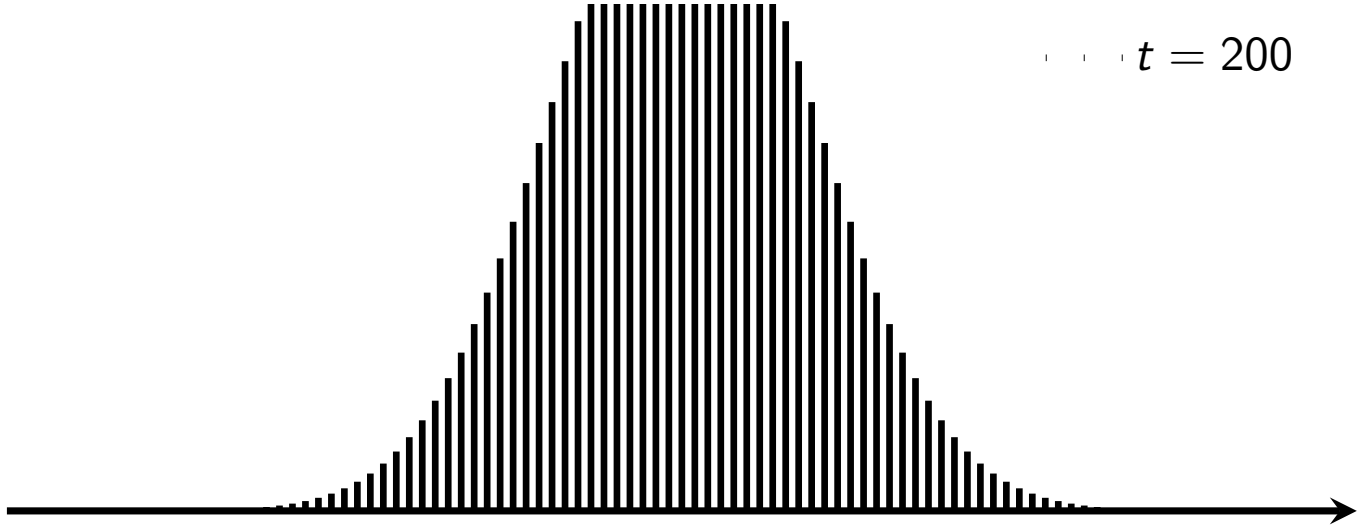
Quantum Fast-Forwarding *(or How to Tame a Quantum)*



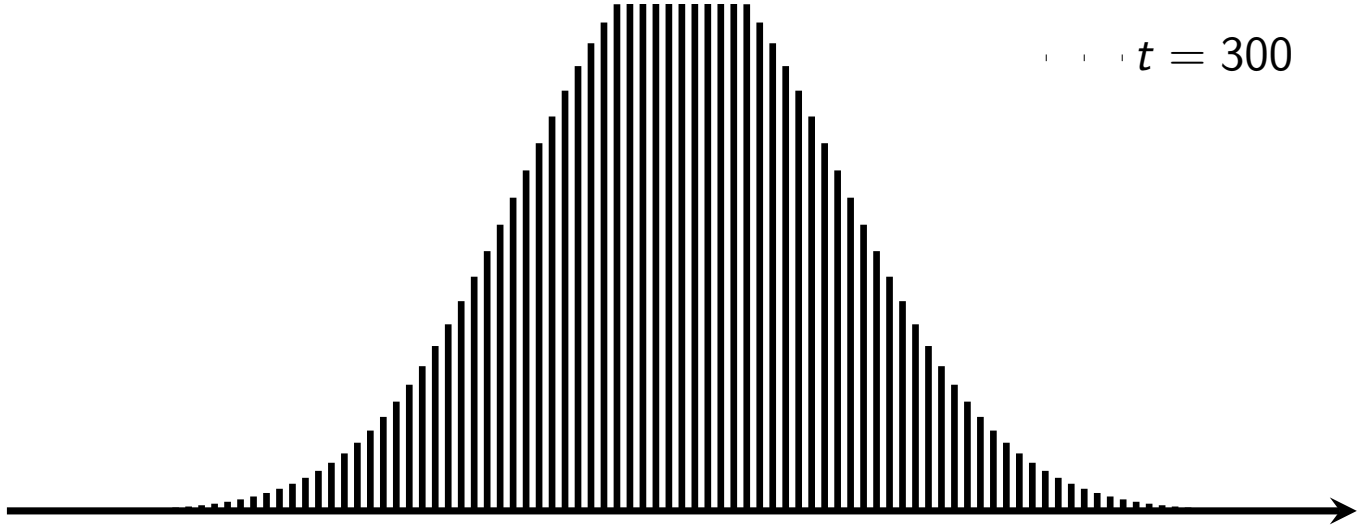
Quantum Fast-Forwarding *(or How to Tame a Quantum)*



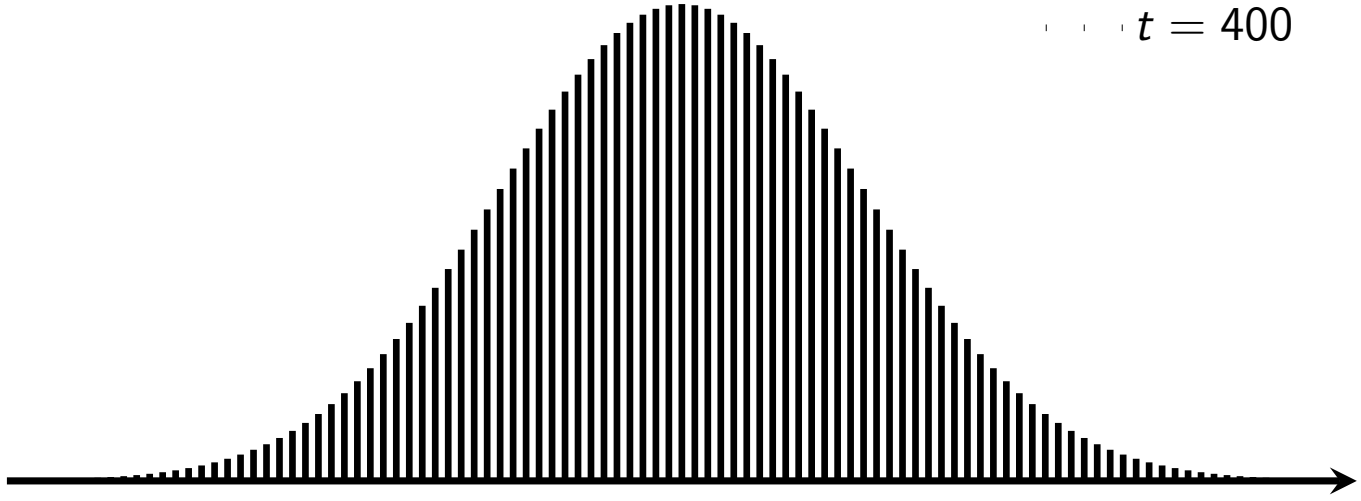
Quantum Fast-Forwarding *(or How to Tame a Quantum)*



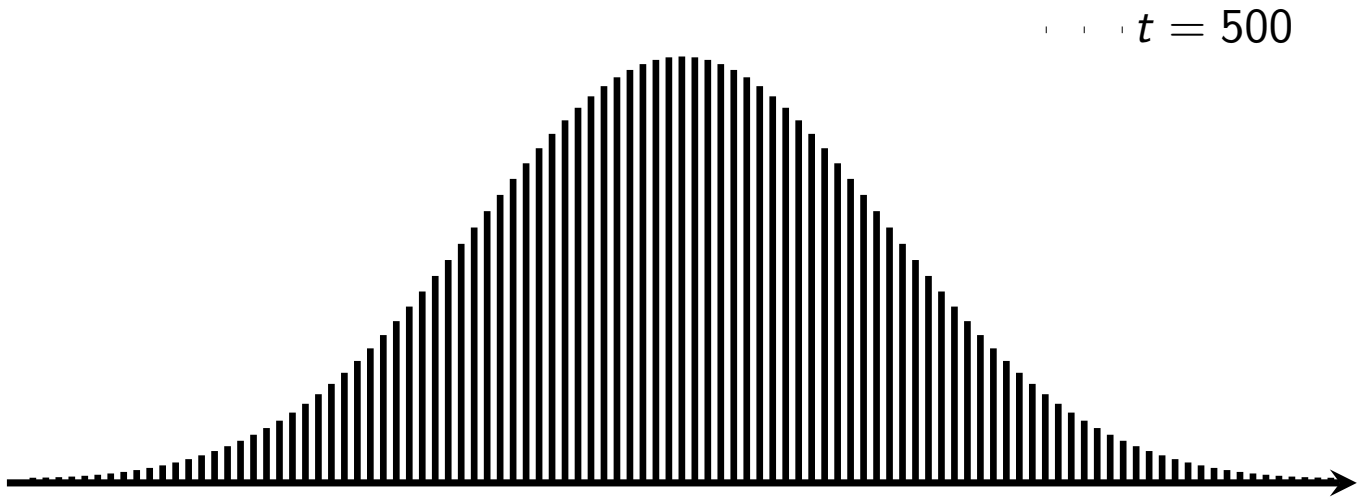
Quantum Fast-Forwarding *(or How to Tame a Quantum)*



Quantum Fast-Forwarding *(or How to Tame a Quantum)*

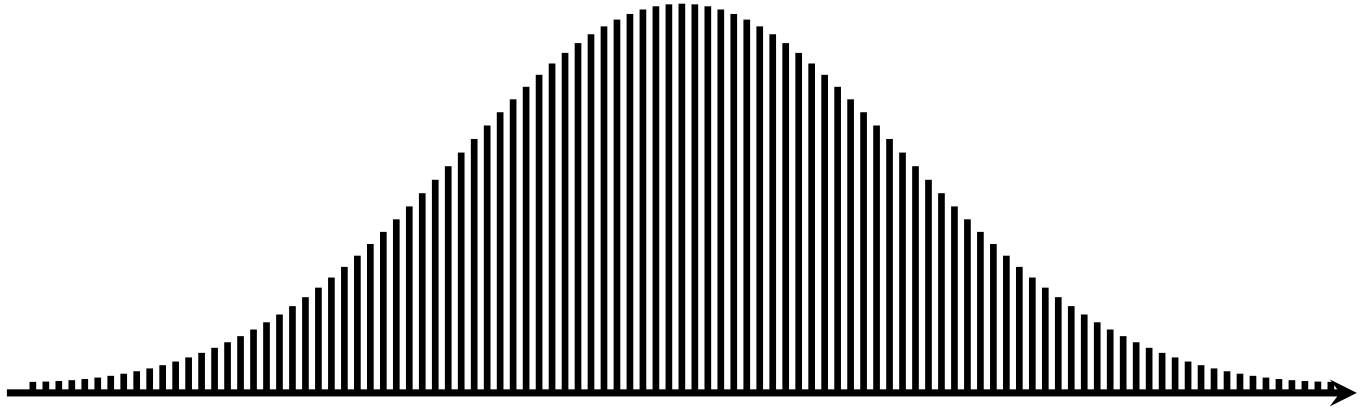


Quantum Fast-Forwarding *(or How to Tame a Quantum)*



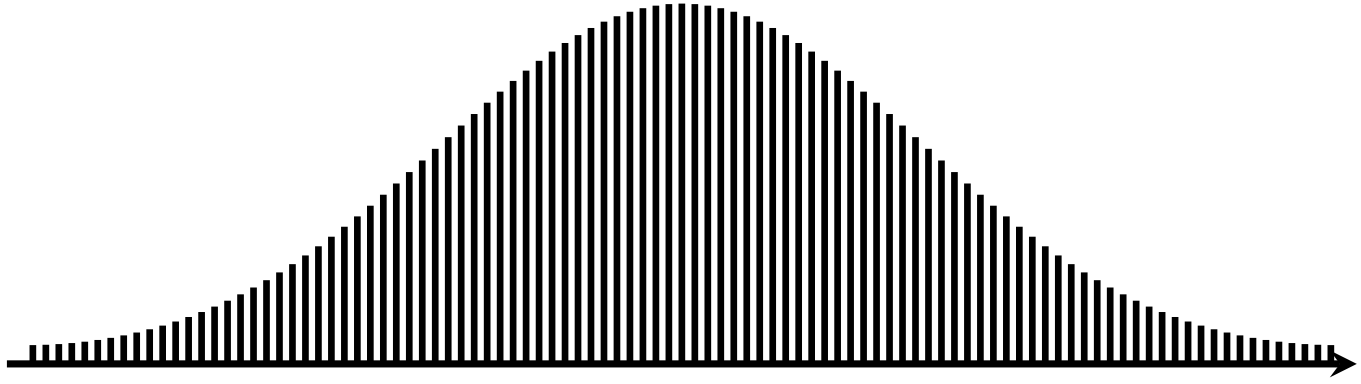
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 600$



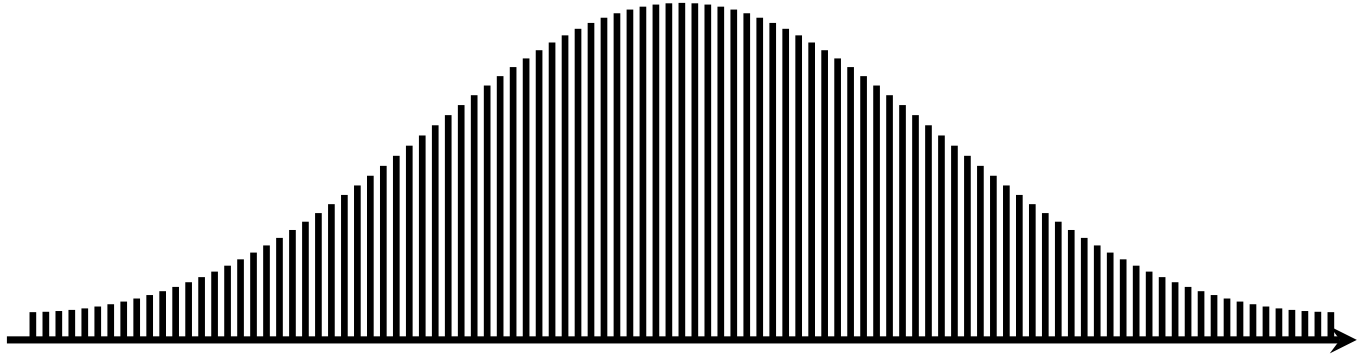
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 700$



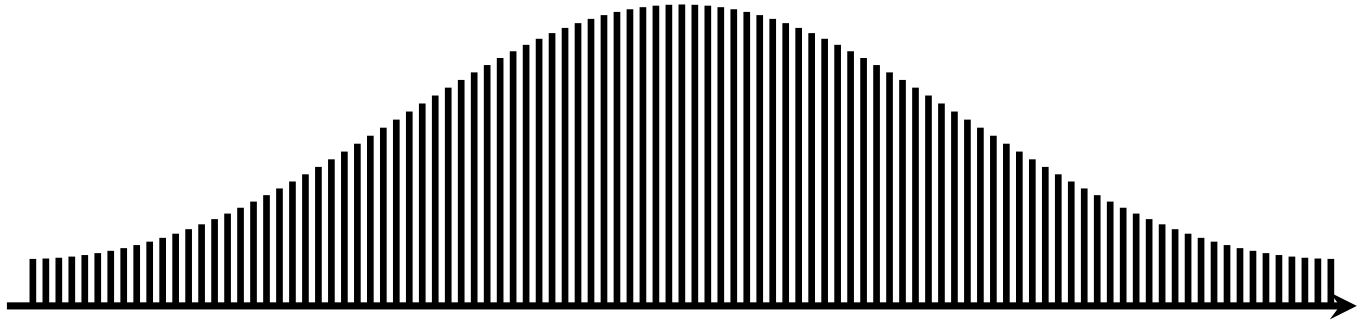
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 800$



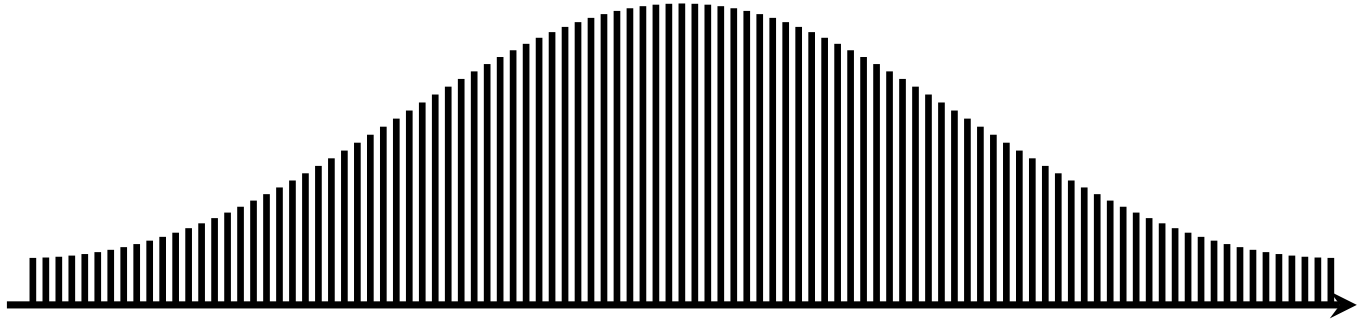
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

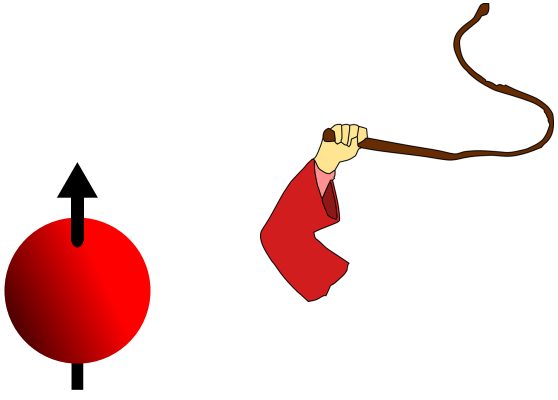
$t = 1000$



Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 1000$





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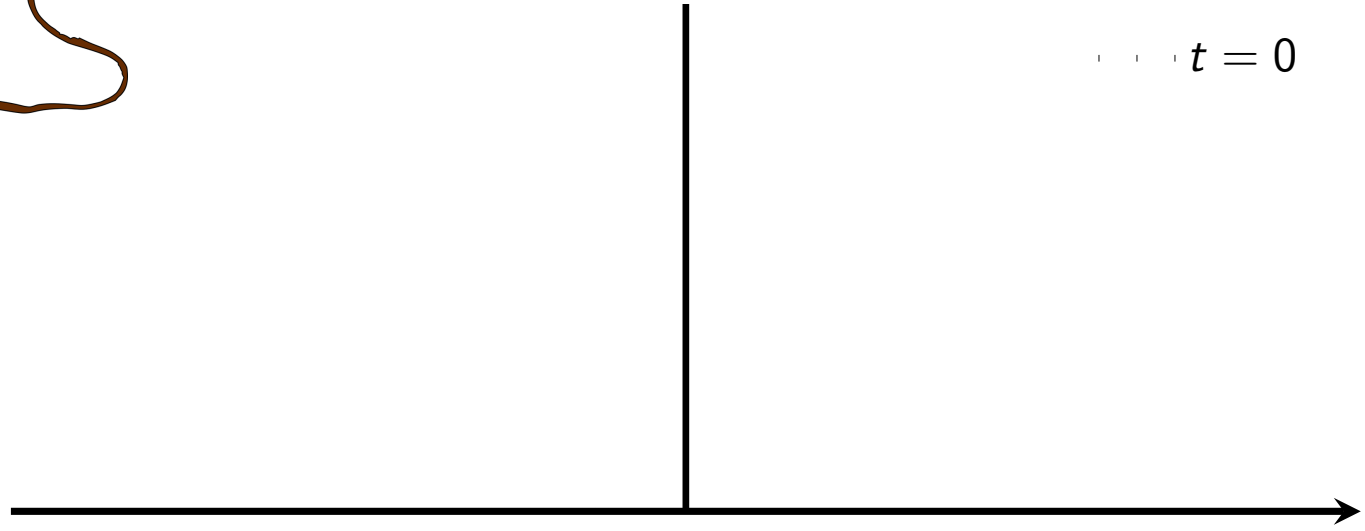
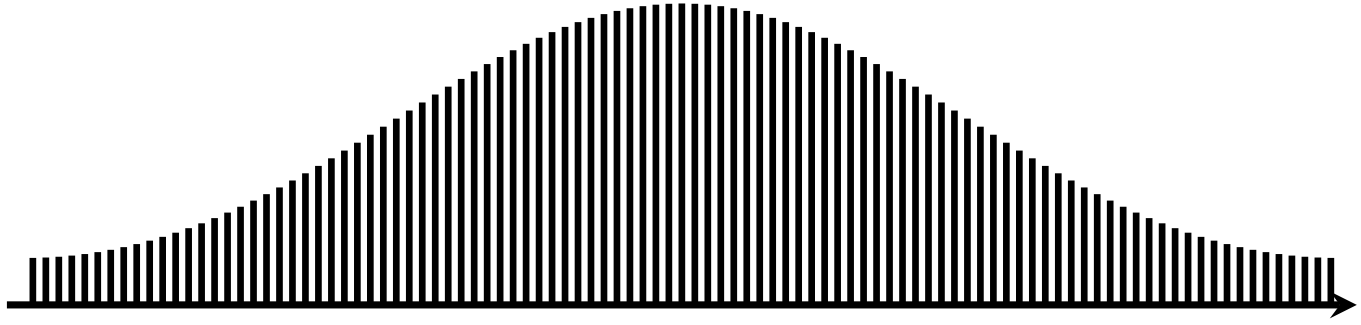
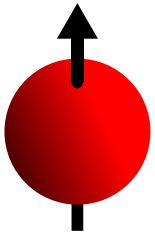


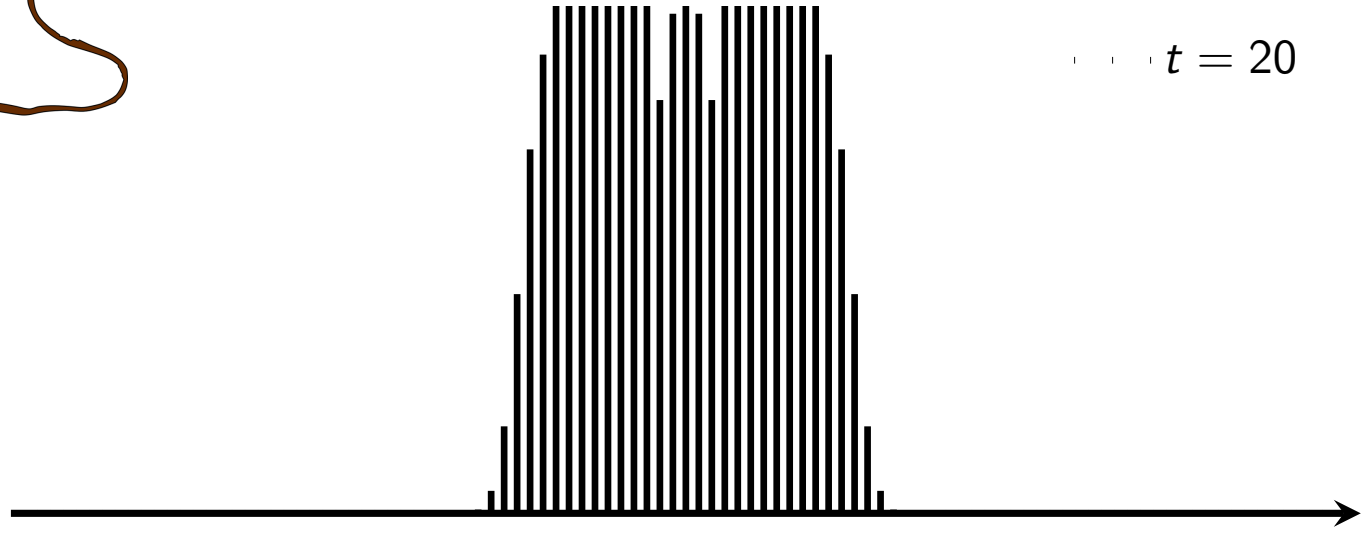
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 1000$



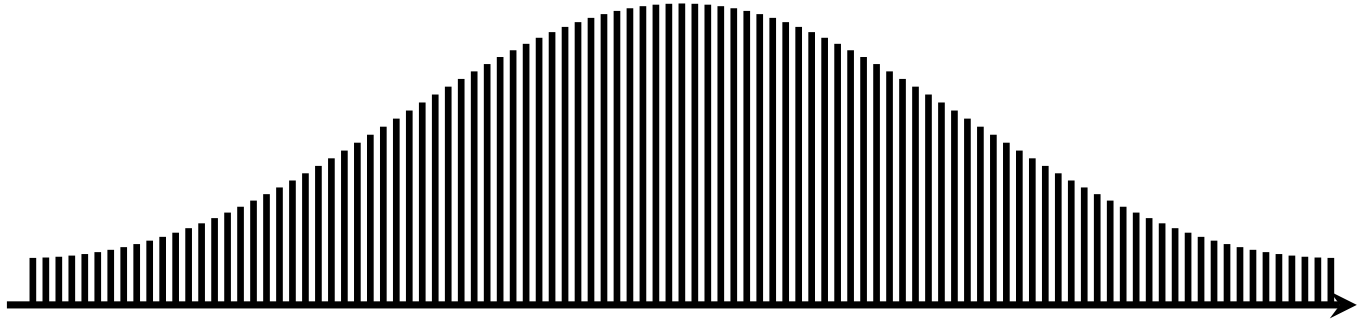


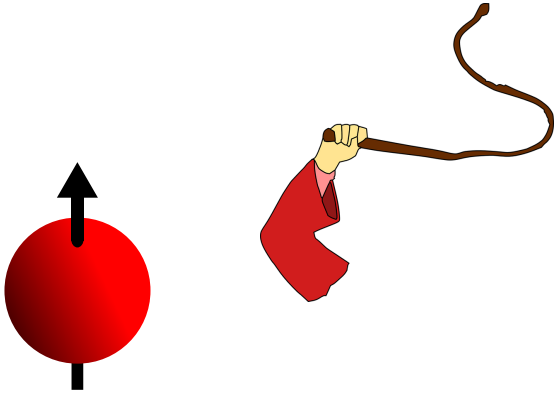
$t = 20$



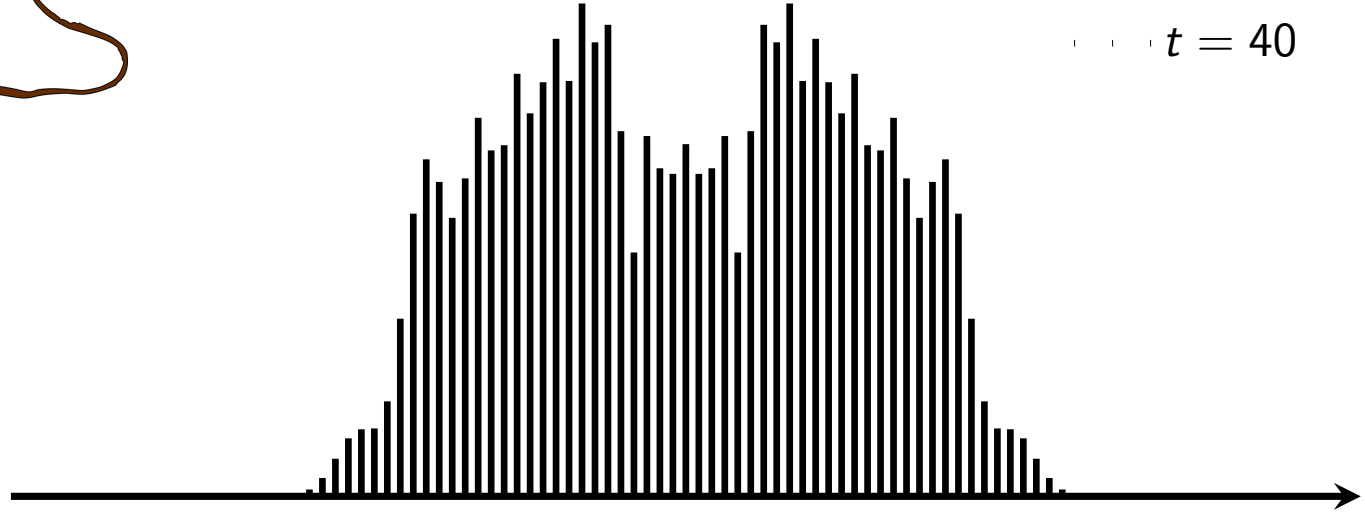
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 1000$



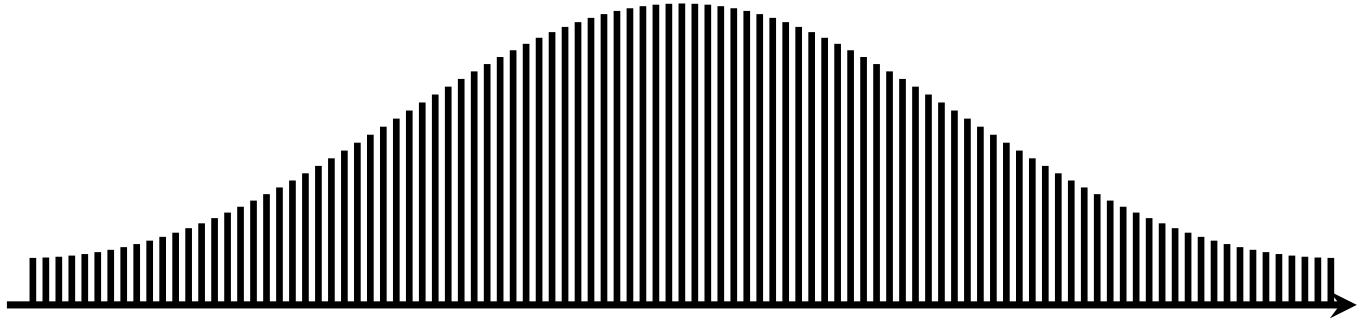


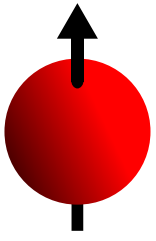
$t = 40$



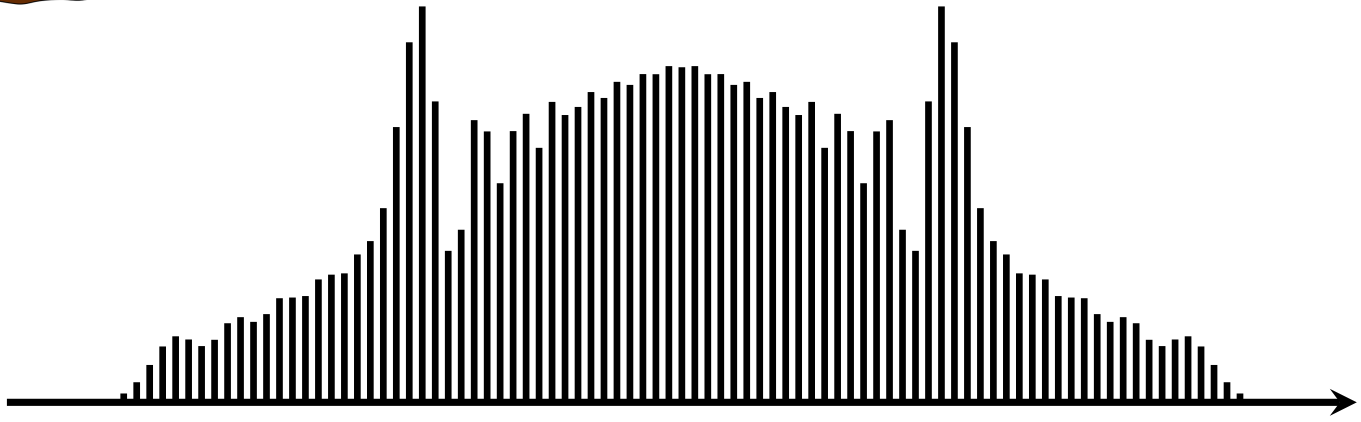
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 1000$



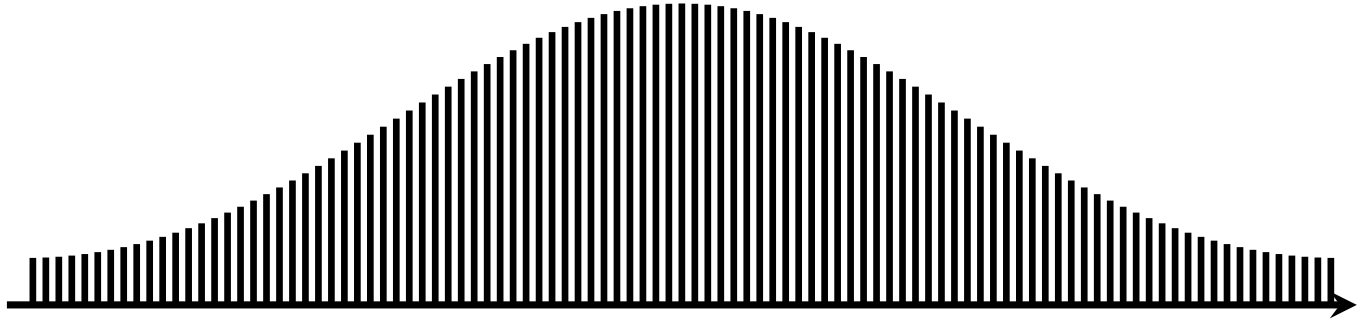


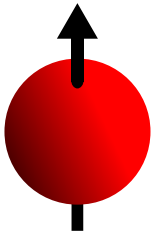
$t = 60$



Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 1000$





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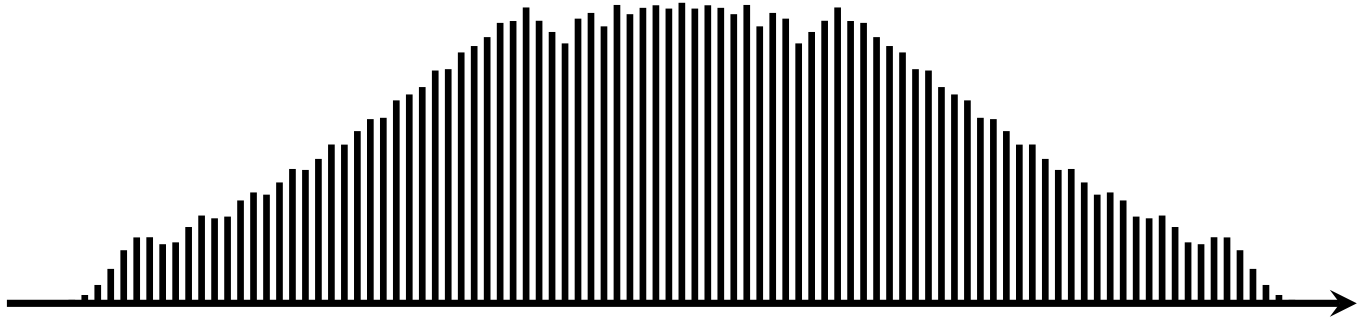
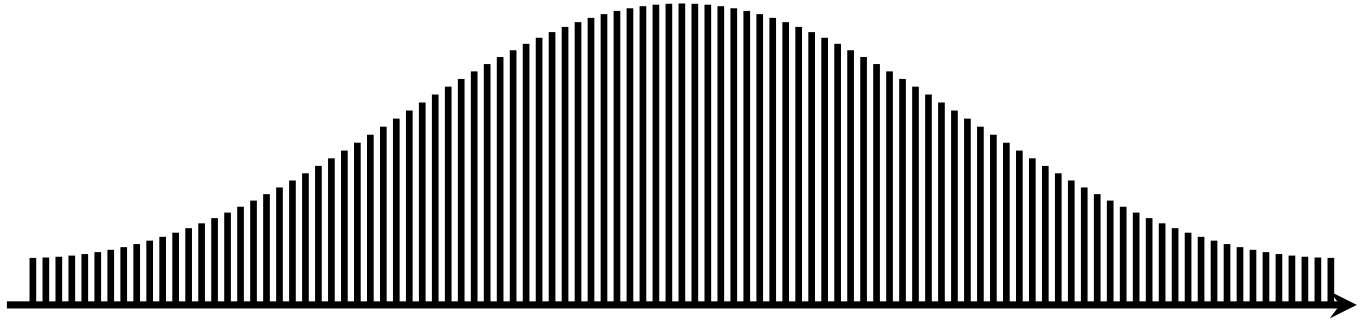
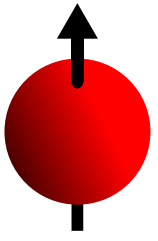


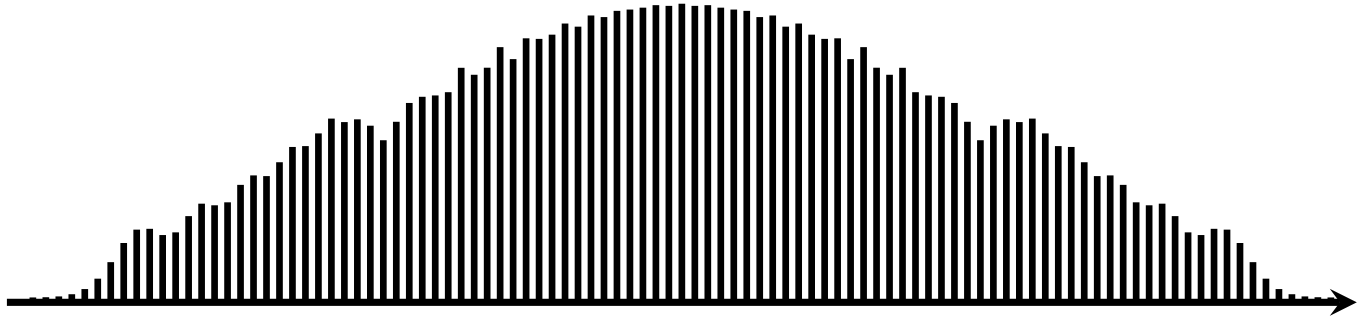
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 1000$



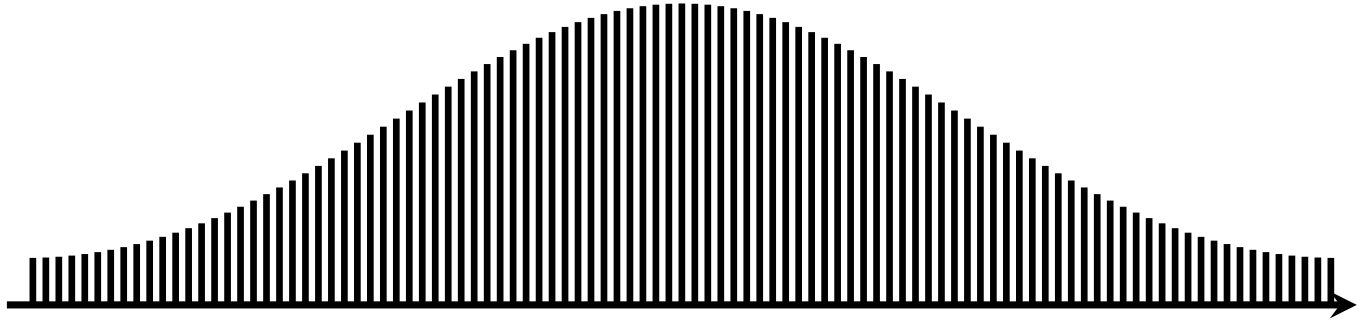


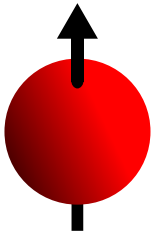
$t = 100$



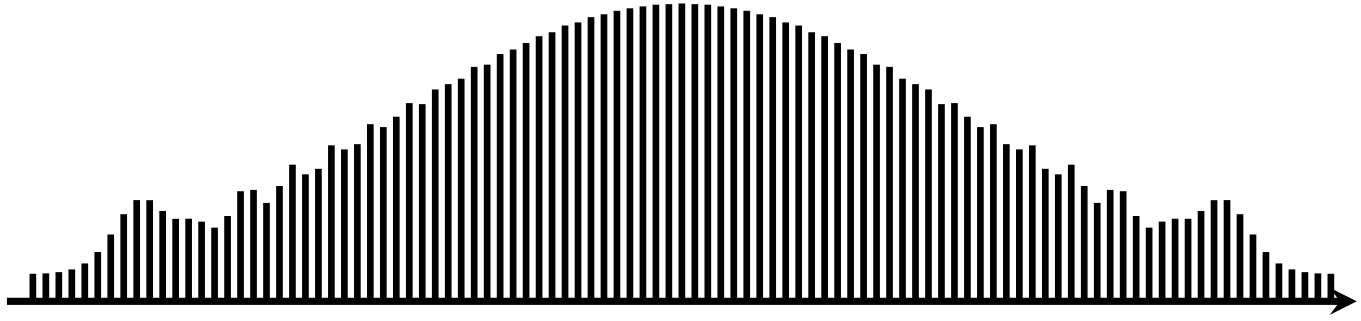
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 1000$



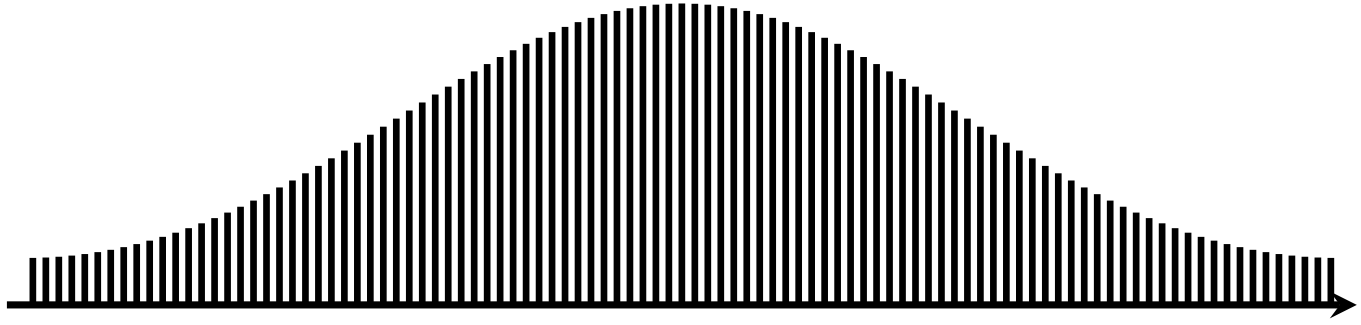


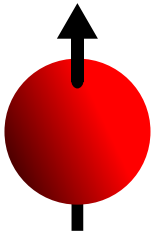
$t = 120$



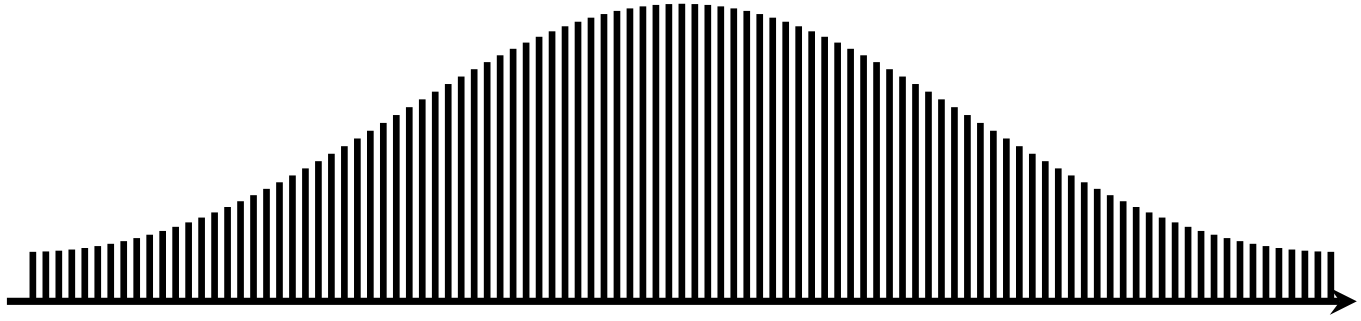
Quantum Fast-Forwarding *(or How to Tame a Quantum)*

$t = 1000$





$t = 140$



- Coins and Quantum
- Speed Limits on Mixing

  Can quantum walks speed up mixing?

  - Classical walks can simulate quantum walks
  - In principle: no quantum speedup possible

- **Fast-Forwarding Classical Walks**

  Can't quantum walks really speed up mixing?

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  - QFF algorithm:
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- Speed Limits on Mixing

  Can quantum walks speed up mixing?

  - Classical walks can simulate quantum walks
  - In principle: no quantum speedup possible

- **Fast-Forwarding Classical Walks**

  Can't quantum walks really speed up mixing?

  - QFF algorithm:
    quantum walks can speed up simple classical walks
  - Realistic problem:
    quantum speedup of known classical algorithms