

Quantum Computing with Parallel Worlds

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University of British Columbia
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Introduction

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Breaking locks

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Three-digit locks have $10^3 = 1000$ combinations.

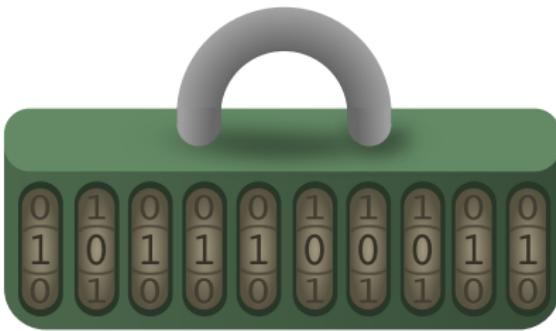
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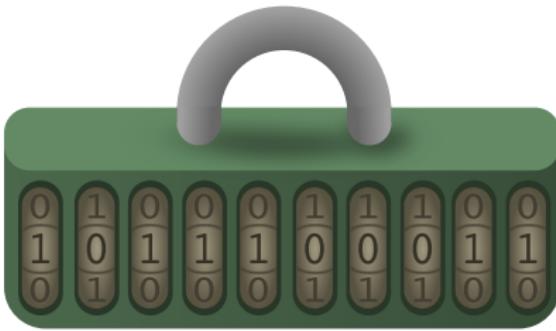
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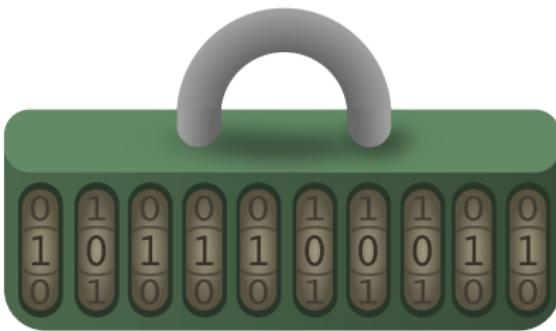
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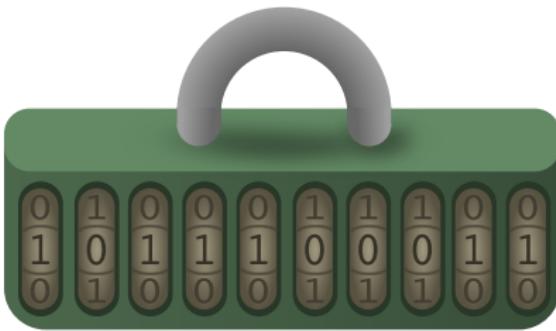
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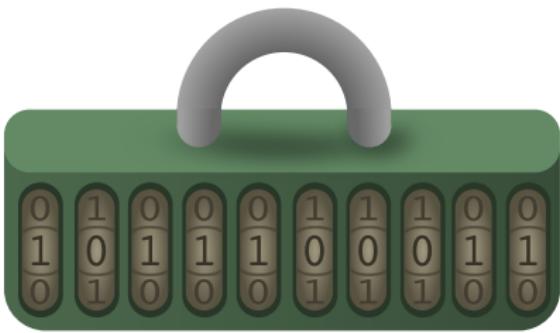
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- Above, we showed combination 739 in both locks.

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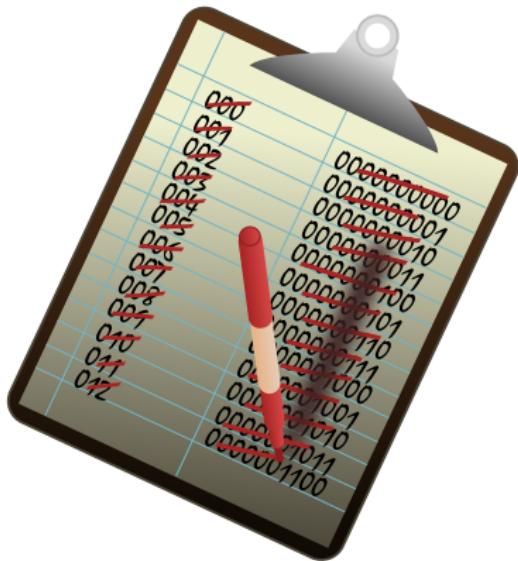
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- ▶ On average, you will test half the combinations, or ~ 500 .

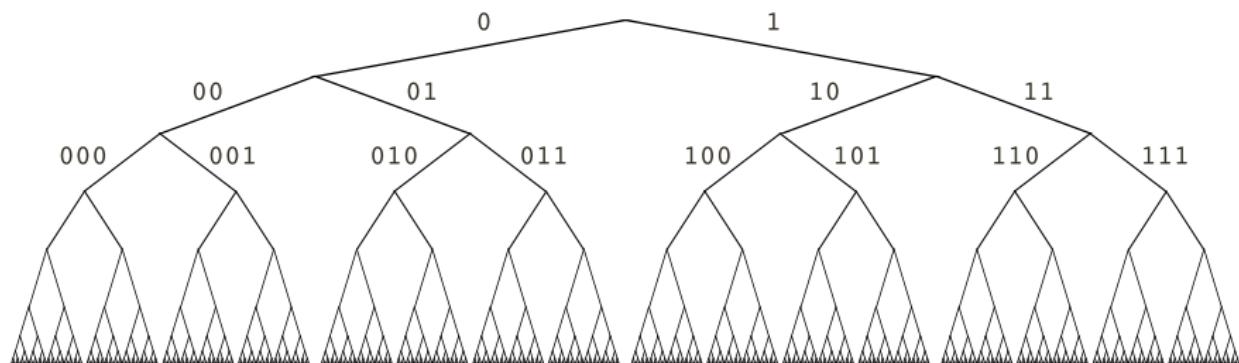
Forking paths

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- ▶ Let's draw a picture of these choices for the binary lock.

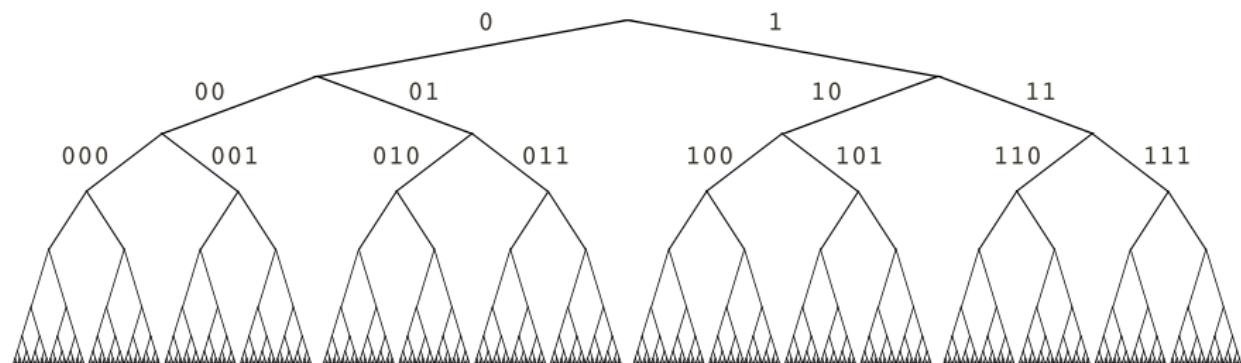
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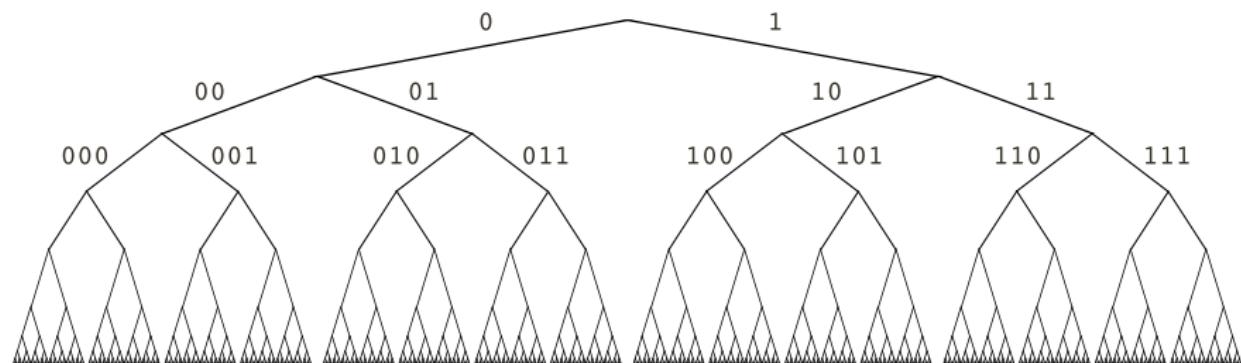
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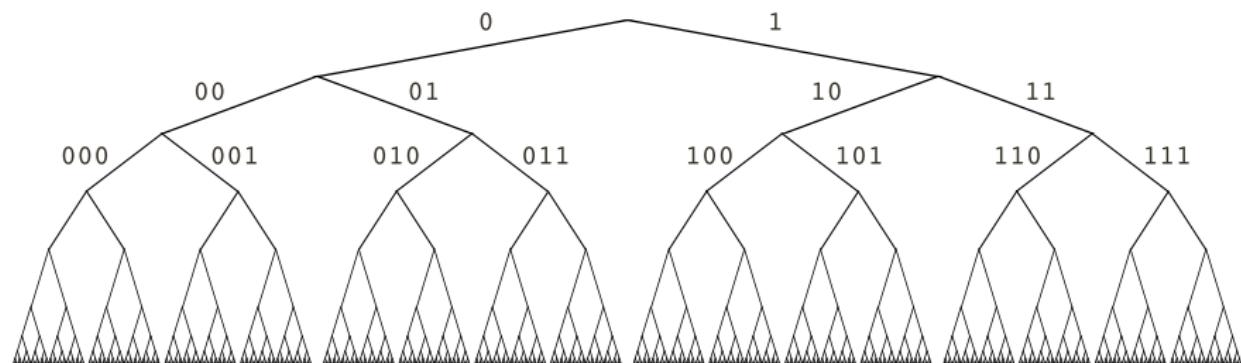
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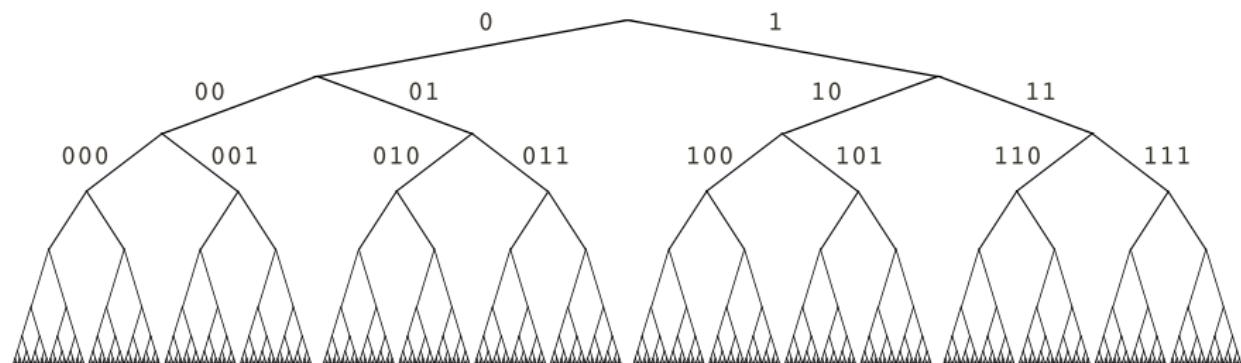
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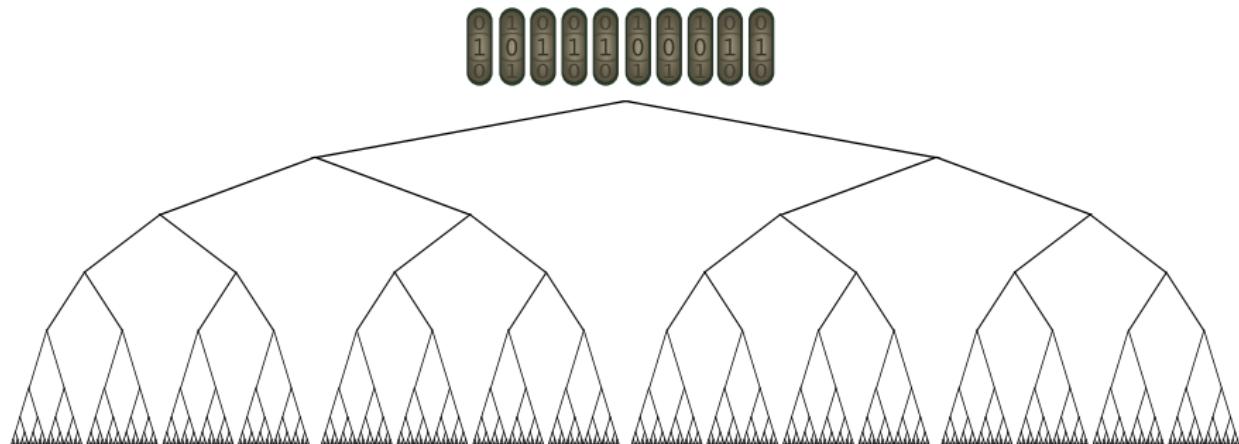
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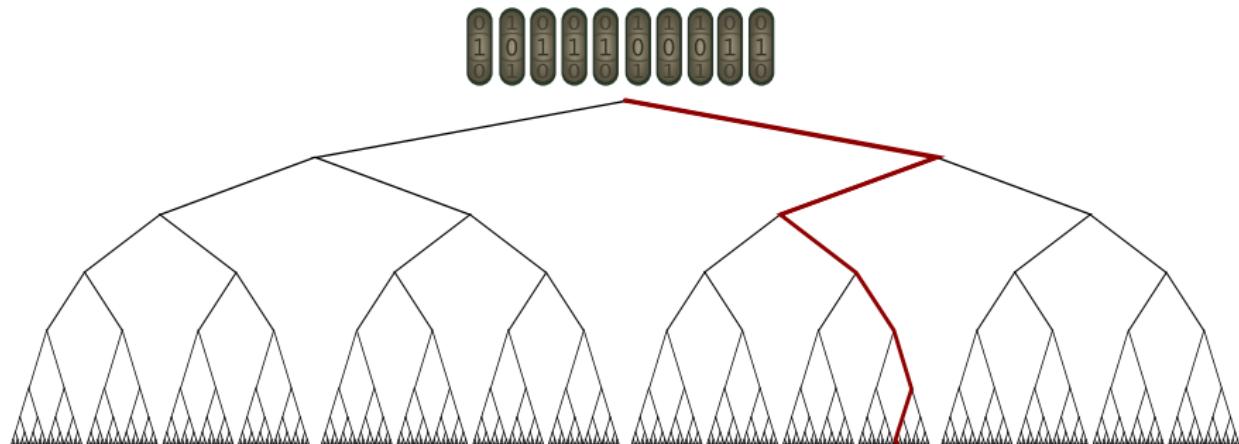
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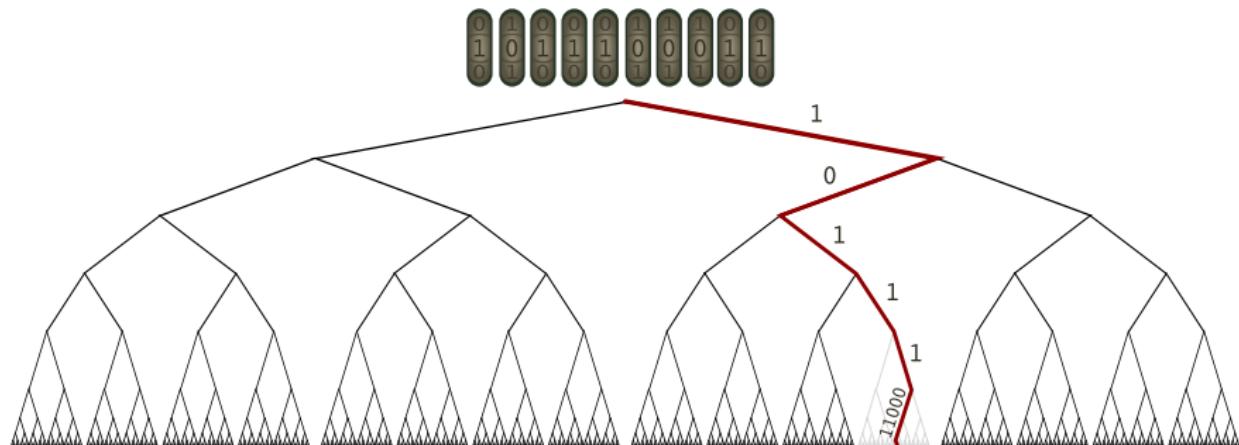
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- ▶ Breaking the lock means **finding the parallel world where we test the right combination**. It would be great if we could explore them all at once!

Schrödinger's magic box

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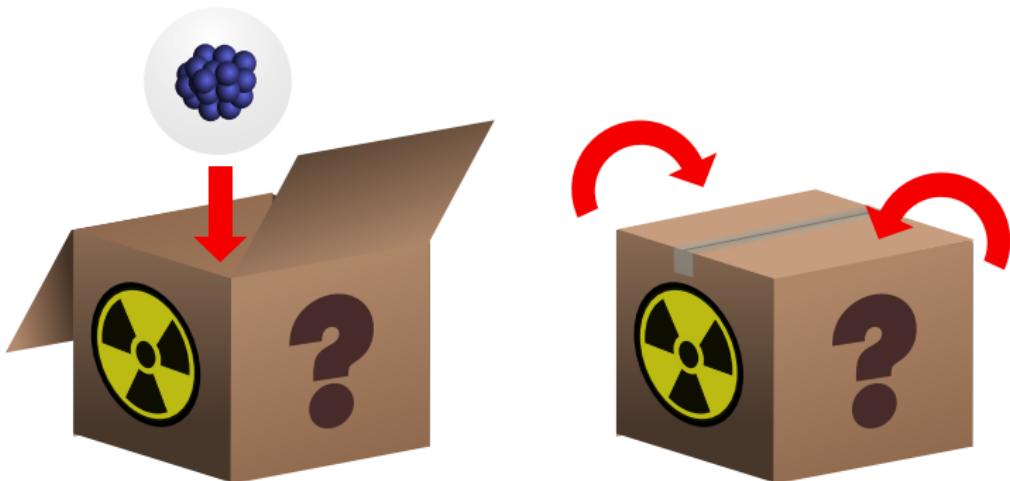
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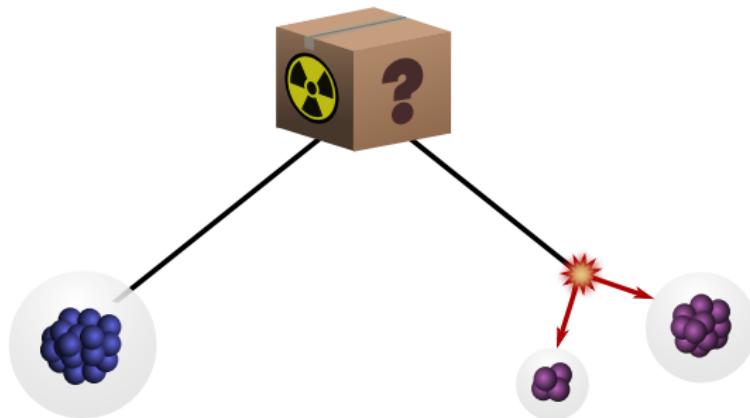
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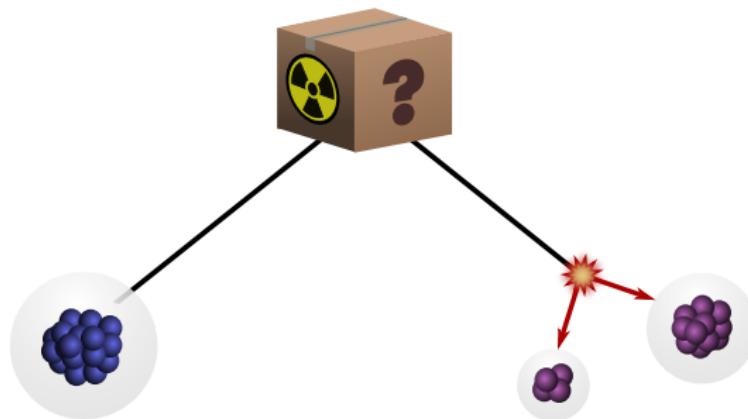
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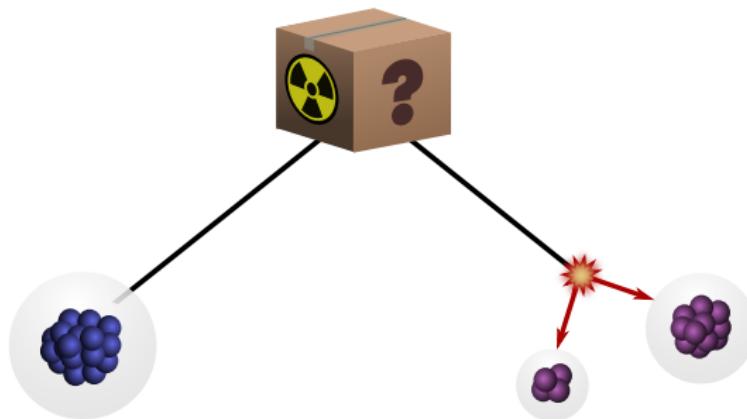
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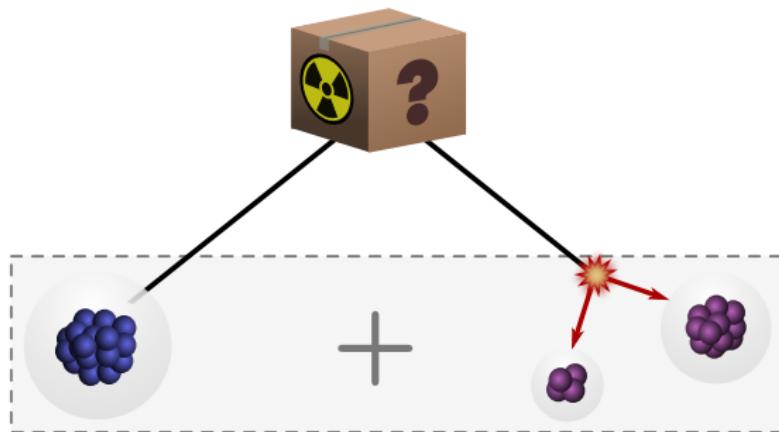
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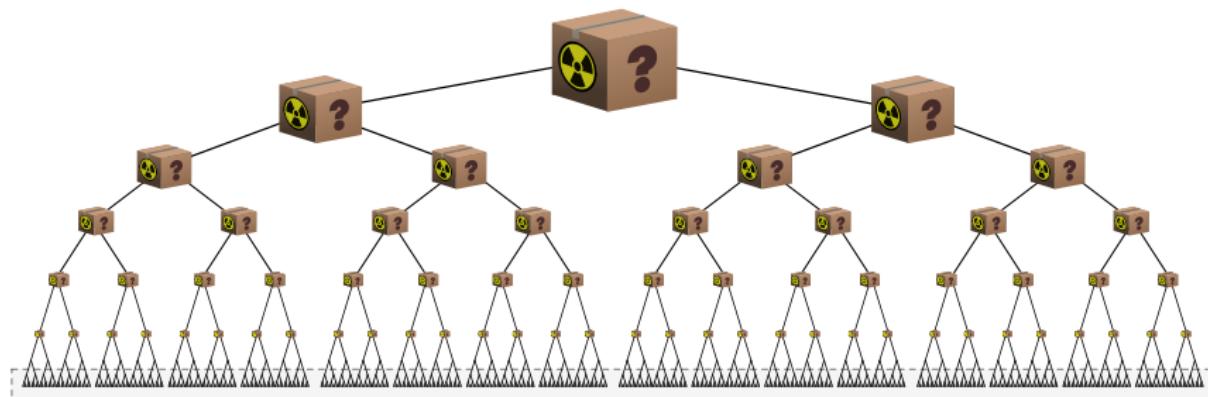
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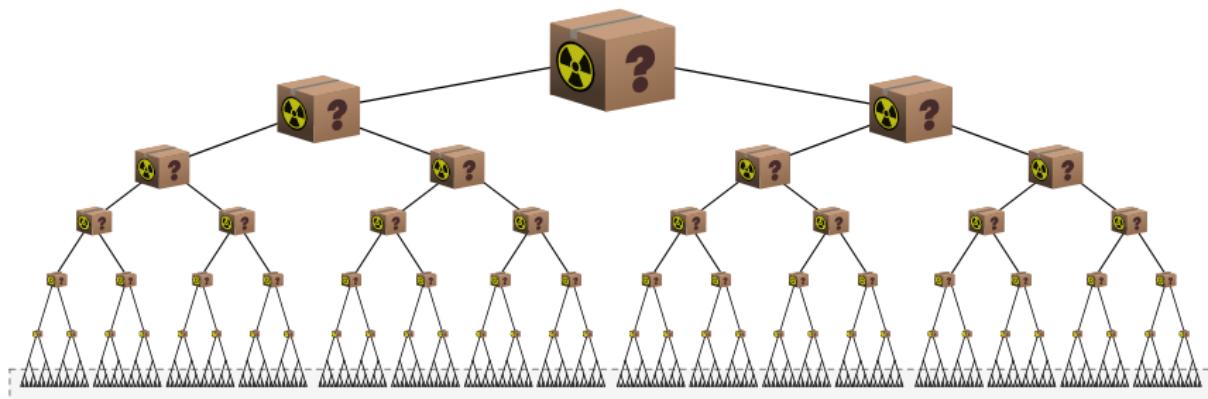
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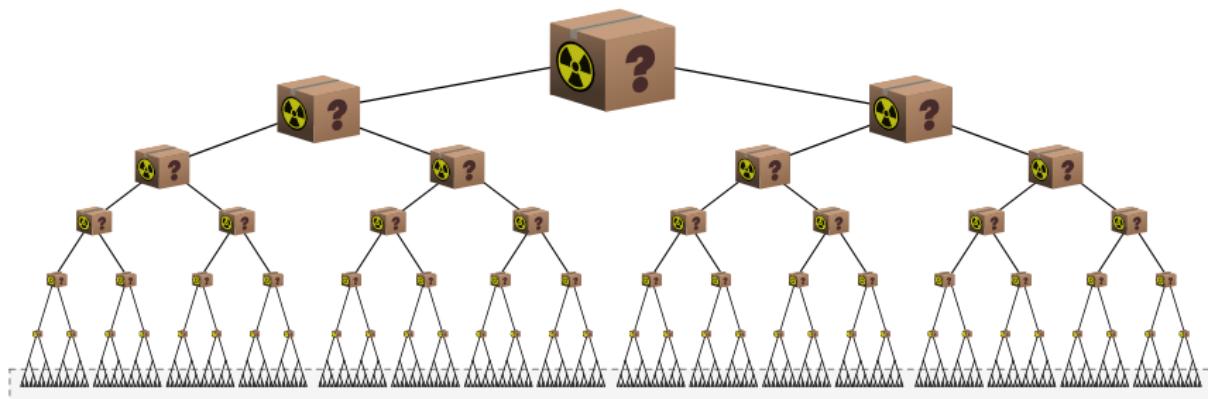
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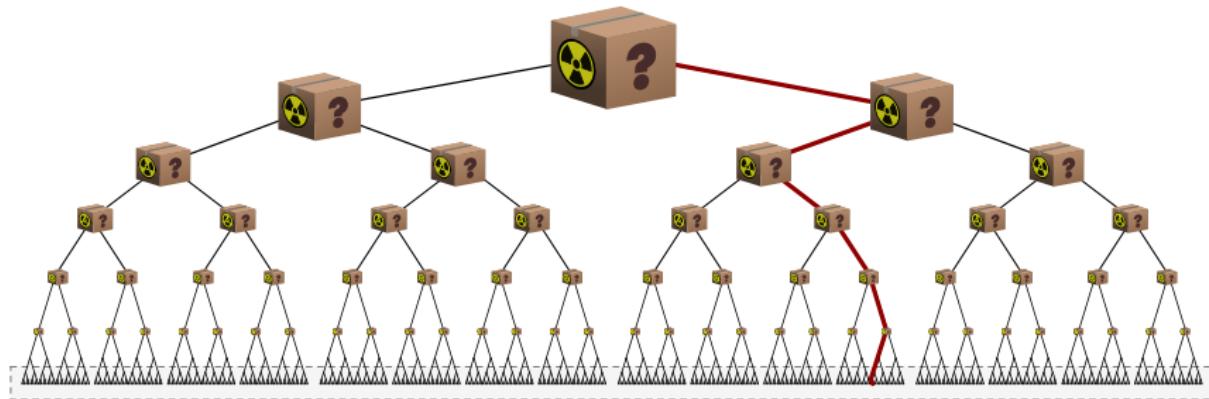
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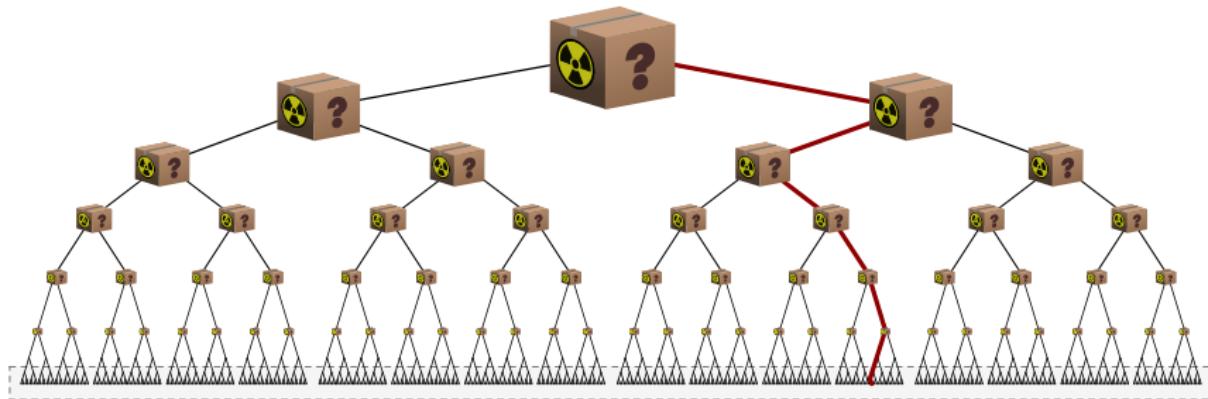
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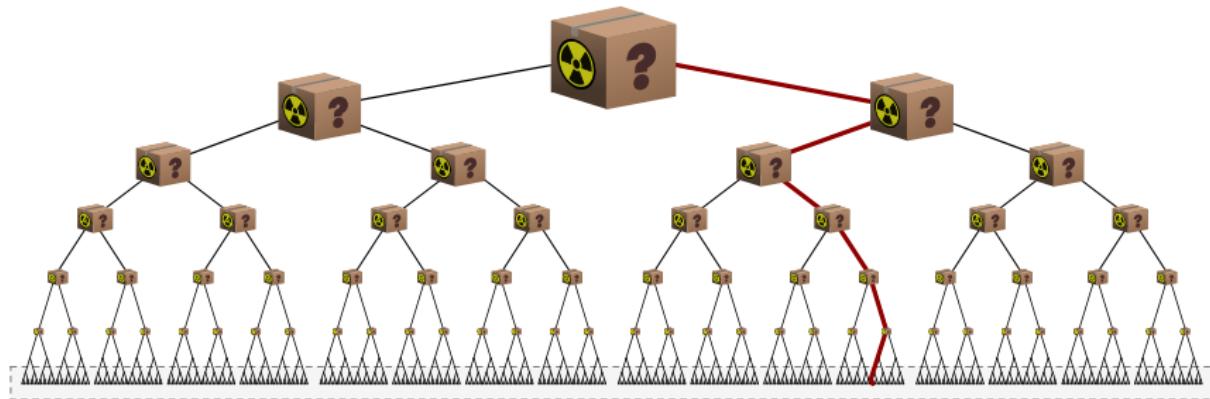
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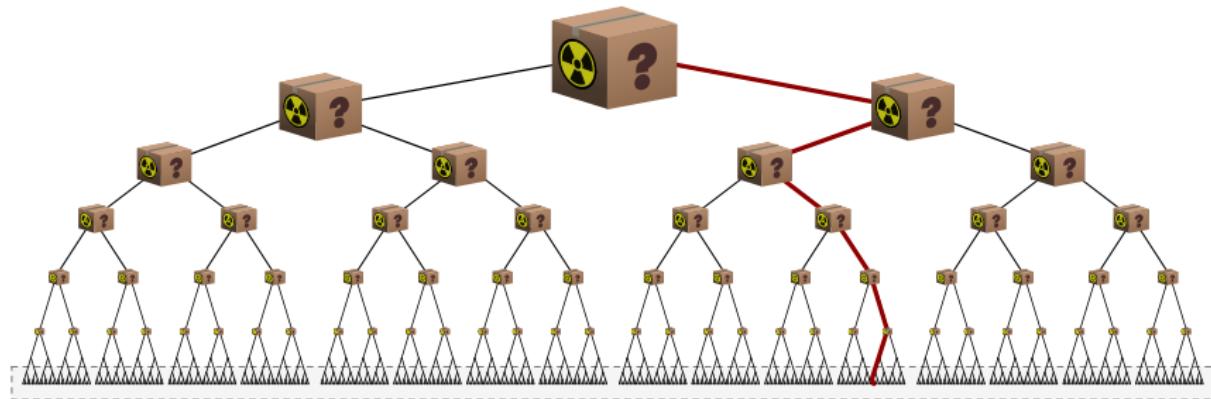
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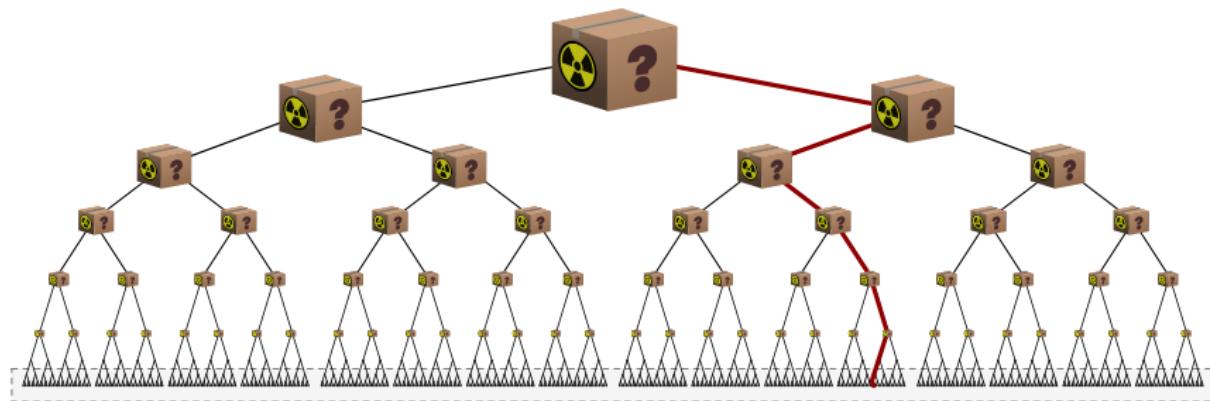
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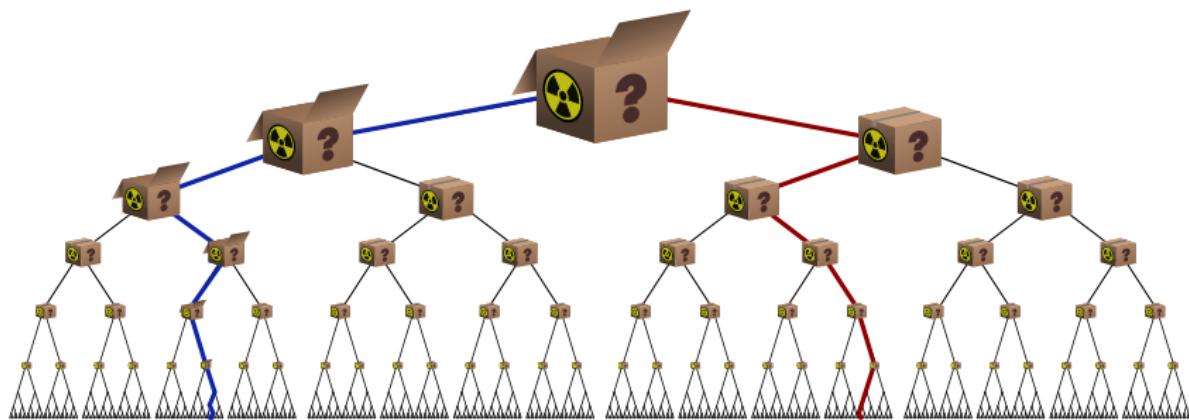
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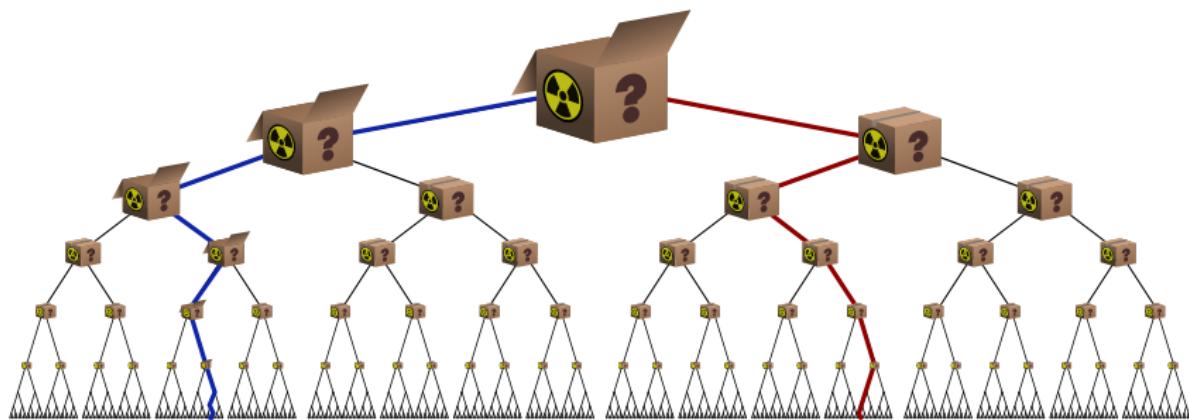
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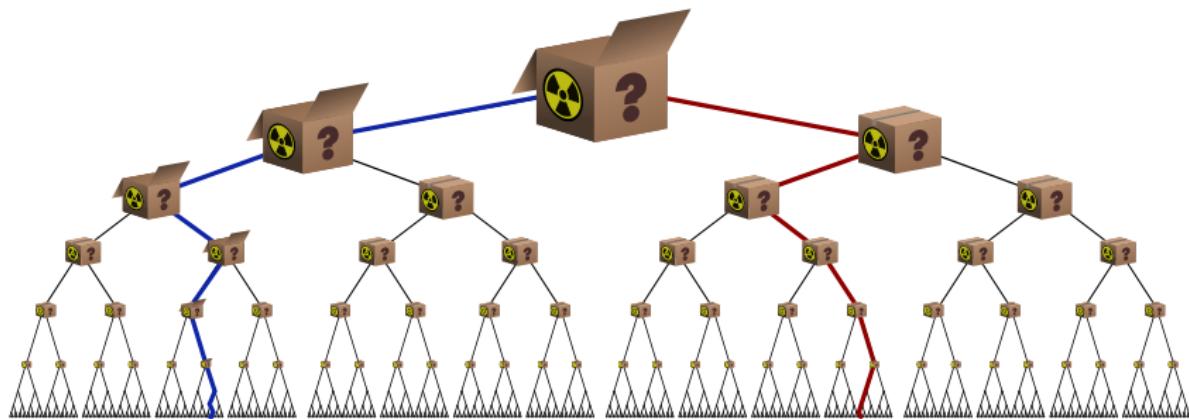
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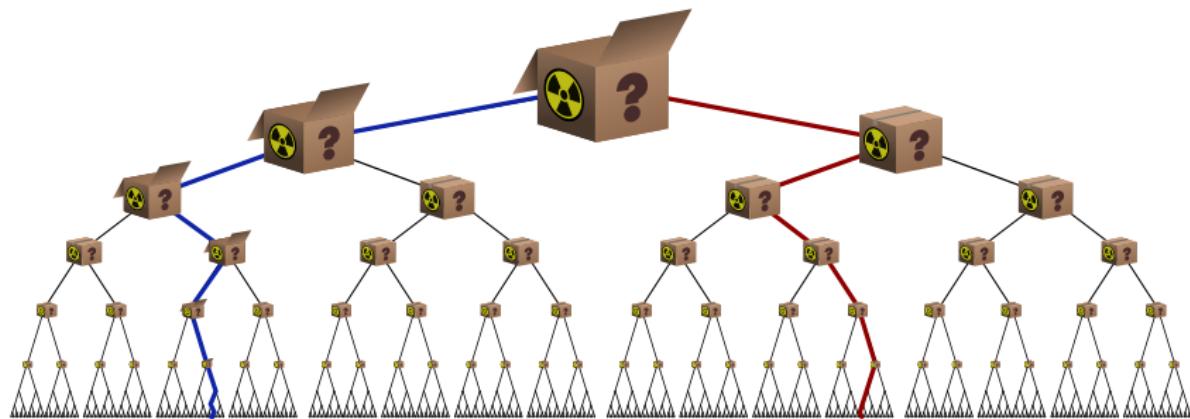
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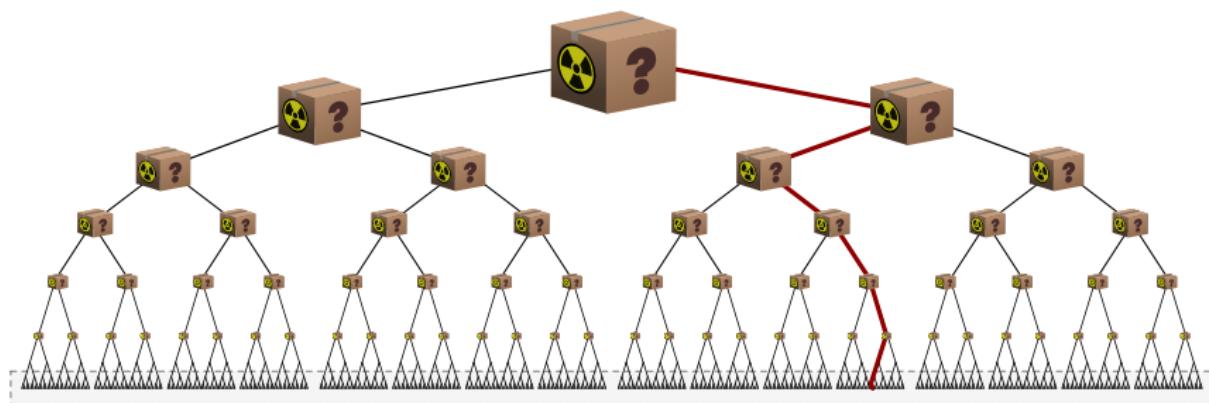
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- ▶ When we open the box, it takes us to a **random point in the grey area**. Superpositon giveth and taketh away!

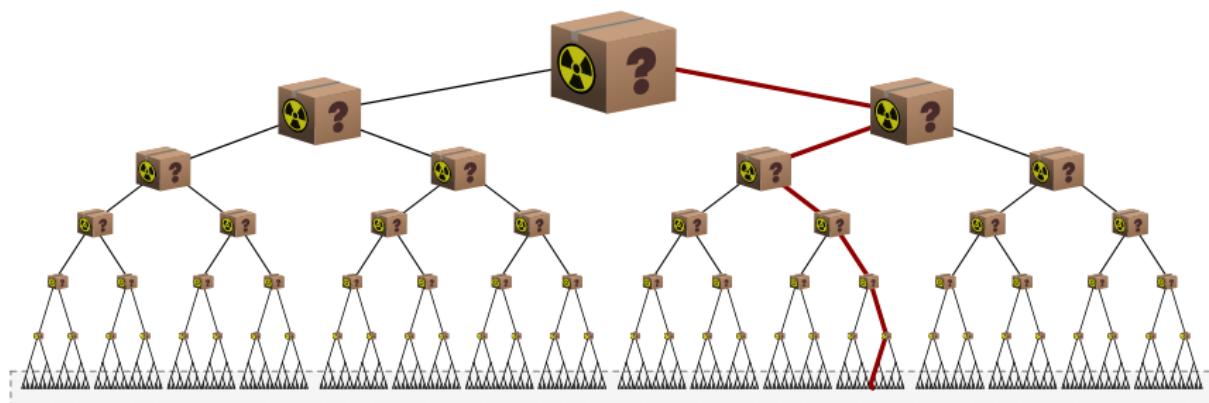
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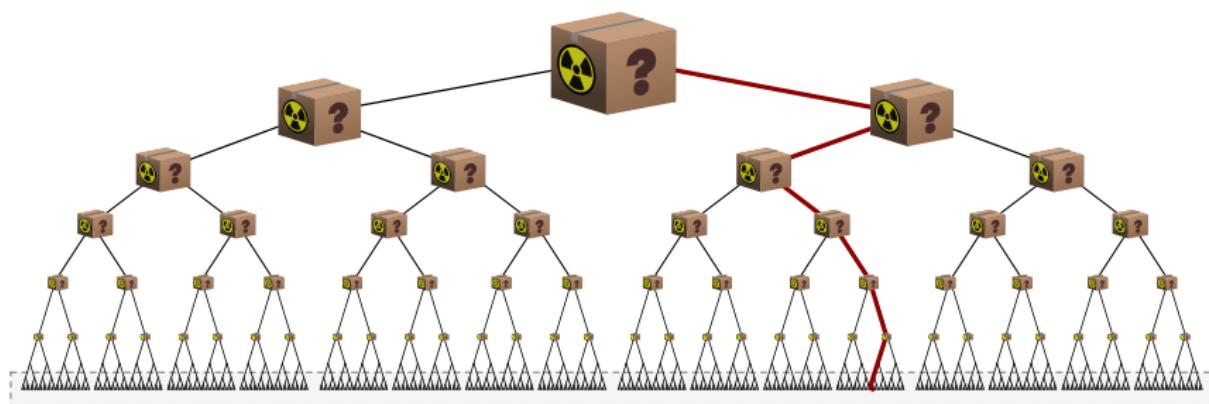
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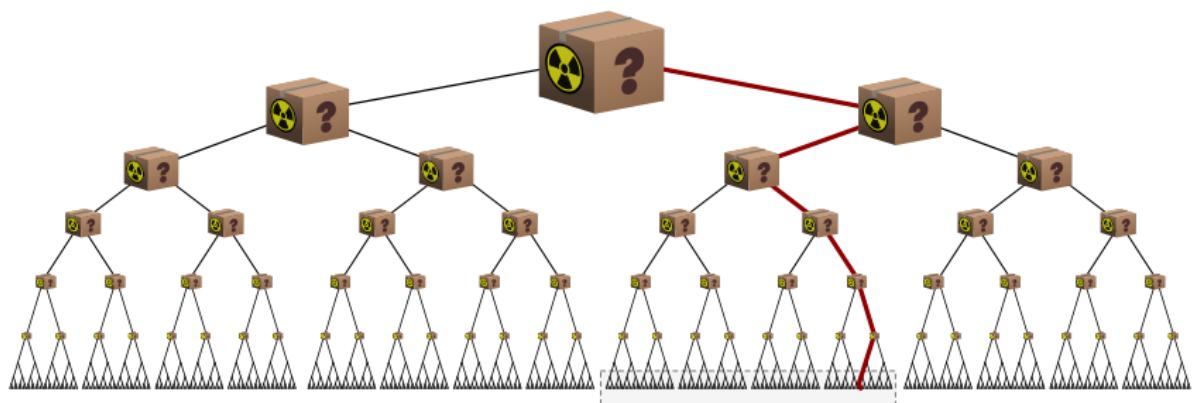
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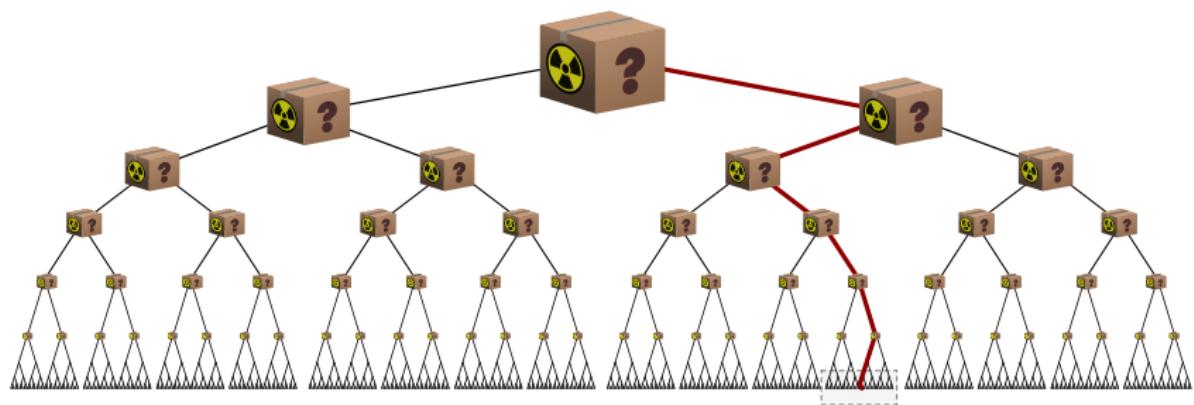
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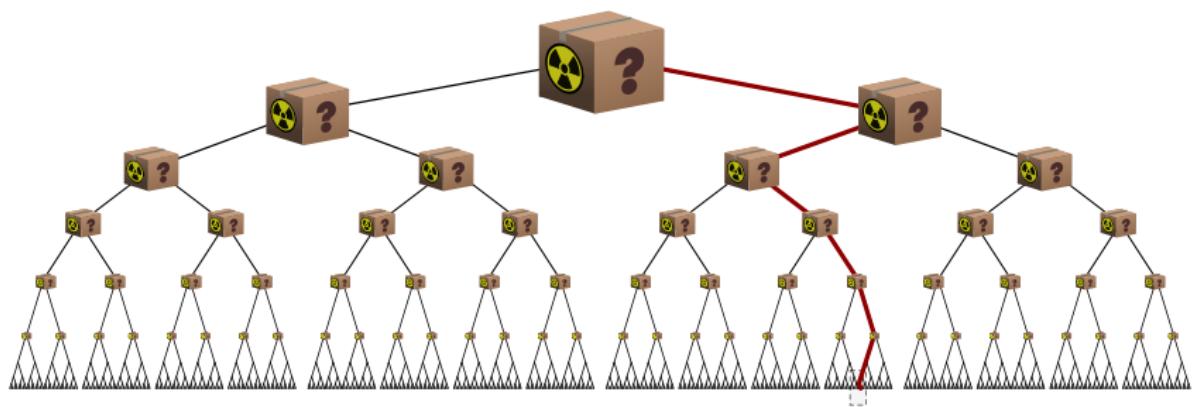
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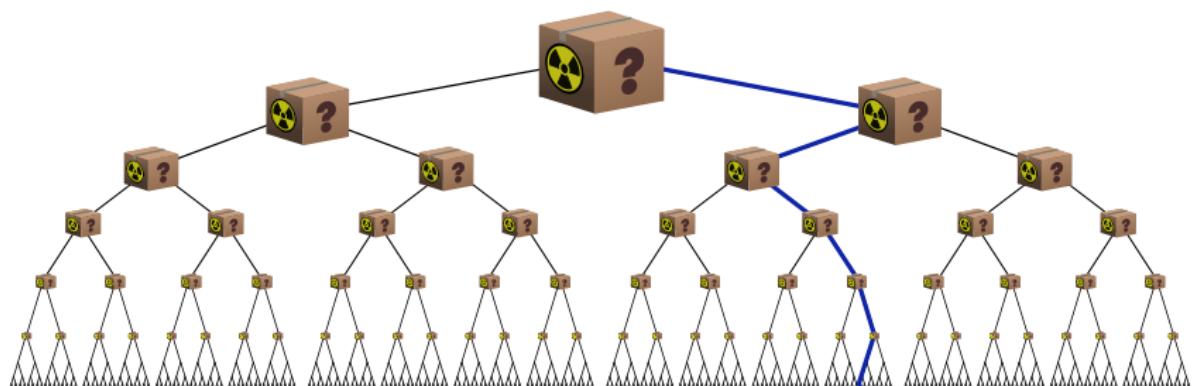
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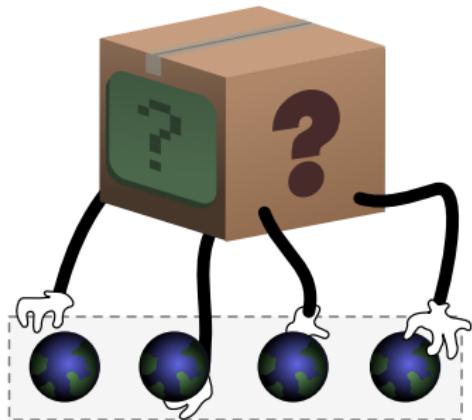
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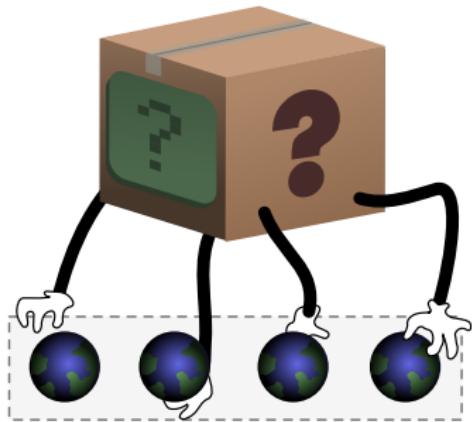
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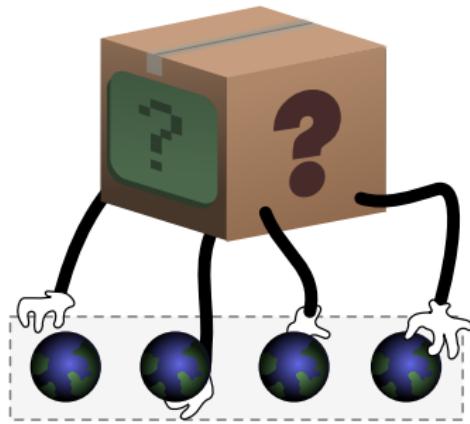
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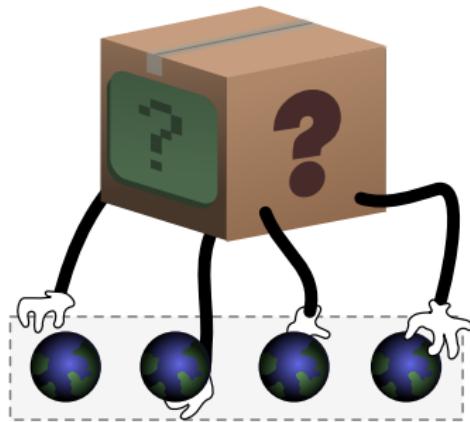
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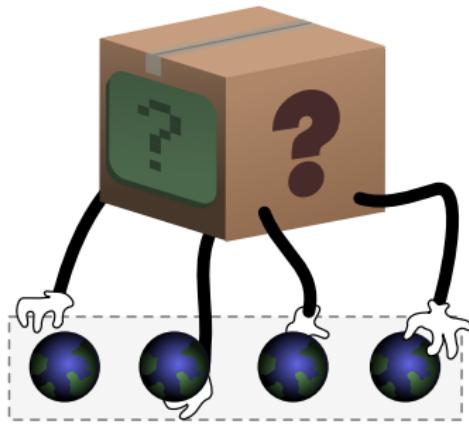
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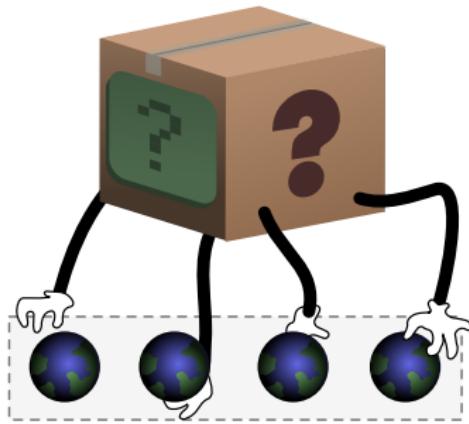
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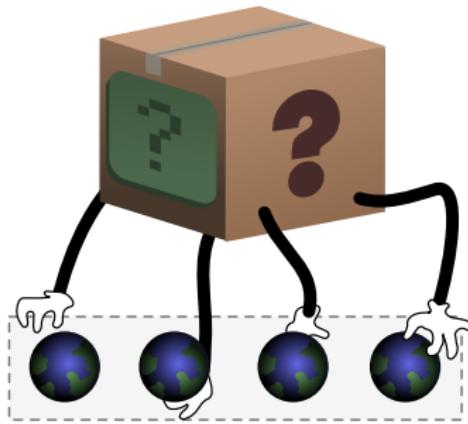
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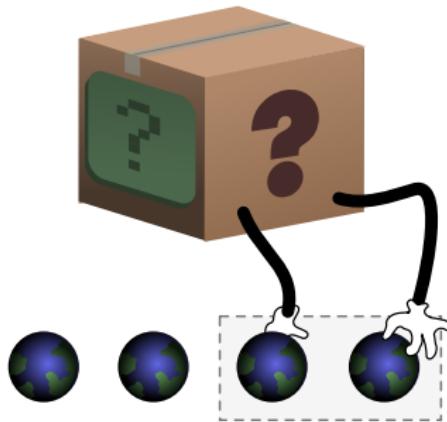
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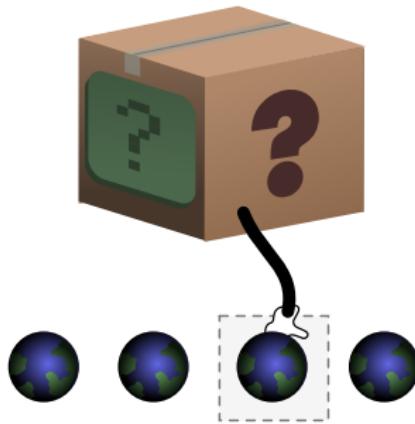
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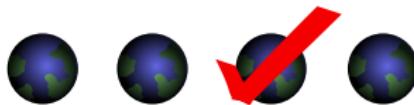
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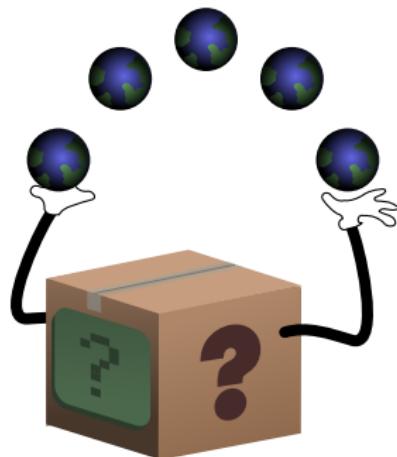
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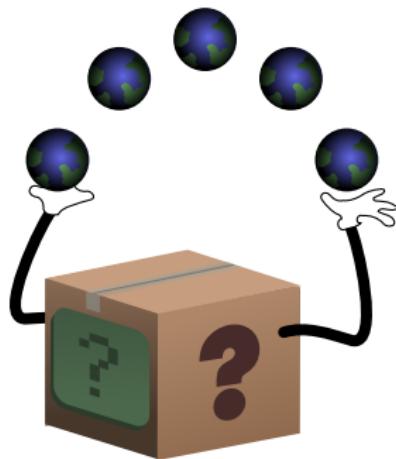
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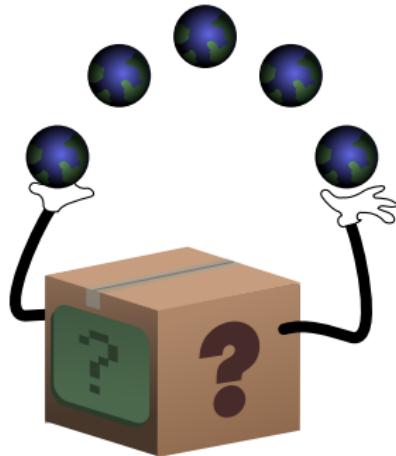
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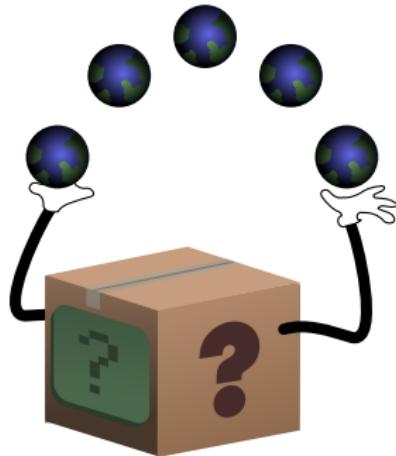
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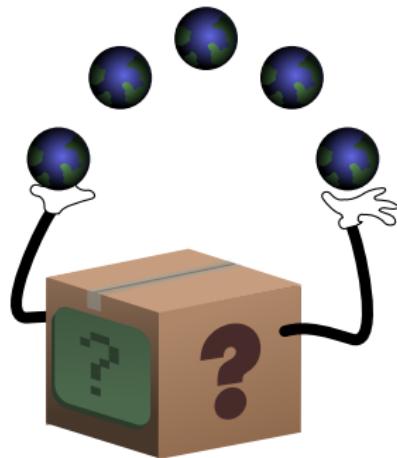
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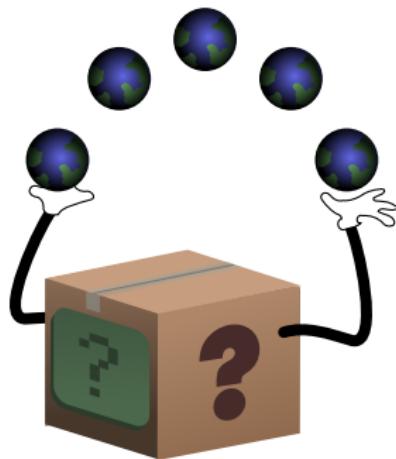
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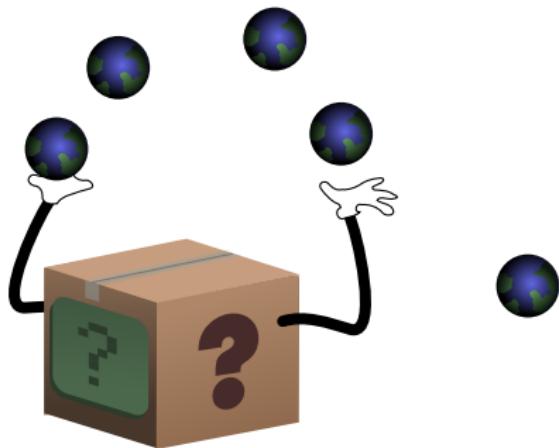
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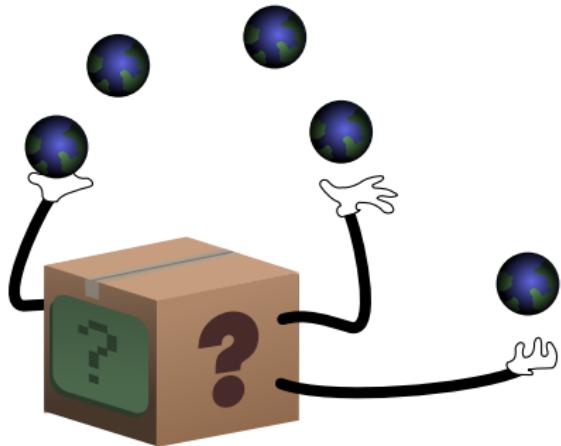
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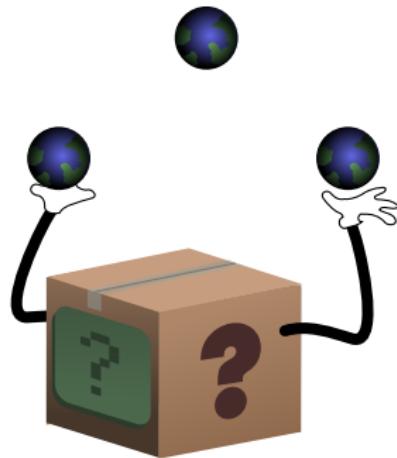
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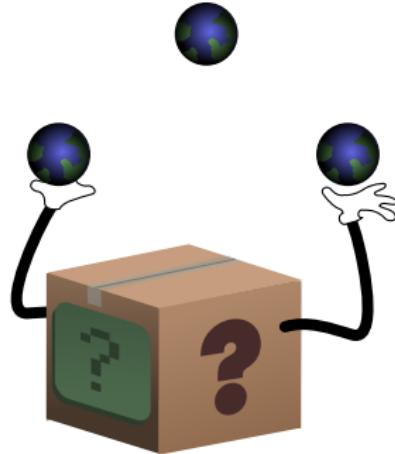
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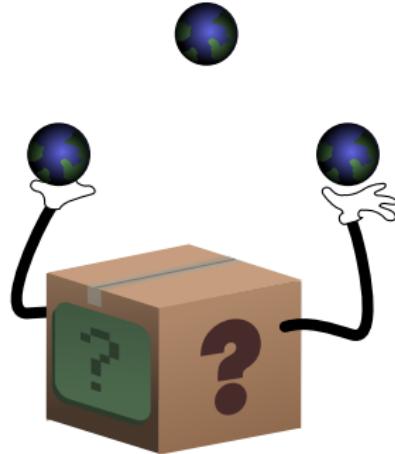
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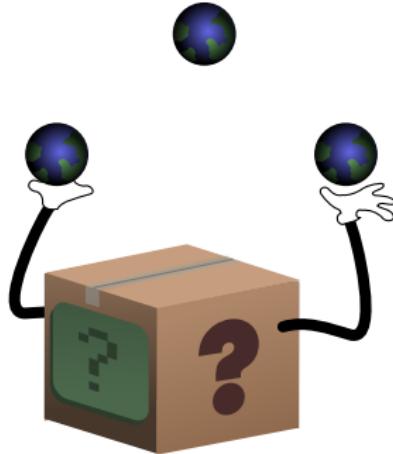
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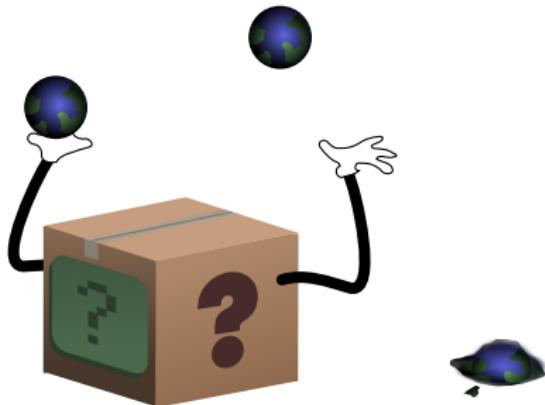
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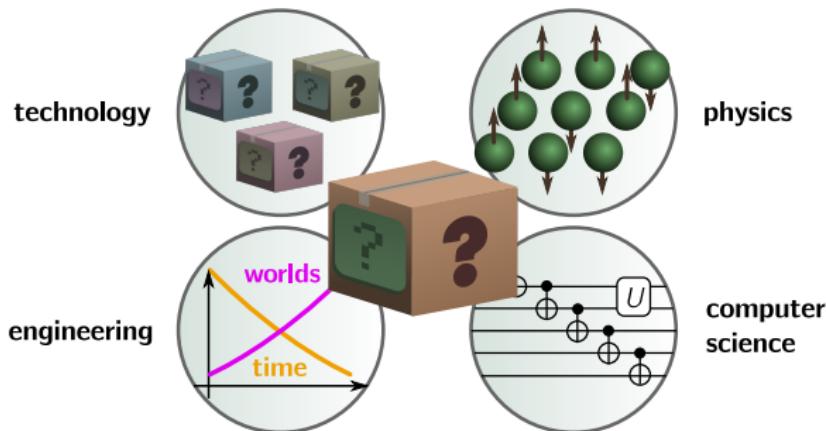
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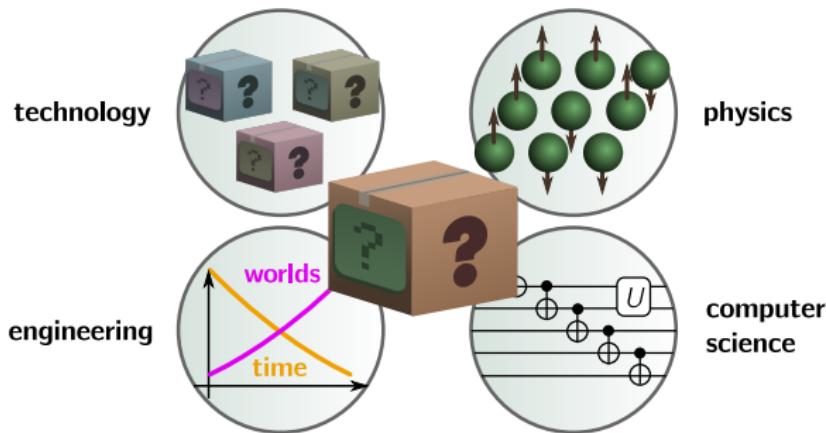
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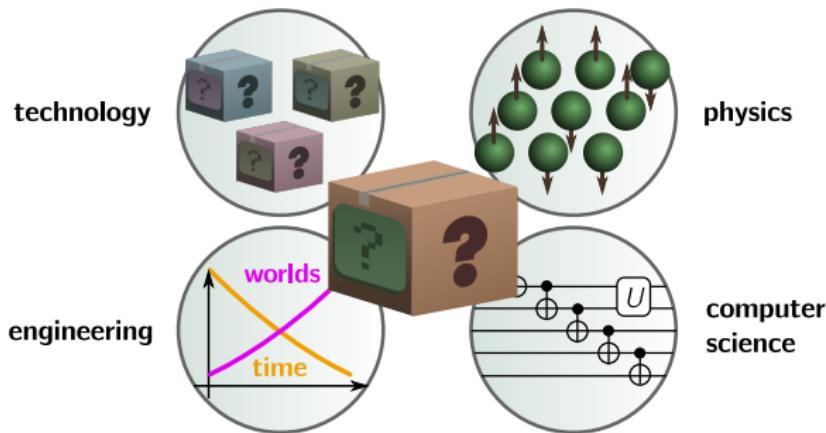
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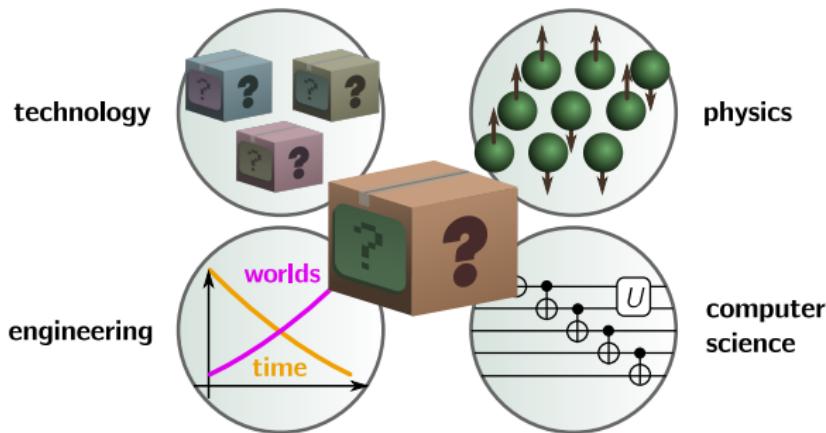
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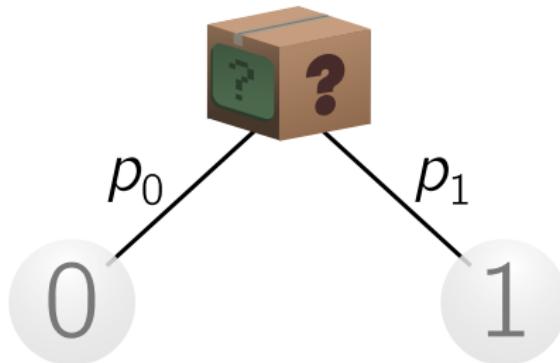
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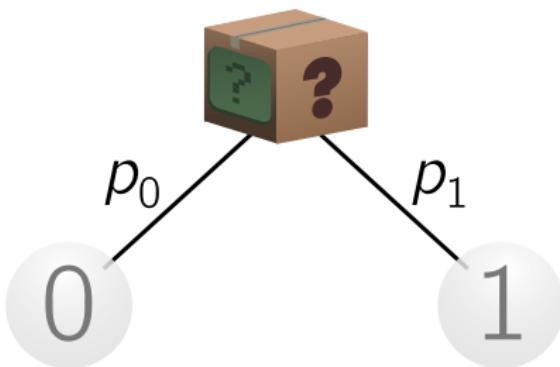
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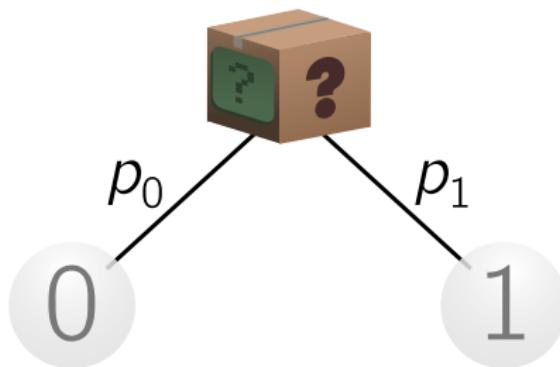
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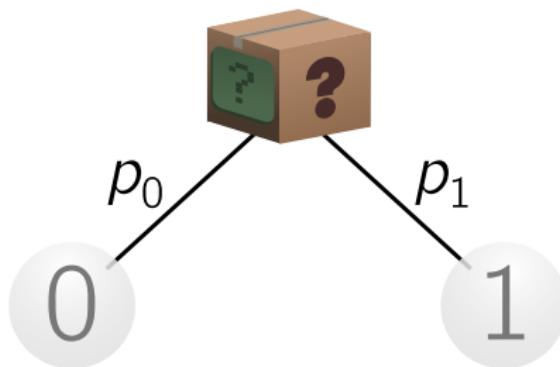
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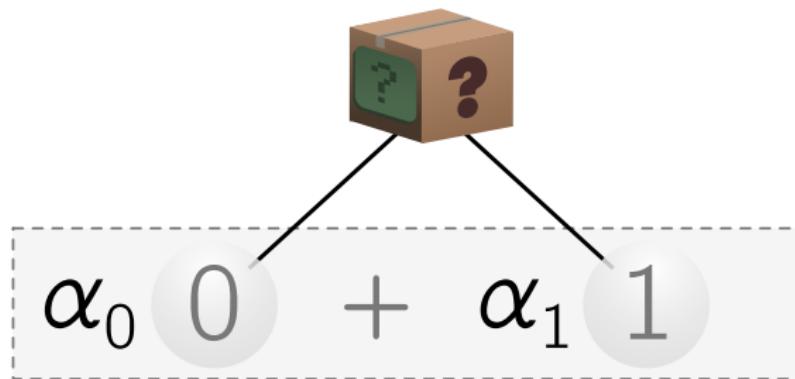
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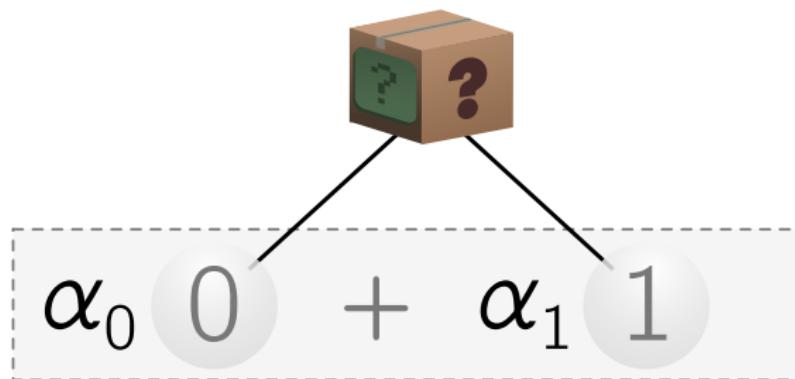
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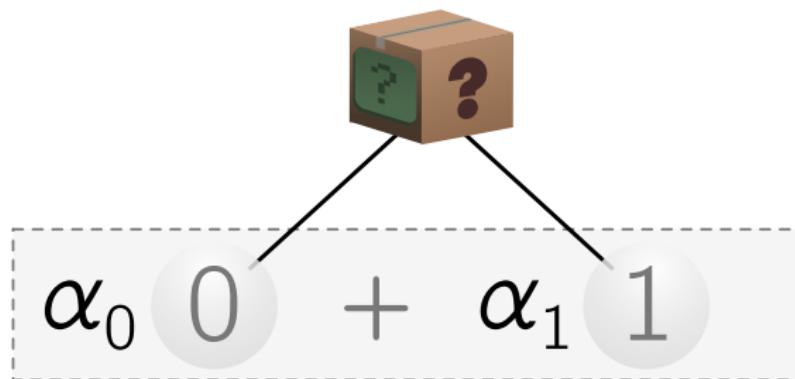
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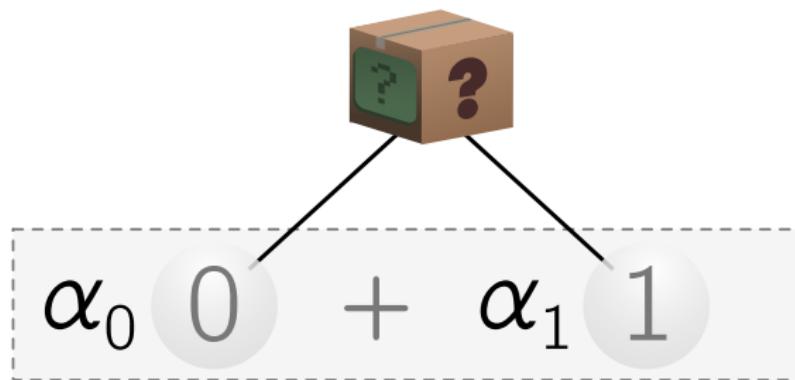
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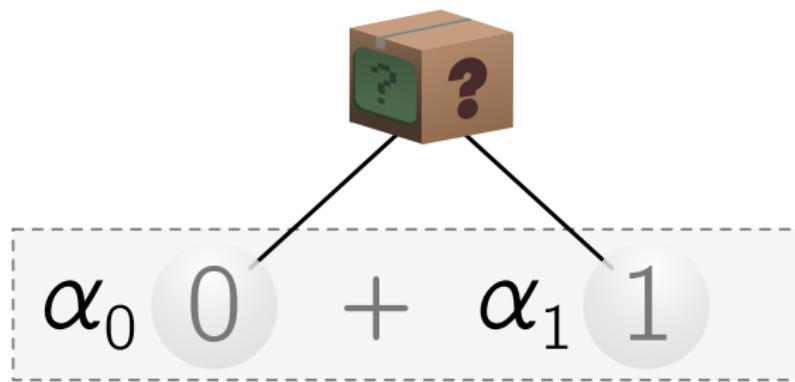
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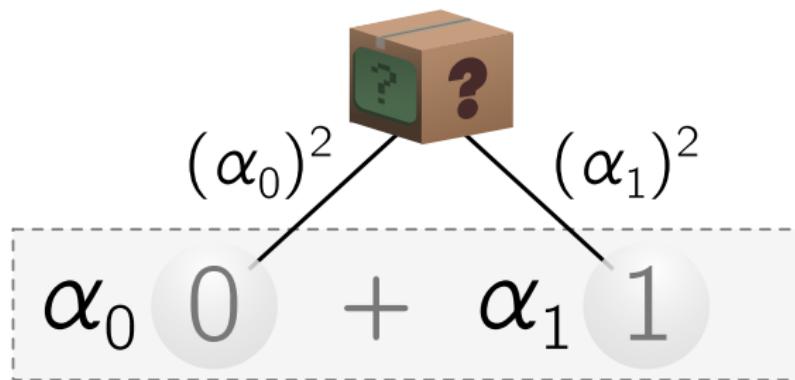
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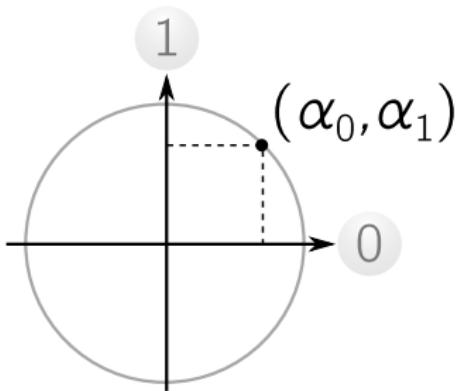
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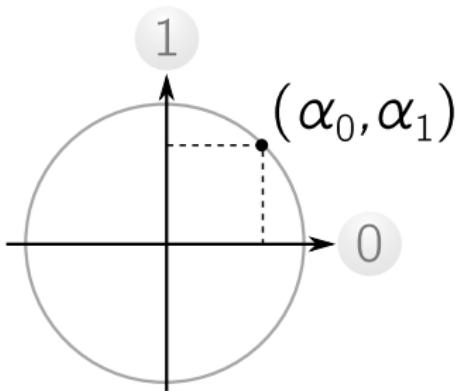


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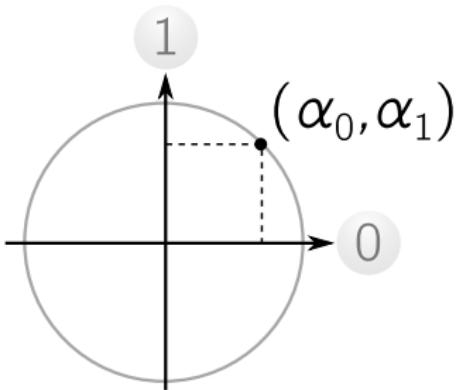
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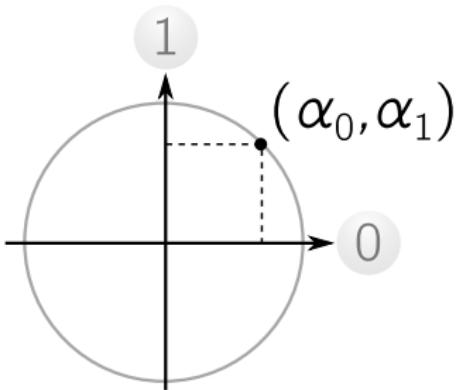
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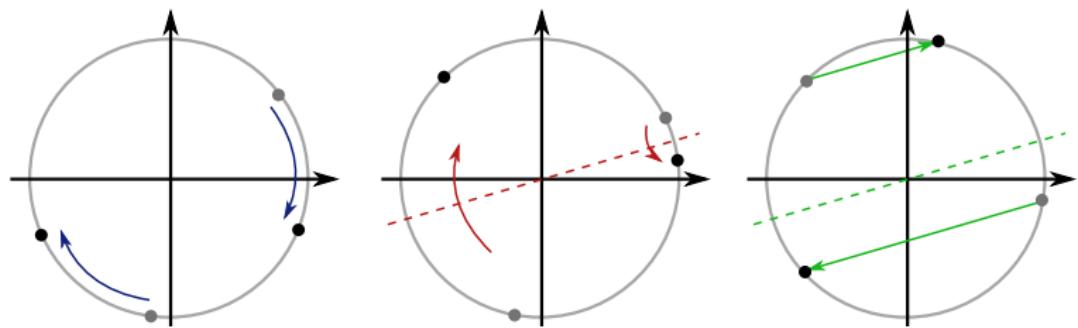
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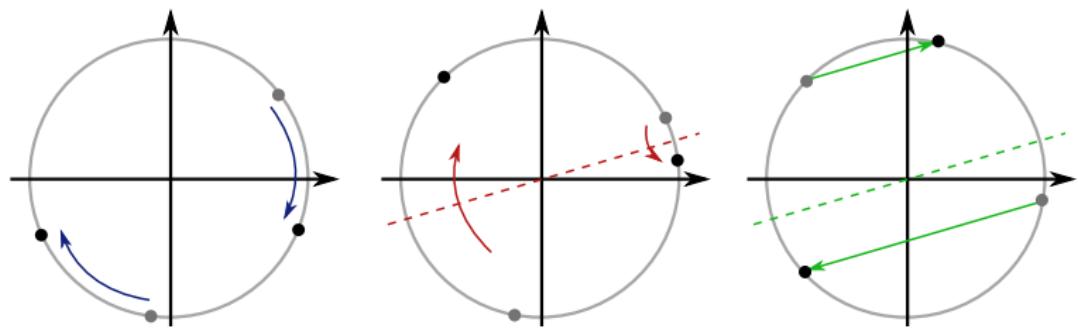
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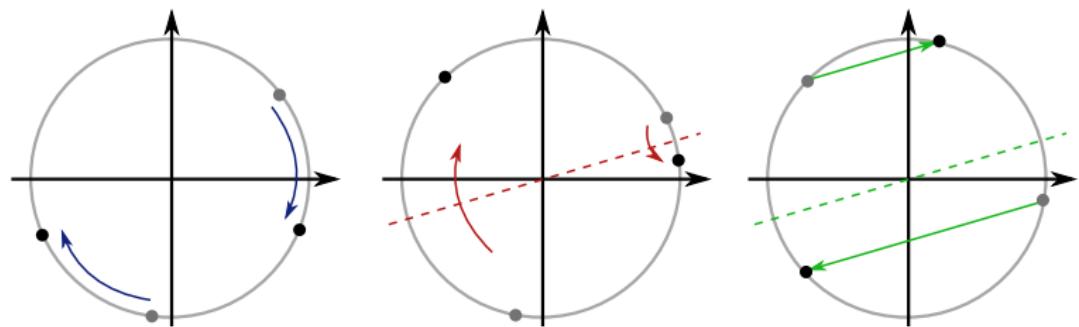
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Legal moves

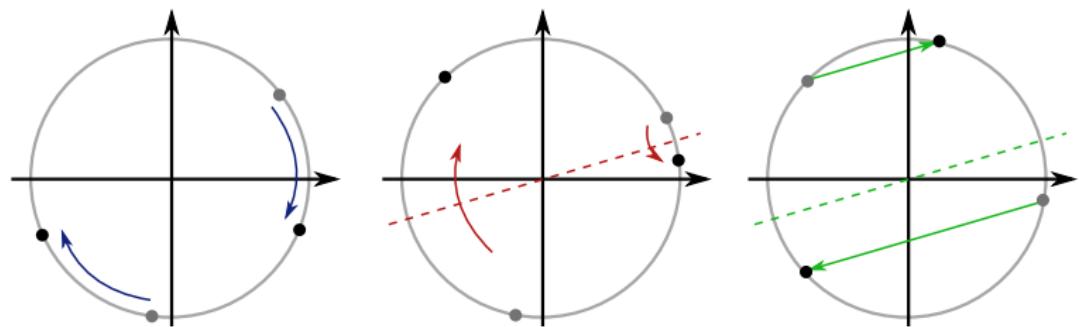
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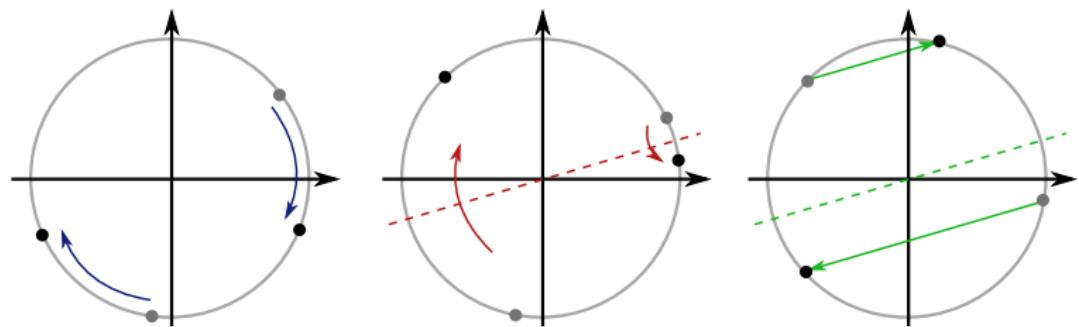
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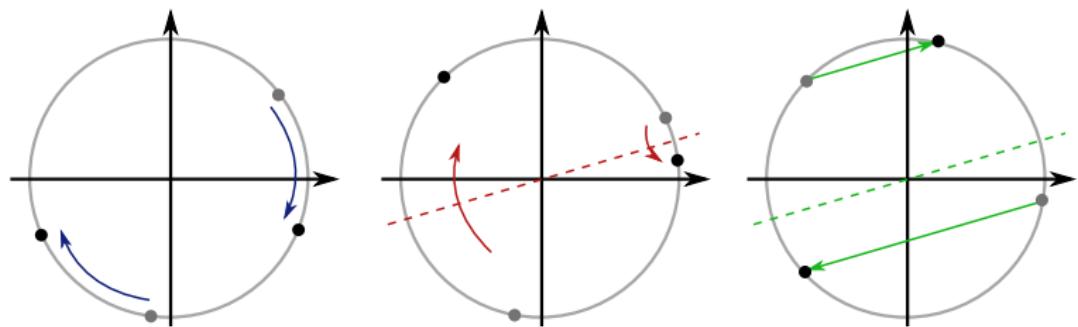
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Legal moves

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- ▶ You might ask: why are these the legal ones? The answer is that they preserve distances between states.
- ▶ (Why is this necessary? Well, because Nature says so.)

A one-bit lock

A one-bit lock

- ▶ Let's try and solve a **single bit lock**.

A one-bit lock

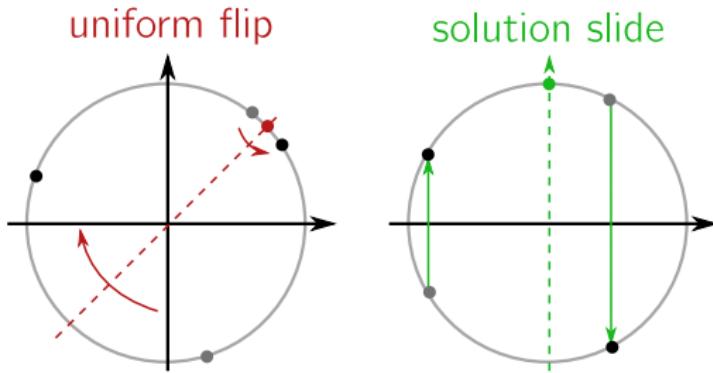
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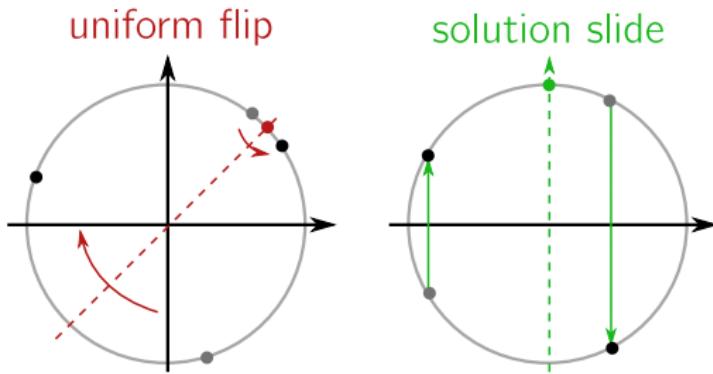
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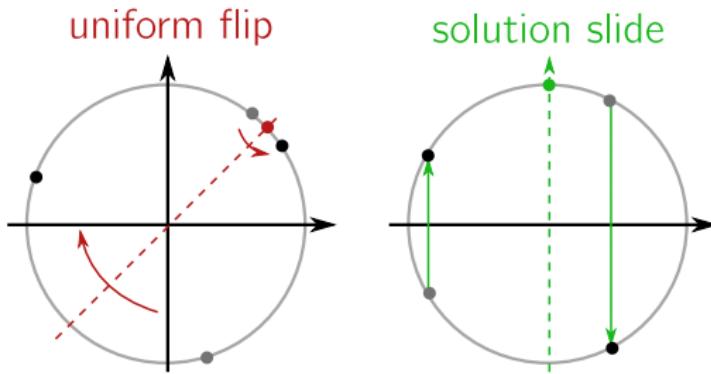
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- The **uniform flip**

A one-bit lock

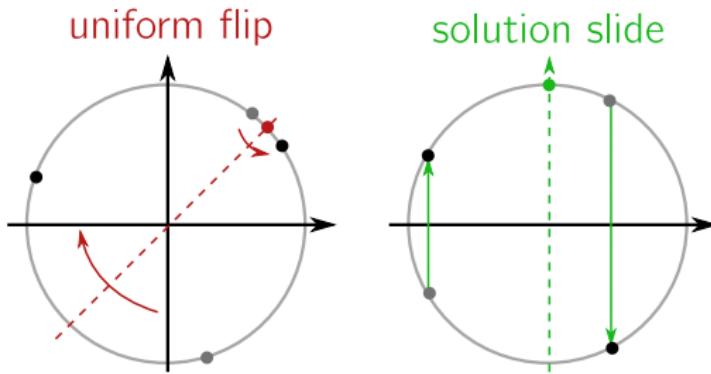
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A one-bit lock

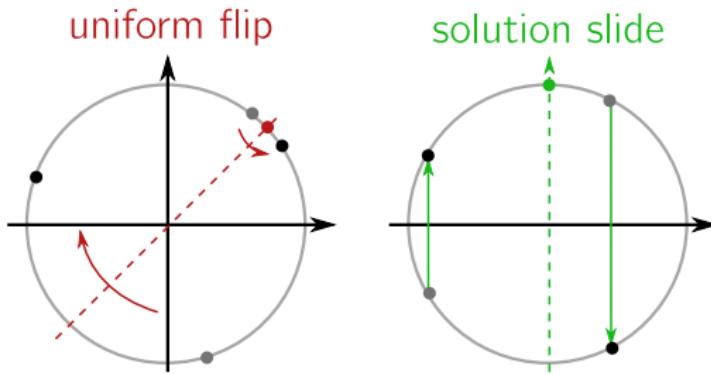
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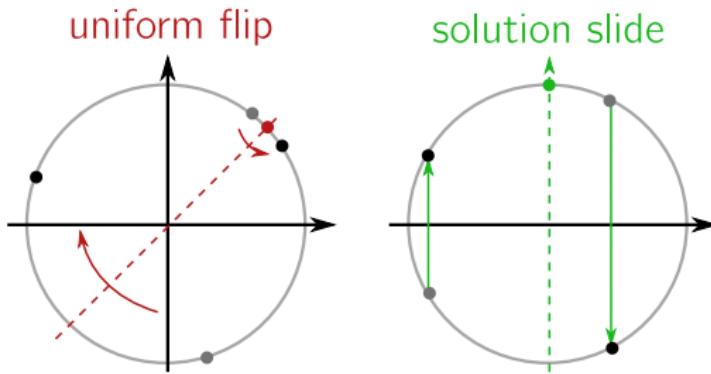
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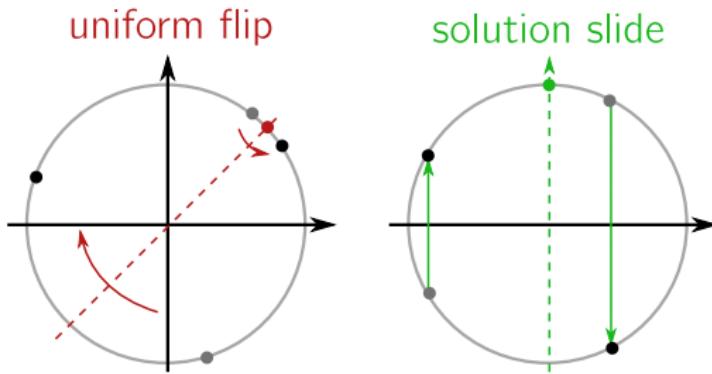
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A bit too hard

A bit too hard

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A bit too hard

- ▶ Let's start in the uniform superposition and try to get close to the solution.

A bit too hard

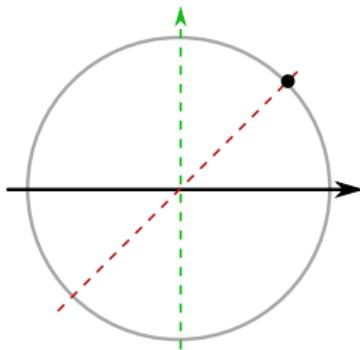
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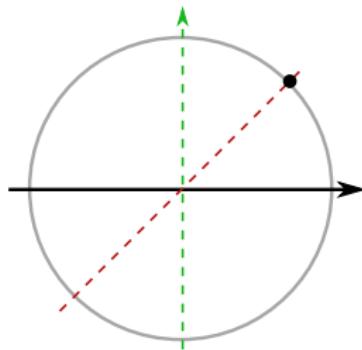
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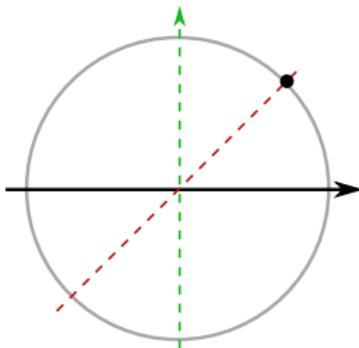
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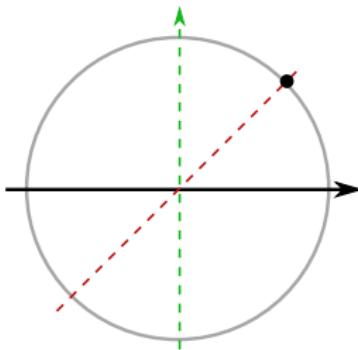
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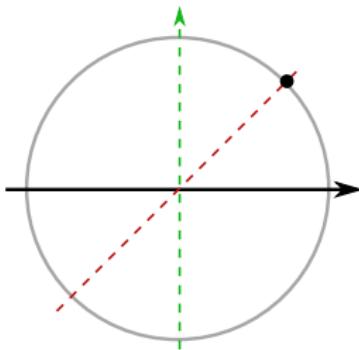
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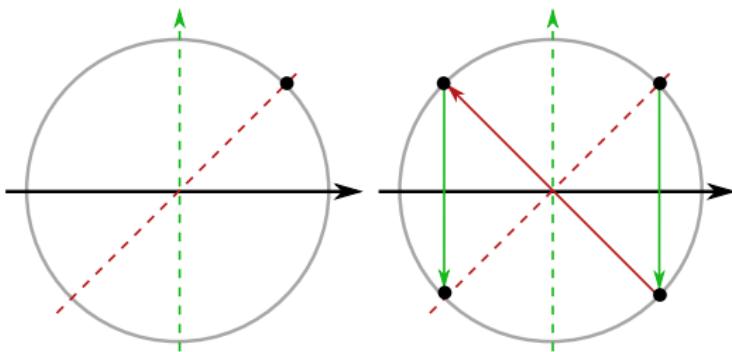
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Many bits make Grover work

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- ▶ Let's try more bits!

Many bits make Grover work

- ▶ Let's try **more bits**! We draw a similar circle,

Many bits make Grover work

- ▶ Let's try **more bits!** We draw a similar circle, containing the **uniform superposition** U

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Many bits make Grover work

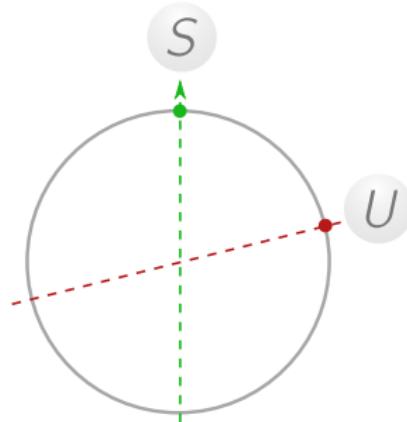
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Many bits make Grover work

- ▶ Let's try **more bits!** We draw a similar circle, containing the **uniform superposition U** and **solution S** .
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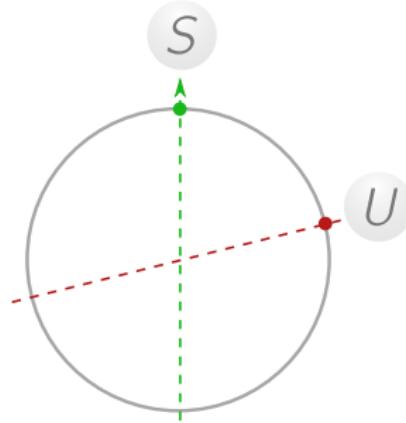
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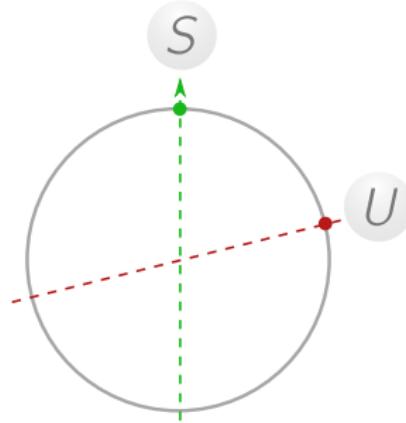
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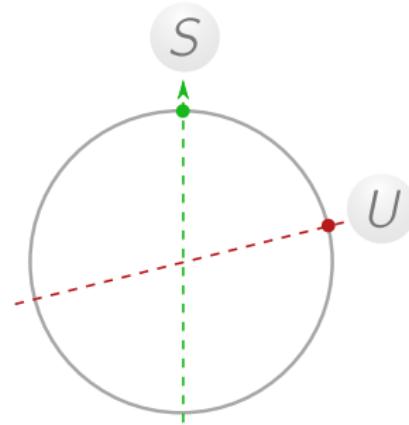
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Many bits make Grover work

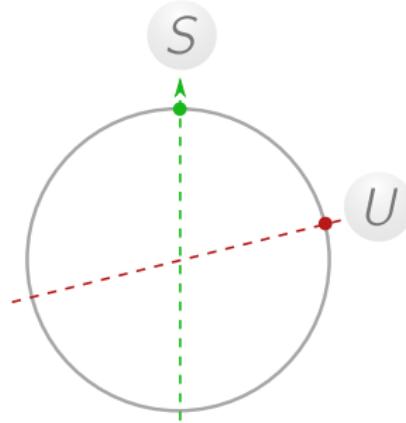
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Many bits make Grover work

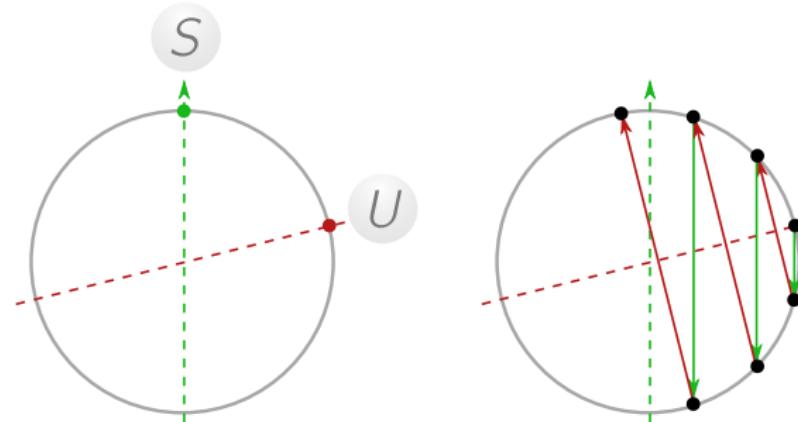
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49 steps

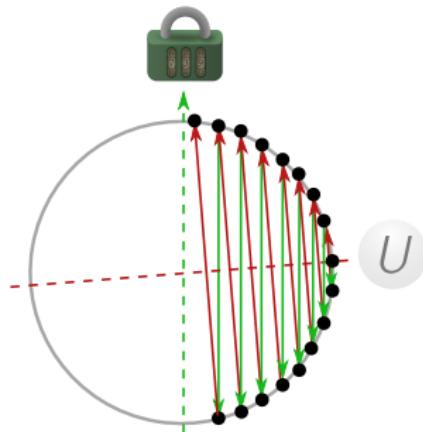
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49 steps

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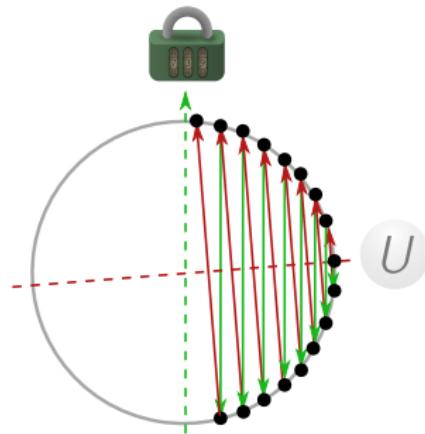
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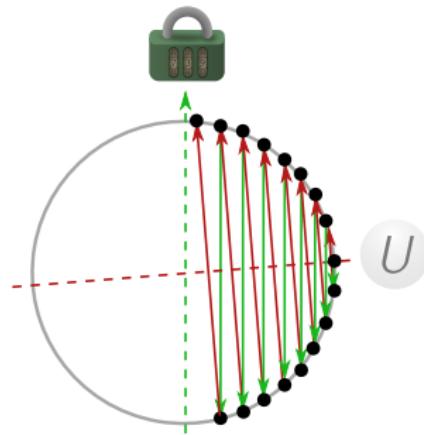
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- For instance, for our ten-bit lock,

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- For instance, for our ten-bit lock, the number of steps is

$$\frac{\pi}{2}\sqrt{2^{10}} \approx 50.$$

Bonus conclusion

- ▶ So, “shrinking the rectangle”

Bonus conclusion

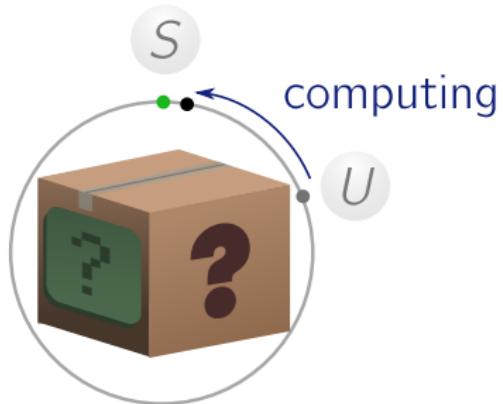
- ▶ So, “shrinking the rectangle” really means **rotating the state of the magic box**

Bonus conclusion

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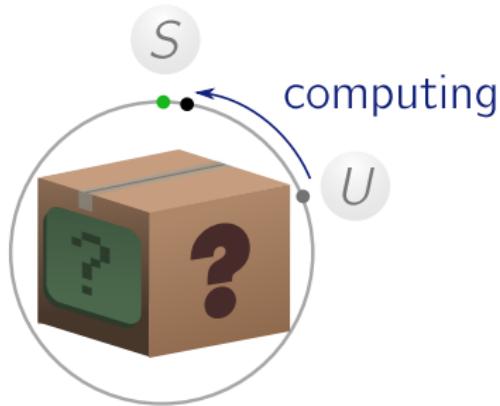
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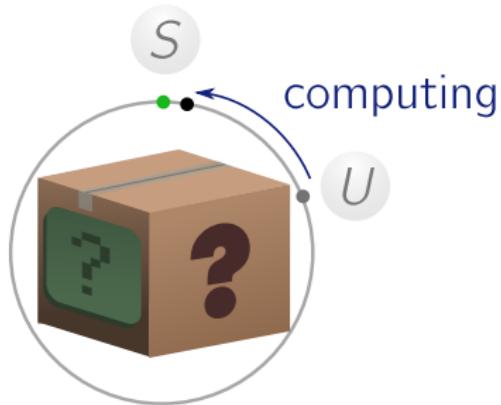
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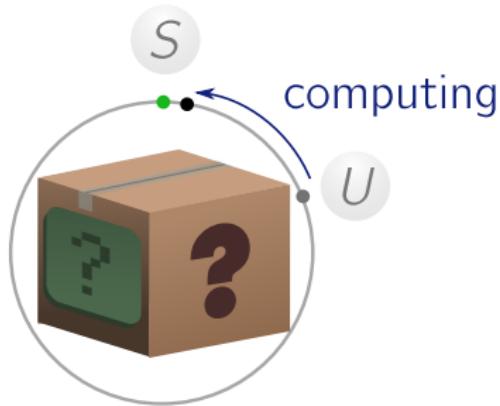
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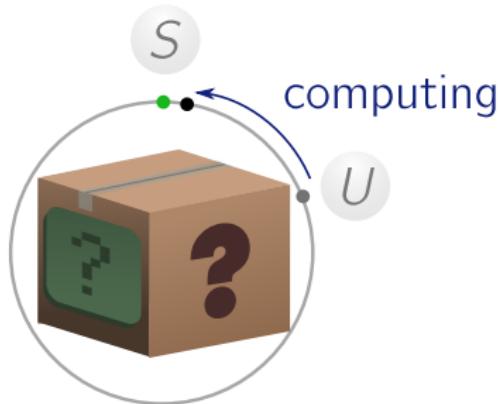
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- ▶ Then the probability of **falling into the universe where we solved the problem** (once we open the box) is high.
- ▶ Hope this gets you excited to learn more!