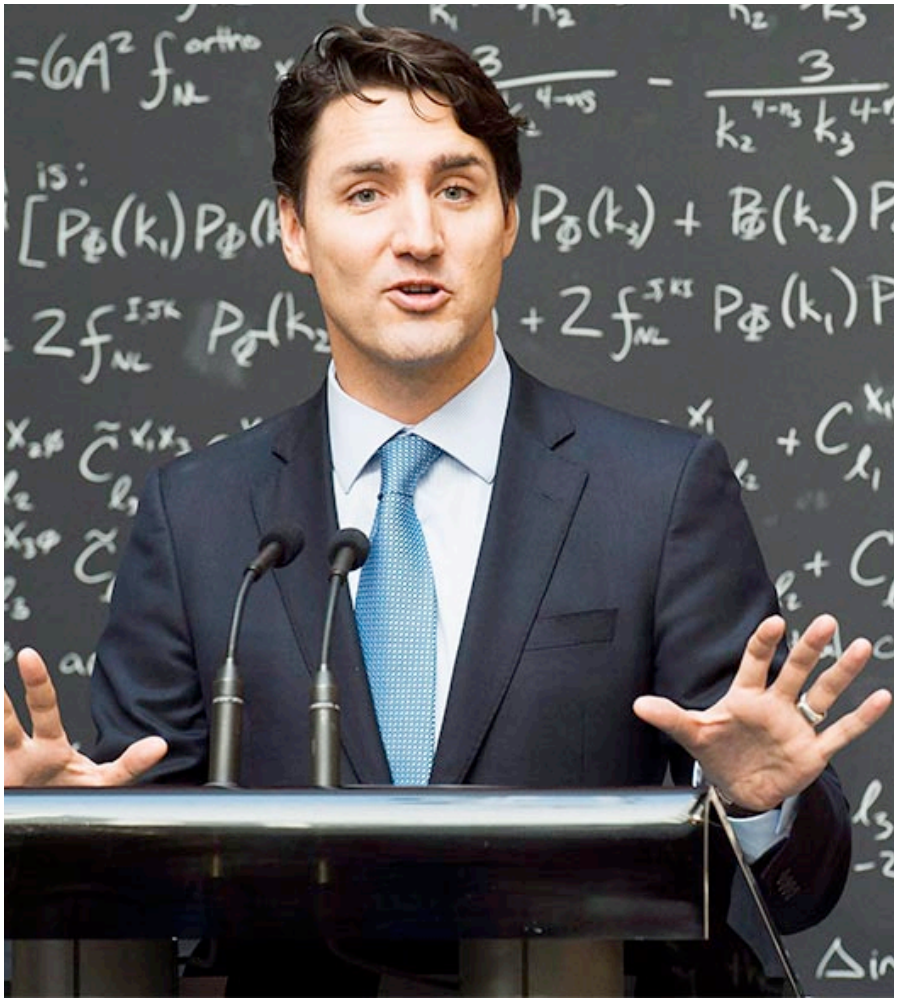
Intro to Quantum Computing

- What is it?
  - Qubits
  - Quantum gates
- Why is it exciting?
  - Quantum algorithms
- How long til I get one?
  - IBM’s 5-qubit processor

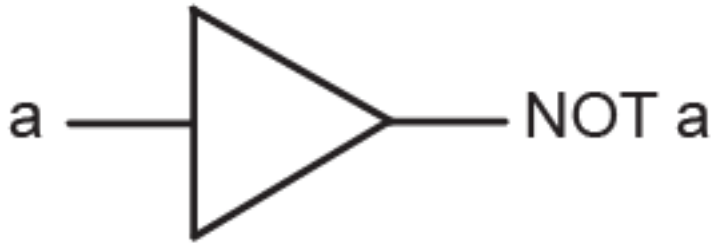
Intro to Quantum Computing



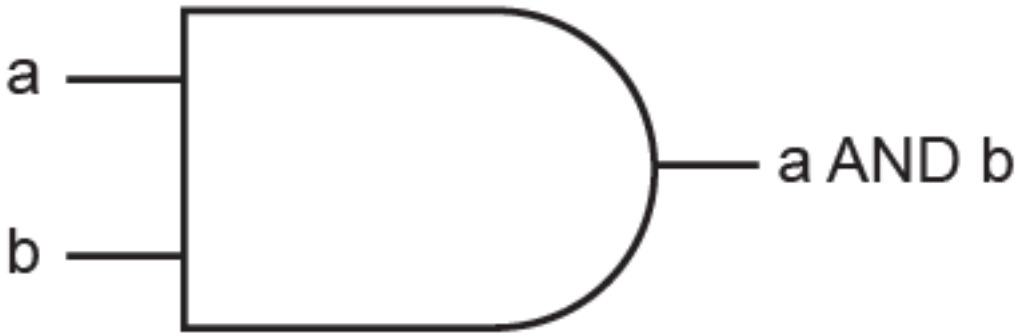
Very simply... normal computers work, either there's power going through a wire or not — a one, or a zero. They're binary systems. What quantum states allow for is much more complex information to be encoded into a single bit...

Right Honourable Justin Trudeau,
23rd Prime Minister of Canada

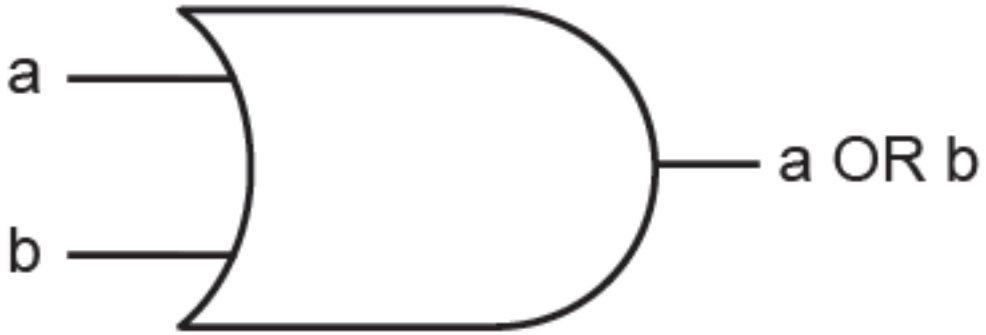
Bits vs. Qubits



a	NOT a
0	1
1	0

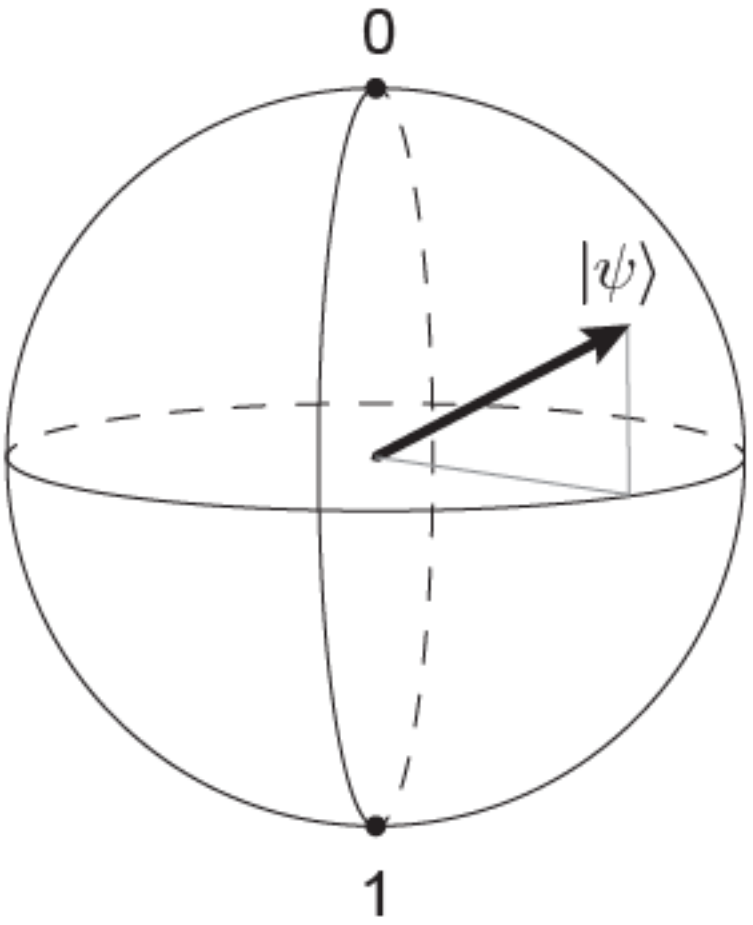


a	b	a AND b
0	0	0
0	1	0
1	0	0
1	1	1



a	b	a OR b
0	0	0
0	1	1
1	0	1
1	1	1

Bits vs. Qubits



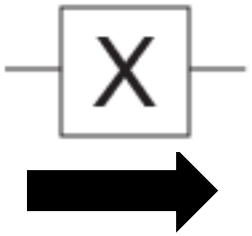
$|\psi\rangle$ is a vector on the sphere

$$|\psi\rangle = \begin{pmatrix} \alpha \\ \beta \end{pmatrix}$$

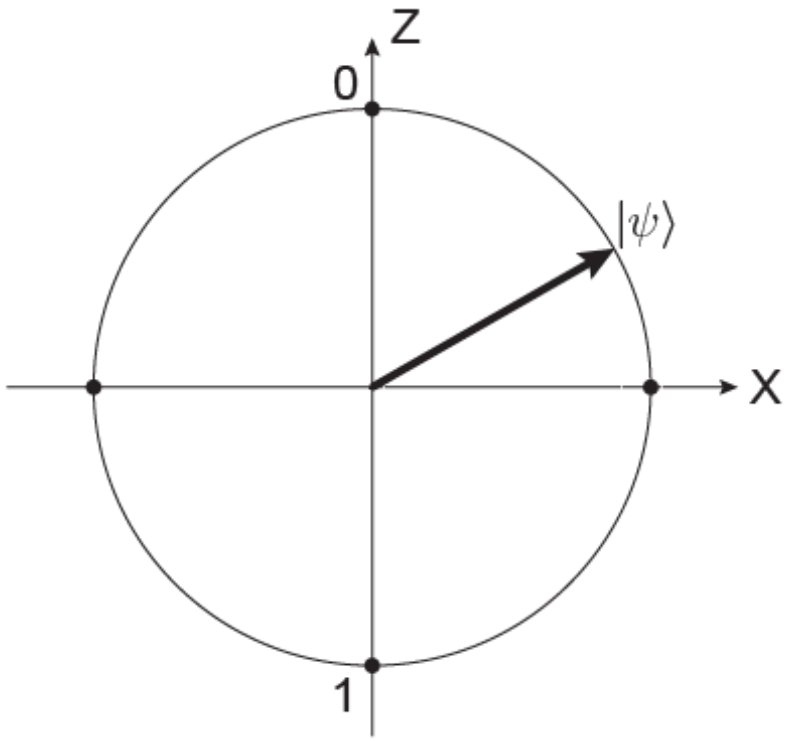
$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

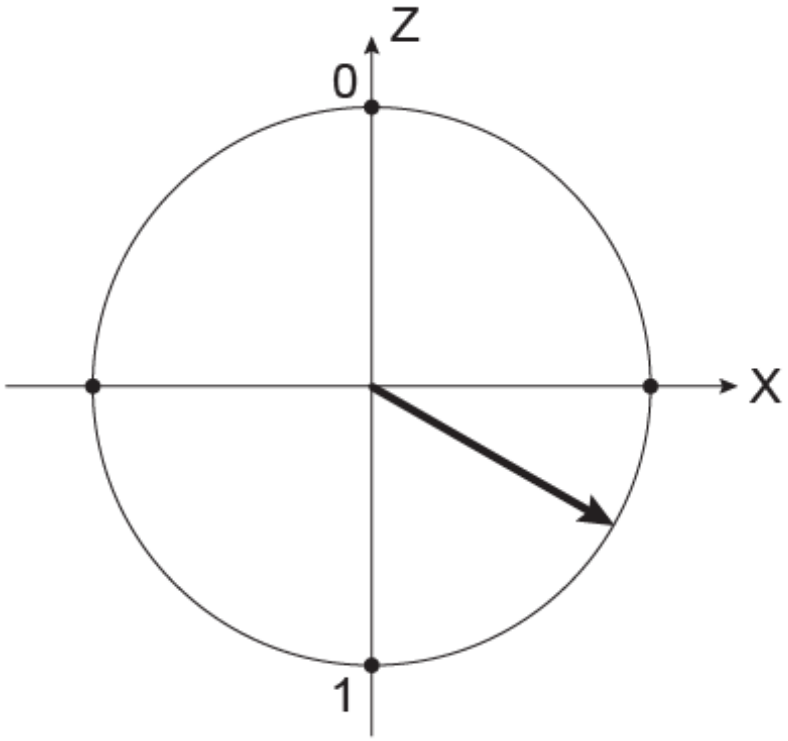
Bits vs. Qubits

$$|\psi\rangle = \begin{pmatrix} \alpha \\ \beta \end{pmatrix}$$



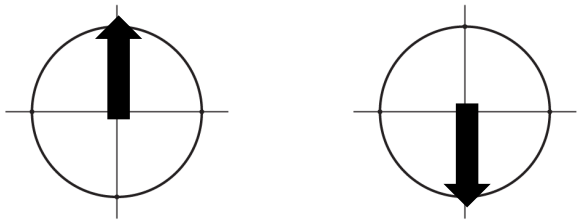
$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} \beta \\ \alpha \end{pmatrix}$$



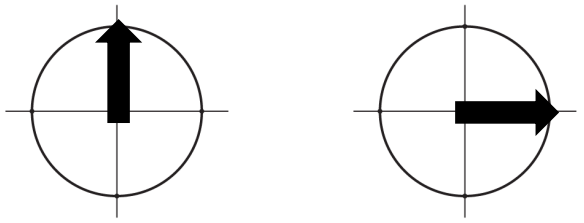


Bits vs. Qubits

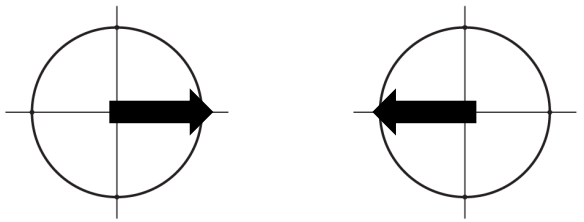
$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$



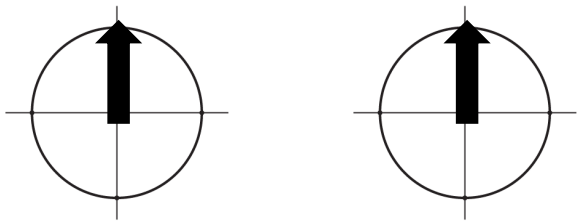
$$\frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$



$$\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

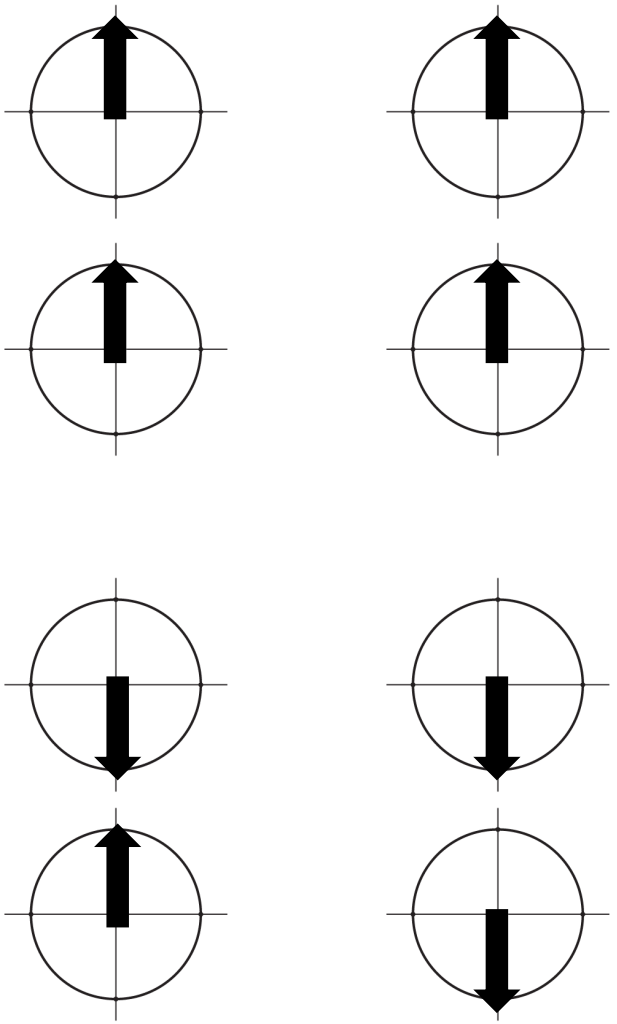


$$\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$



Bits vs. Qubits

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

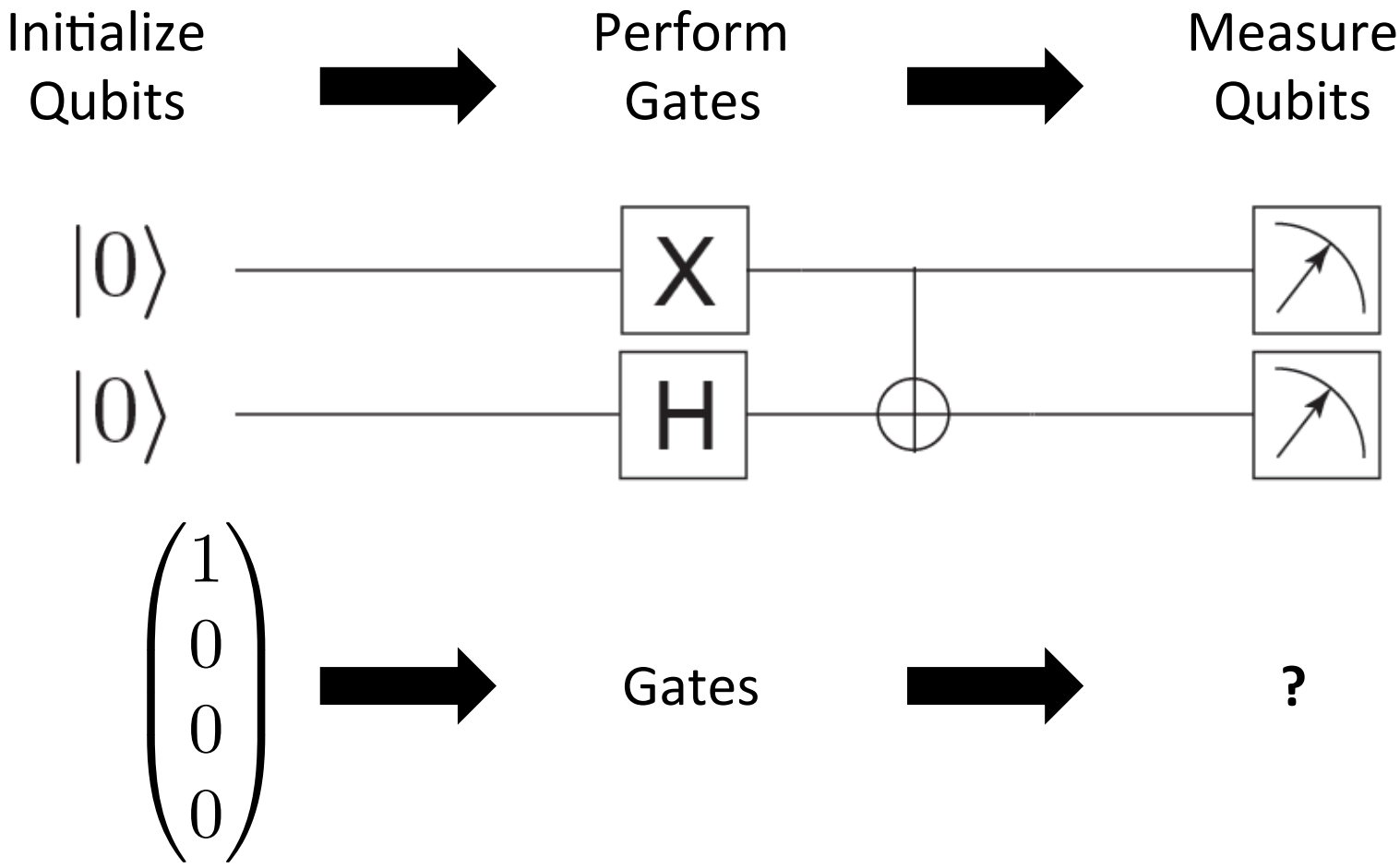


Measure Qubits

$$\begin{pmatrix} 1 \\ 0 \end{pmatrix} \xrightarrow{\frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}} \begin{pmatrix} \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} \end{pmatrix} \rightarrow \begin{aligned} P(\text{“0”}) &= 1/2 \\ P(\text{“1”}) &= 1/2 \end{aligned}$$

- Measurement is RANDOM choice of “0” or “1”.
- Probabilities of outcomes are the squares of the vector elements.

Quantum Circuit



Let's simulate it in Python!

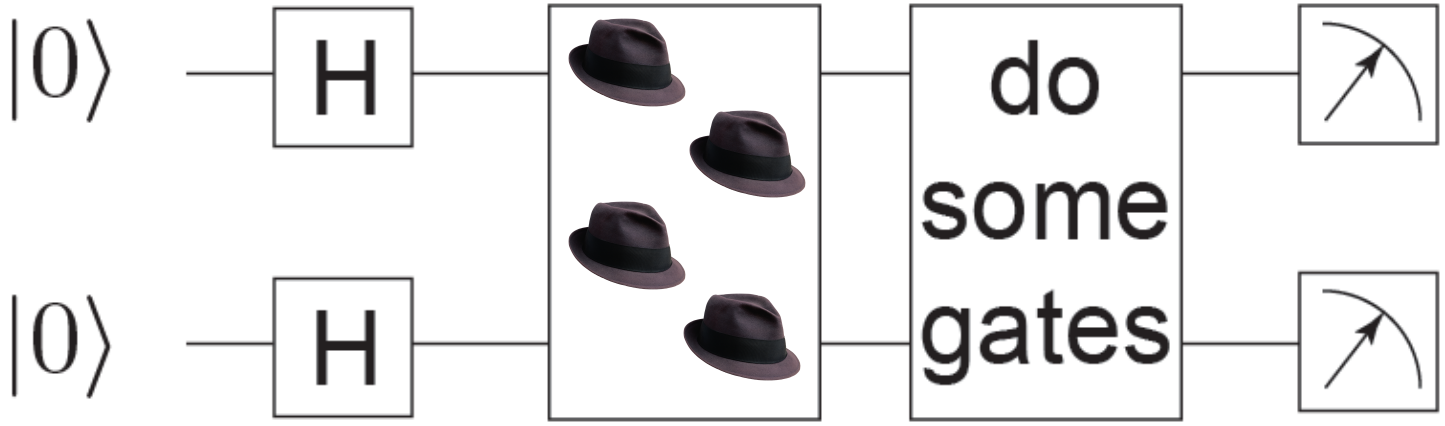
Grover's Search Algorithm



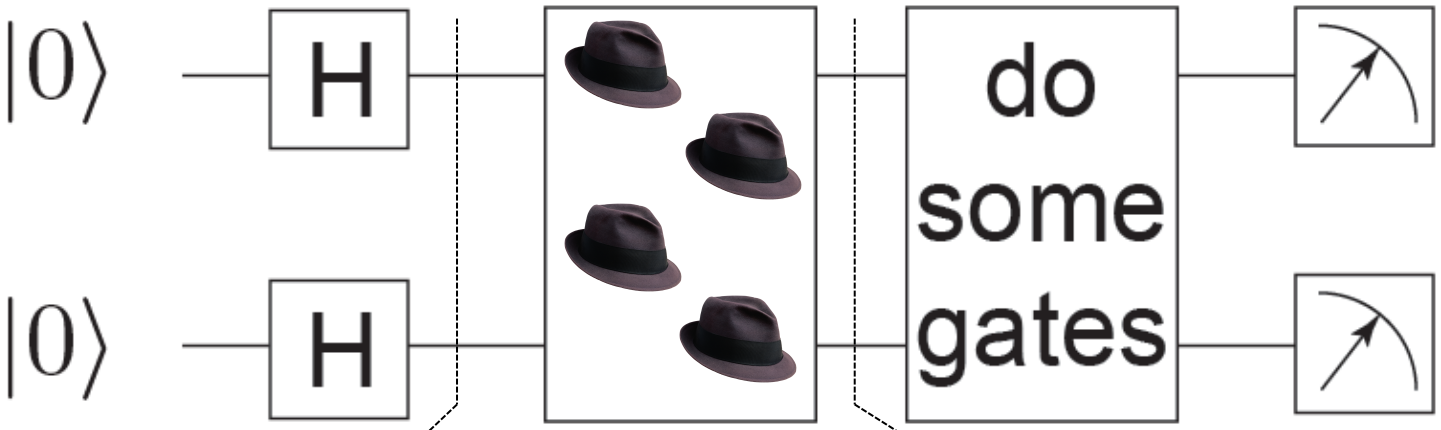

- How many guesses does it take to find the rabbit?
- Worst case? On average?

Grover's Search Algorithm

00 01 10 11

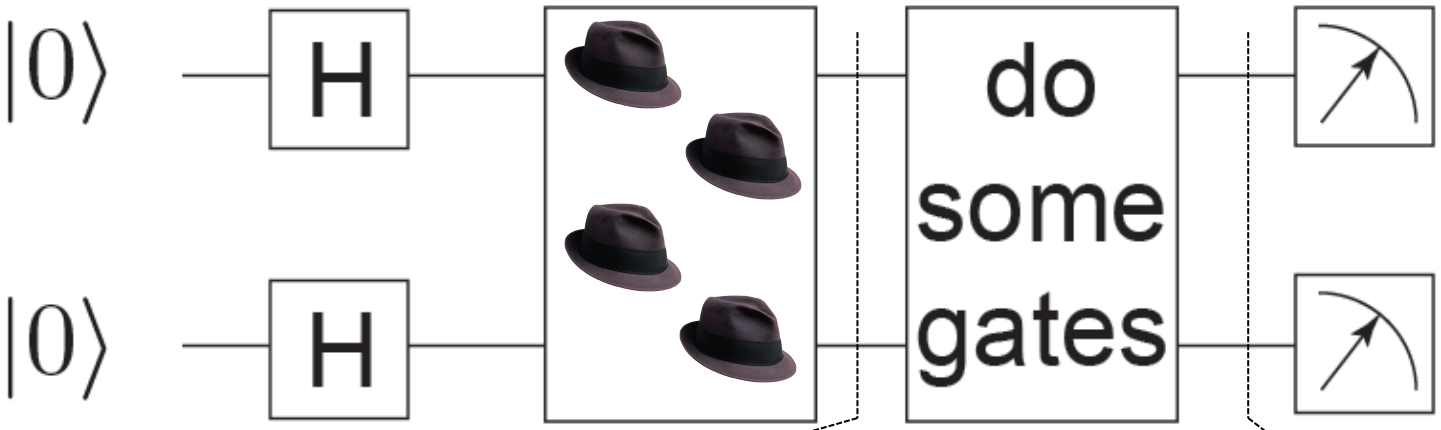


Grover's Search Algorithm



$$\frac{1}{2}\begin{pmatrix}1\\1\\1\\1\end{pmatrix} \rightarrow \begin{pmatrix}1&0&0&0\\0&1&0&0\\0&0&-1&0\\0&0&0&1\end{pmatrix} \rightarrow \frac{1}{2}\begin{pmatrix}1\\1\\-1\\1\end{pmatrix}$$

Grover's Search Algorithm



$$\frac{1}{2}\begin{pmatrix}1\\1\\-1\\1\end{pmatrix} \rightarrow W = \frac{1}{2}\begin{pmatrix}-1 & 1 & 1 & 1\\ 1 & -1 & 1 & 1\\ 1 & 1 & -1 & 1\\ 1 & 1 & 1 & -1\end{pmatrix} \rightarrow \begin{pmatrix}0\\0\\1\\0\end{pmatrix}$$

Grover's Search Algorithm

Back to Python!

And then to IBM!