

# Applied Physics Seminar: Bits and Qubits

Notes on digital computers and quantum computers

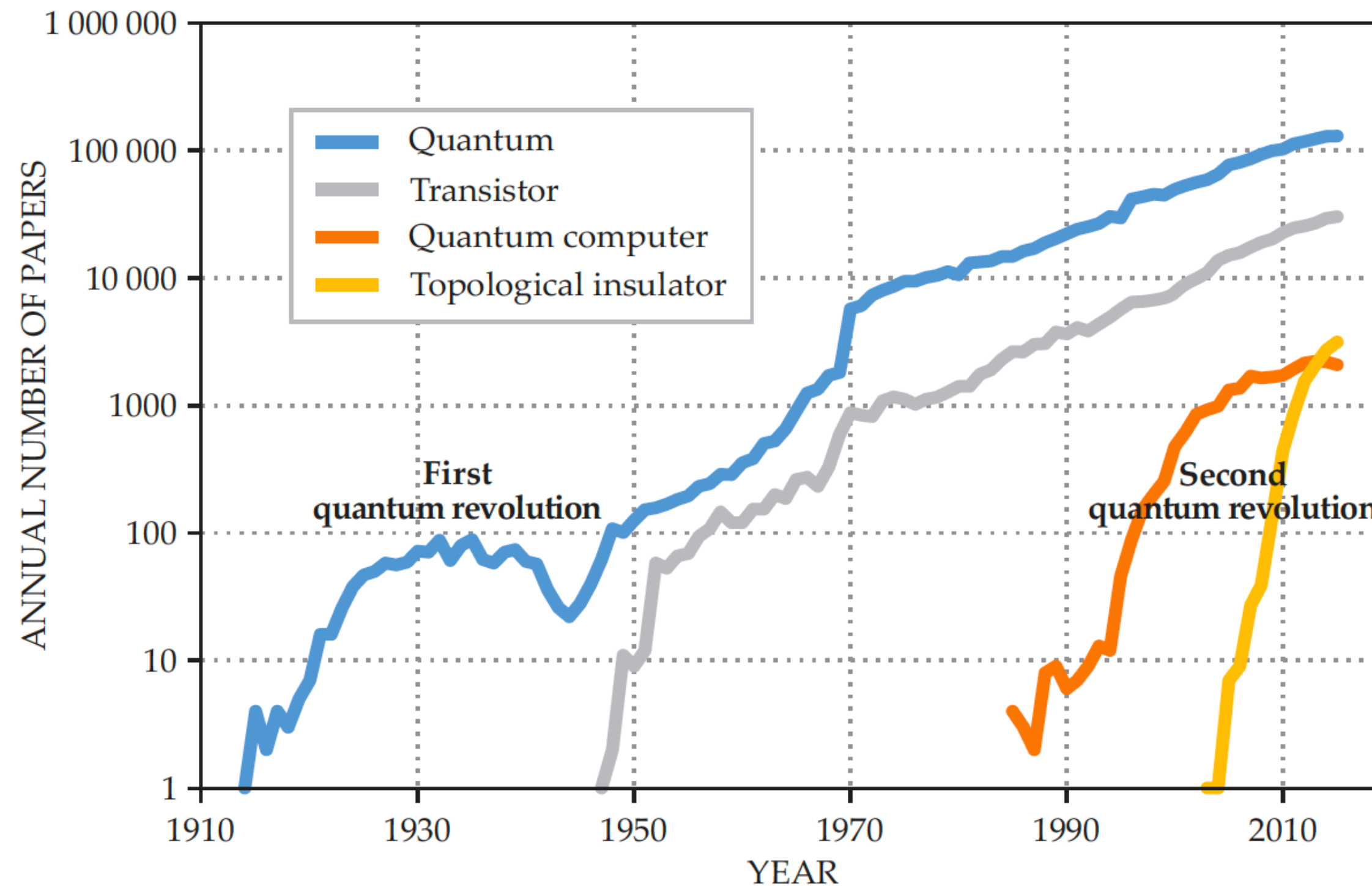
Commentary

Enabling a quantum leap

At the turn of the 20th century, the scientific consensus was that physics was solved and only a few questions, such as the origin and nature of the photoelectric effect, remained unanswered. Enter the early 20th-century invention of quantum mechanics, which introduced strangeness and spookiness to the seemingly complete classical world. Some of the greatest minds of the time, including Max Planck, Werner Heisenberg, Albert Einstein, Paul Dirac, and Niels Bohr, collaborated to produce counterintuitive theories offering explanations of empirical phenomena.

That first quantum revolution effectively gave us the language for understanding the building blocks of the universe. It also enabled such amazing technological developments as the transistor and most of the materials in our smartphones—just two examples of devices that have had immense societal impact.

Today we are witnessing the early days of the second quantum revolution, in which elements of quantum mechan-



**QUANTUM RESEARCH PAPERS.** Annual number of published papers that include quantum-related words in title or abstract. The first quantum revolution included development of quantum mechanics and invention of the transistor. The second revolution started recently and is marked by convergence of various disciplines with quantum mechanics. (Data source: Scopus.)

Current Legislation



Examples: hr5, sres9, "health care"



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## H.R.6227 - National Quantum Initiative Act

115th Congress (2017-2018) | [Get alerts](#)

BILL

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**Sponsor:** [Rep. Smith, Lamar \[R-TX-21\]](#) (Introduced 06/26/2018)**Committees:** House - Science, Space, and Technology**Latest Action:** House - 06/27/2018 Ordered to be Reported (Amended) by Voice Vote. ([All Actions](#))**Tracker:**

Introduced → Passed House → Passed Senate → To President → Became Law

### More on This Bill

[Constitutional Authority Statement](#)[CBO Cost Estimates \[0\]](#)

### Subject — Policy Area:

Science, Technology, Communications

[View subjects »](#)

Summary (1)

Text (1)

Actions (4)

Titles (2)

Amendments (0)

Cosponsors (35)

Committees (1)

Related Bills (1)

### Summary: H.R.6227 — 115th Congress (2017-2018)

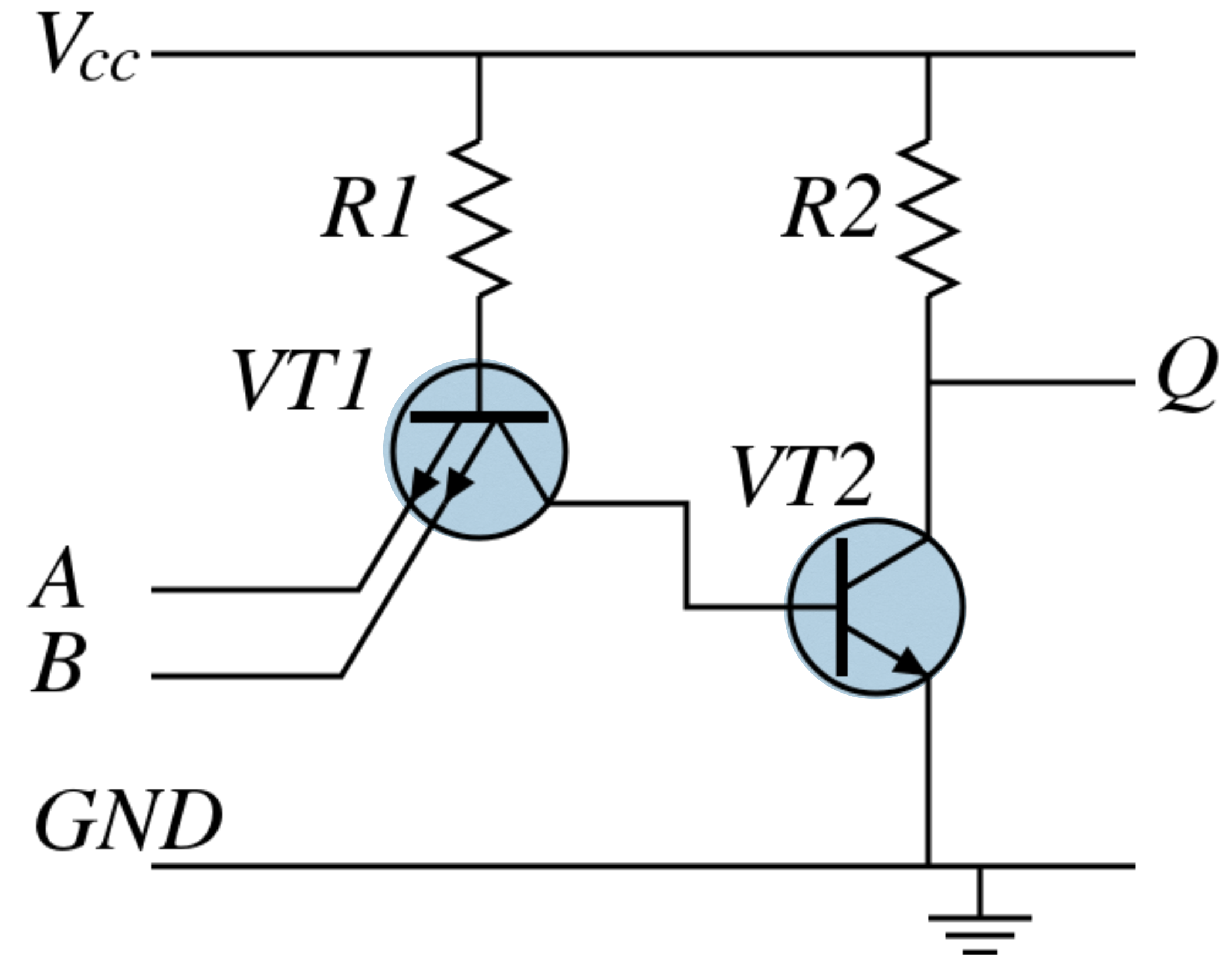
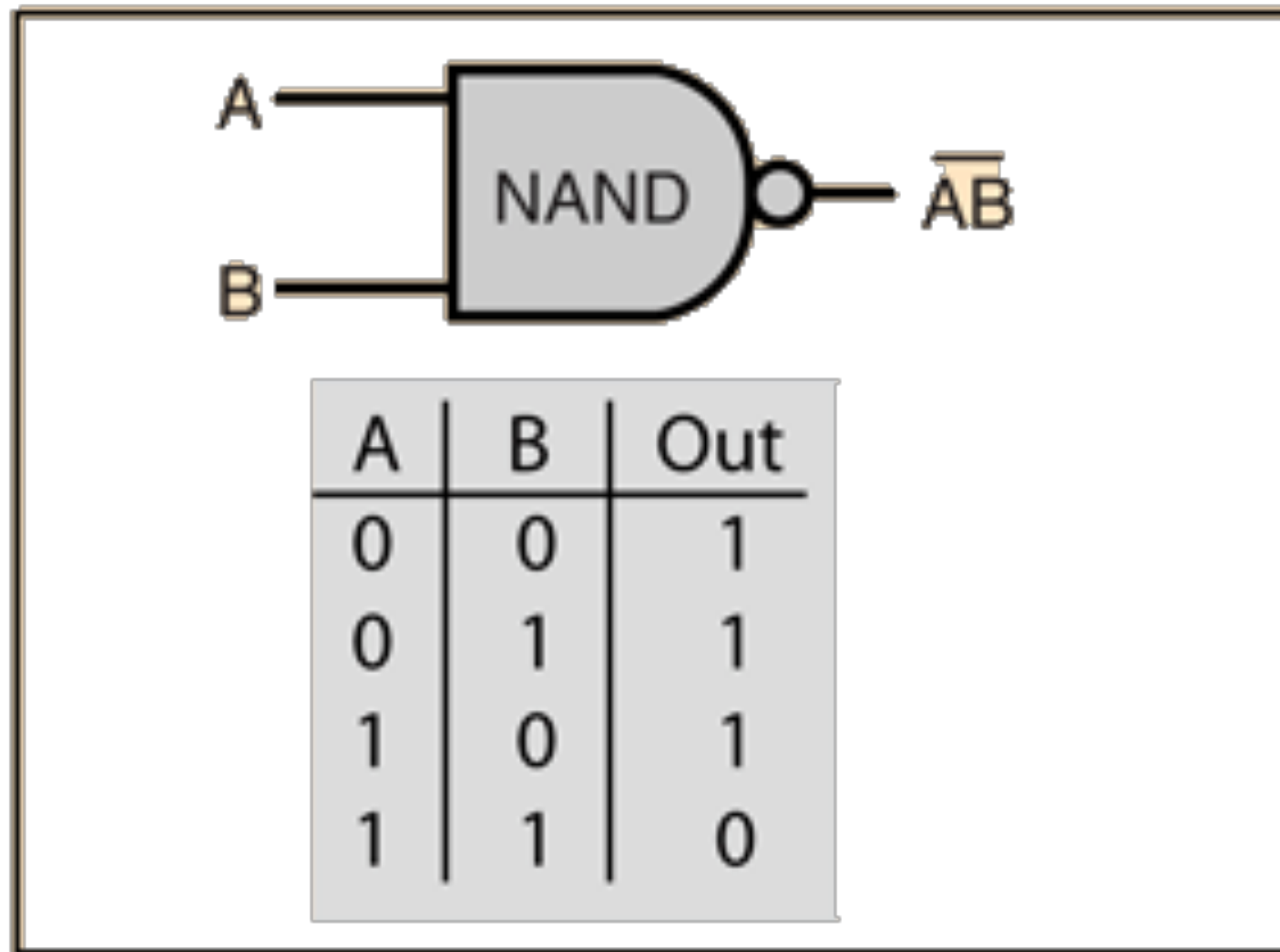
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This bill directs the President to implement a National Quantum Initiative Program to, among other things, establish the goals and priorities for a 10-year plan to accelerate the development of quantum information science and technology applications.

There is one summary for H.R.6227. [Bill summaries](#) are authored by [CRS](#).

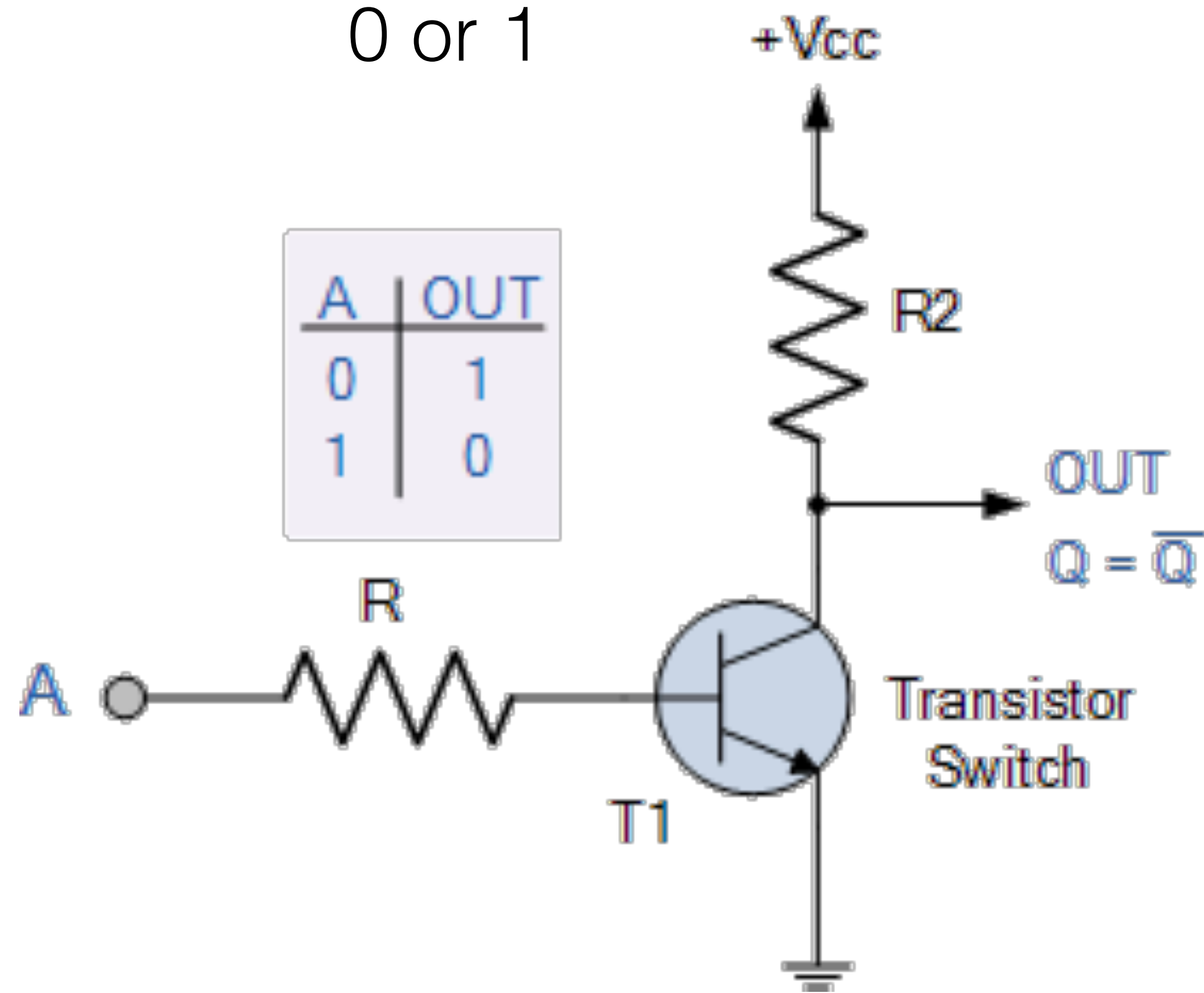
# Bits

0 or 1



# Bits

0 or 1



# QuBits

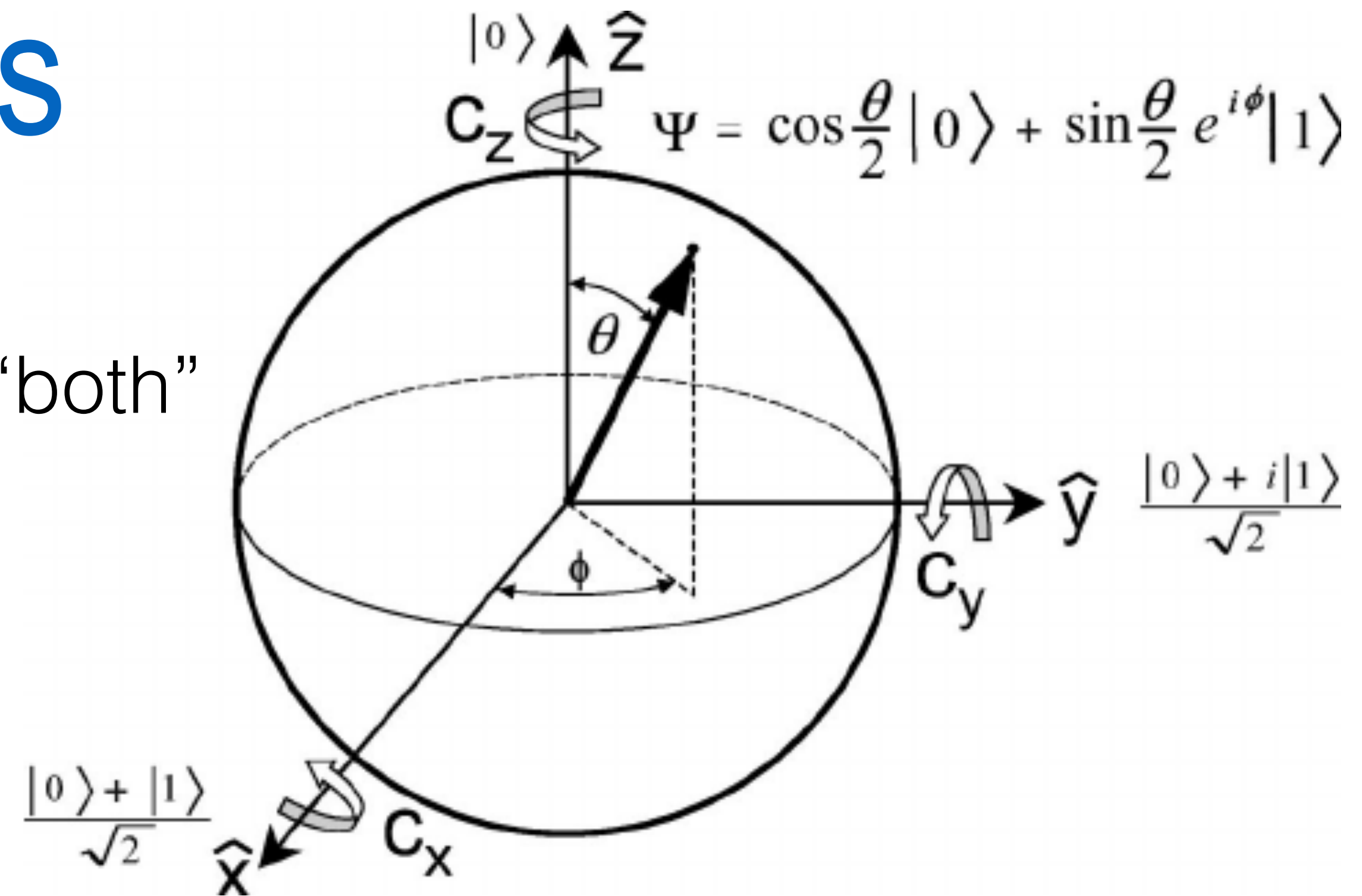
$|0\rangle$  or  $|1\rangle$  or “both”

$$|A\rangle = \alpha_0 |0\rangle + \alpha_1 |1\rangle$$

where  $(\alpha_0, \alpha_1)$  are complex numbers and  $|\alpha_0|^2 + |\alpha_1|^2 = 1$

# QuBits

$|0\rangle$  or  $|1\rangle$  or “both”



$$|A\rangle = \cos\frac{\theta}{2}|0\rangle + e^{i\phi}\sin\frac{\theta}{2}|1\rangle$$

# Photons and Polarization States

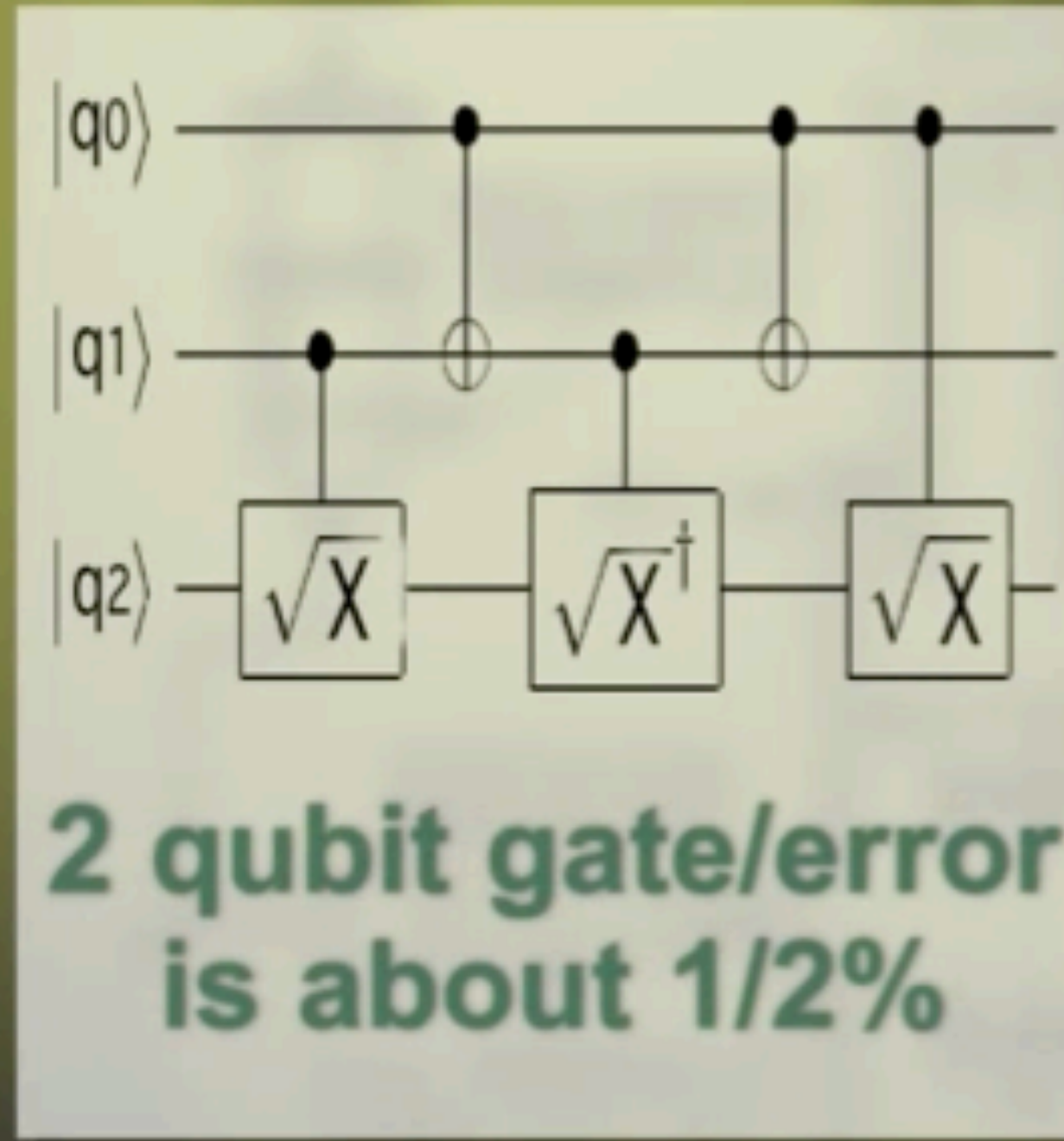
$$|x\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \quad |R\rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ i \end{pmatrix}$$

$$|y\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \quad |L\rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ -i \end{pmatrix}$$

$$|\psi\rangle = \psi_R |R\rangle + \psi_L |L\rangle$$



<https://www.youtube.com/watch?v=vaEvPFJarDI>



**Dr. David Wineland - Physicist**  
NIST (National Institute of Standards & Technology)



1:07 / 2:17

