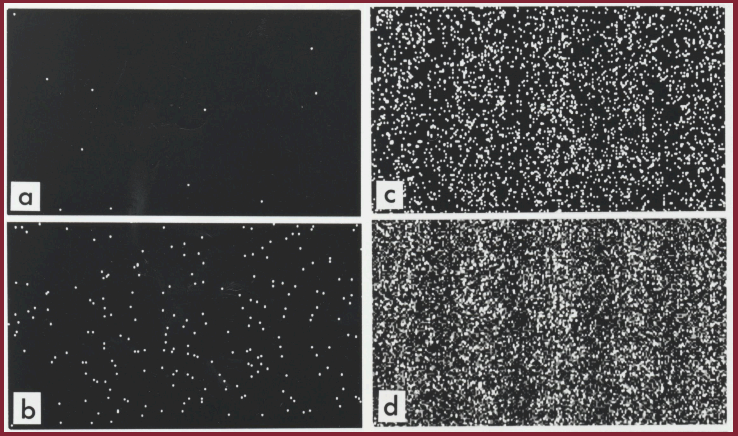
Why nobody understands Quantum Mechanics

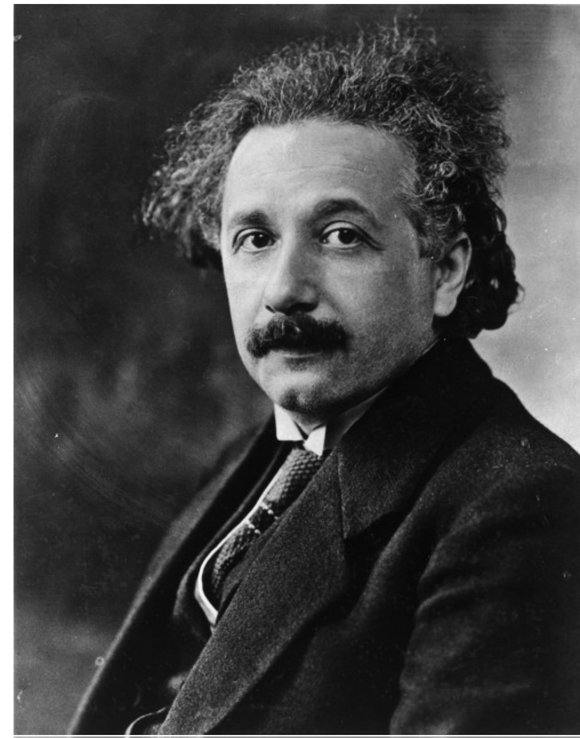
Andrea Di Biagio



Yoga with Anysa Workshop

What's up with quantum theory?

Erwin Schrödinger
1926



Albert Einstein
1926

What's up with quantum theory?

If all the quantum jumping is here to stay, then I am sorry that I ever became involved in quantum mechanics.

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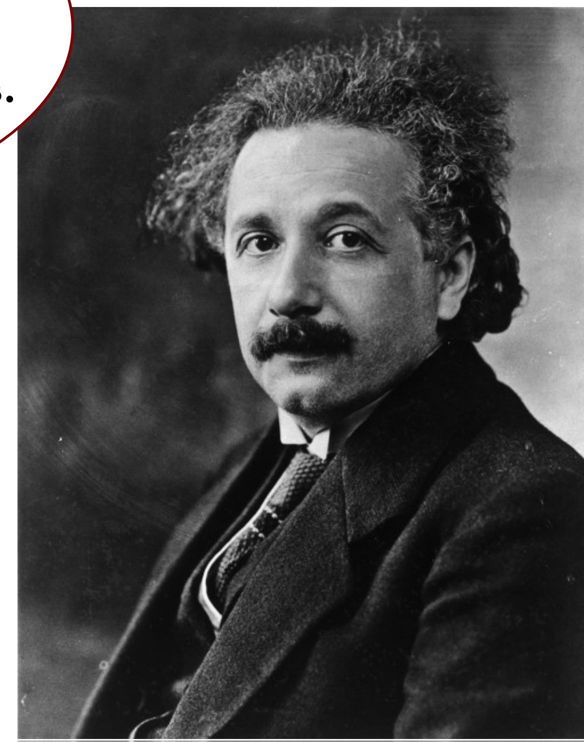

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H. Stapp, Schrödinger's cat (2009)

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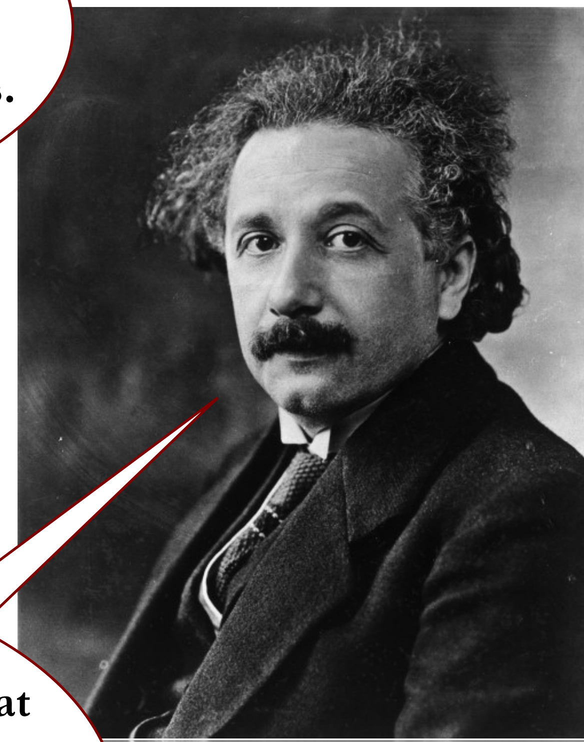
Erwin Schrödinger
1926

H. Stapp, Schrödinger's cat (2009)

... an inner voice tells me that it is not yet the real thing. The theory says a lot, but does not really bring us any closer to the secret of the "old one."



Albert Einstein
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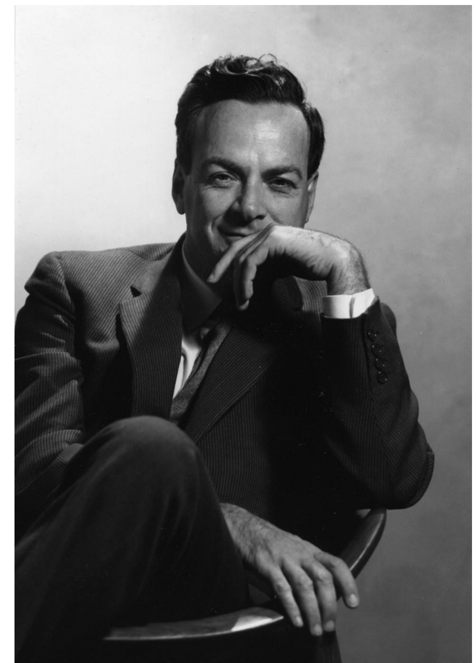
The Born-Einstein Letters (1971)

What's up with quantum theory?

Niels Bohr
1952

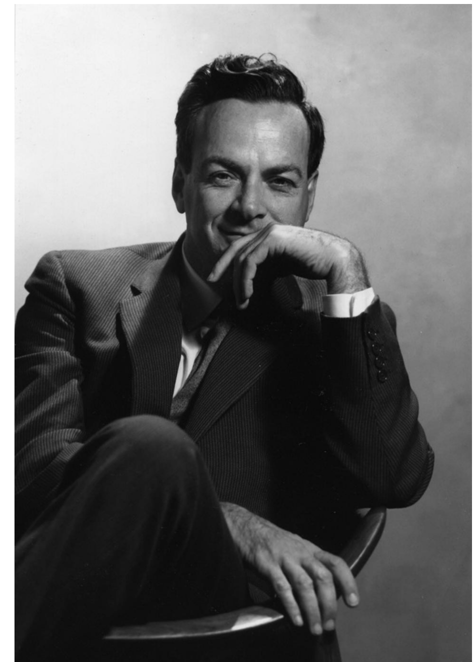


Richard Feynman
1965

What's up with quantum theory?

Those who are not shocked when they first come across quantum theory cannot possibly have understood it.

Niels Bohr
1952



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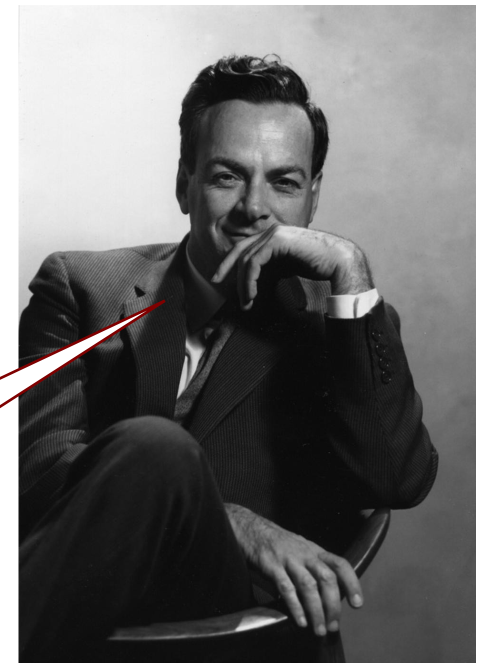


I think I can safely say that nobody understands quantum mechanics.

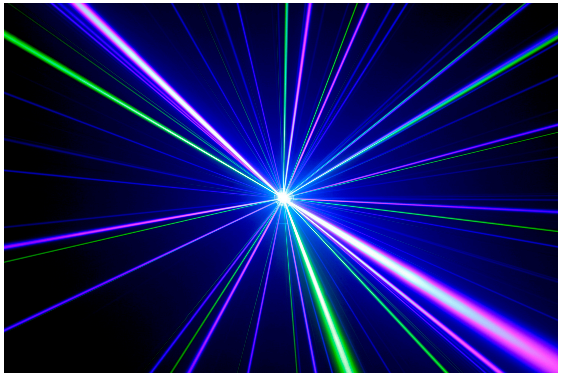
Richard Feynman
1965

https://www.youtube.com/watch?v=5tvzmuUPpNw

W. Heisenberg. *Physics and Beyond.* (1971)

Technological Applications

Technological Applications



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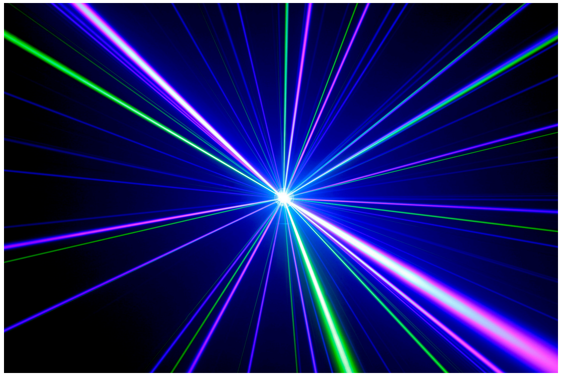

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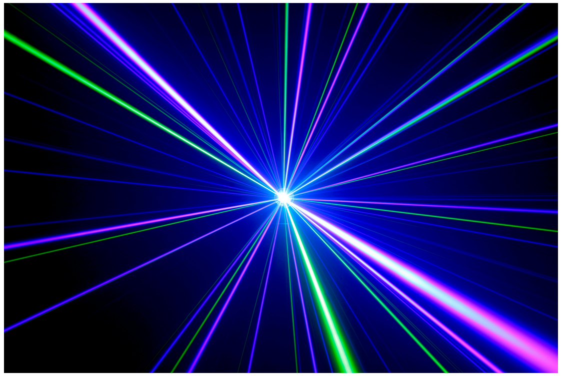

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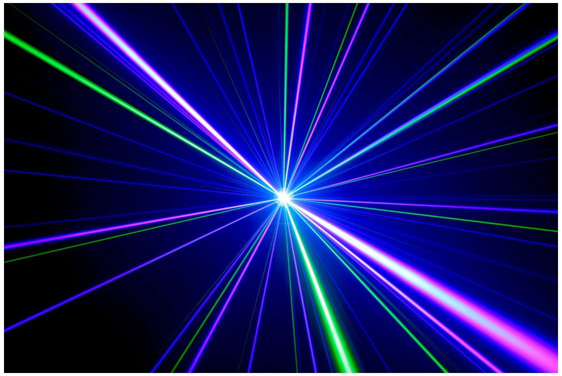

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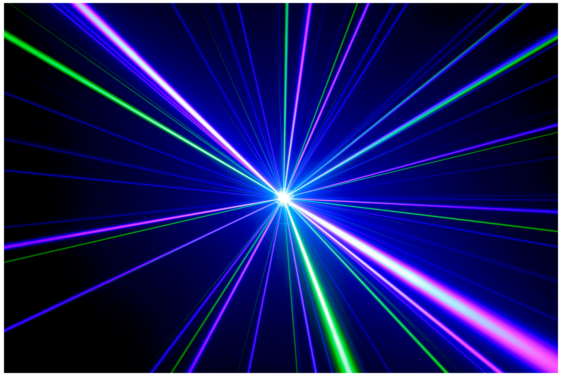

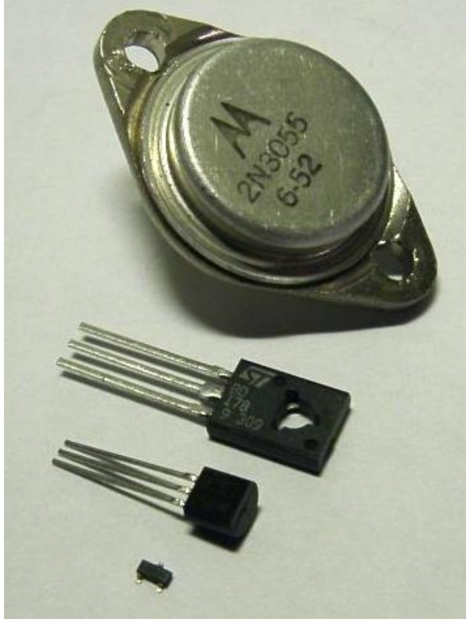

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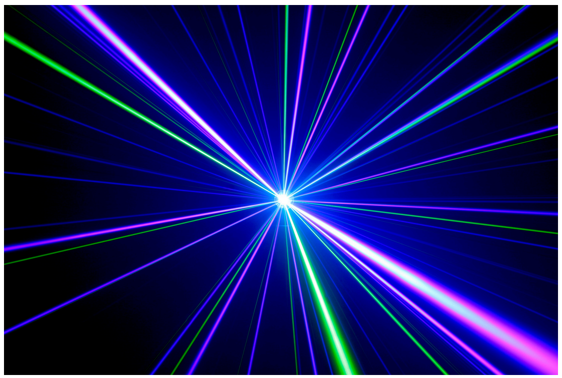

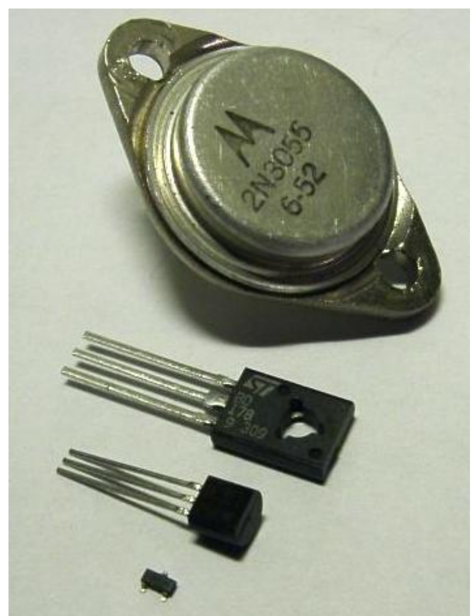

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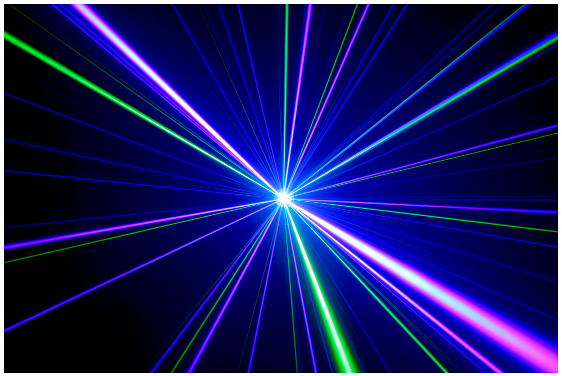

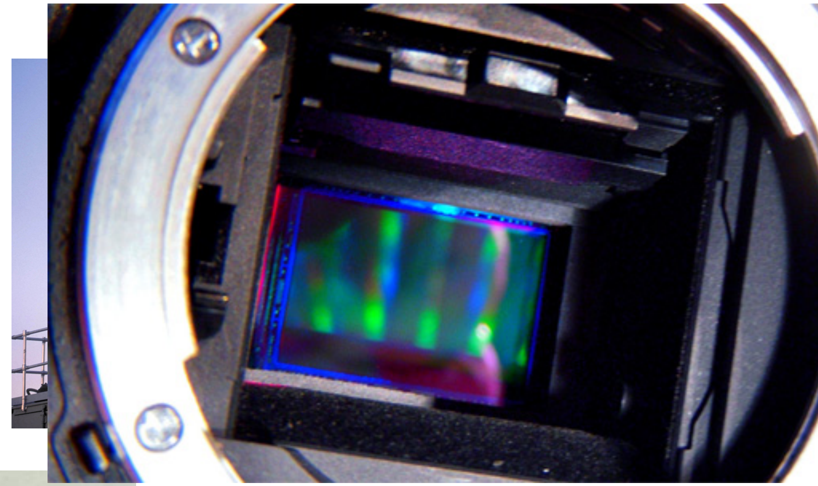

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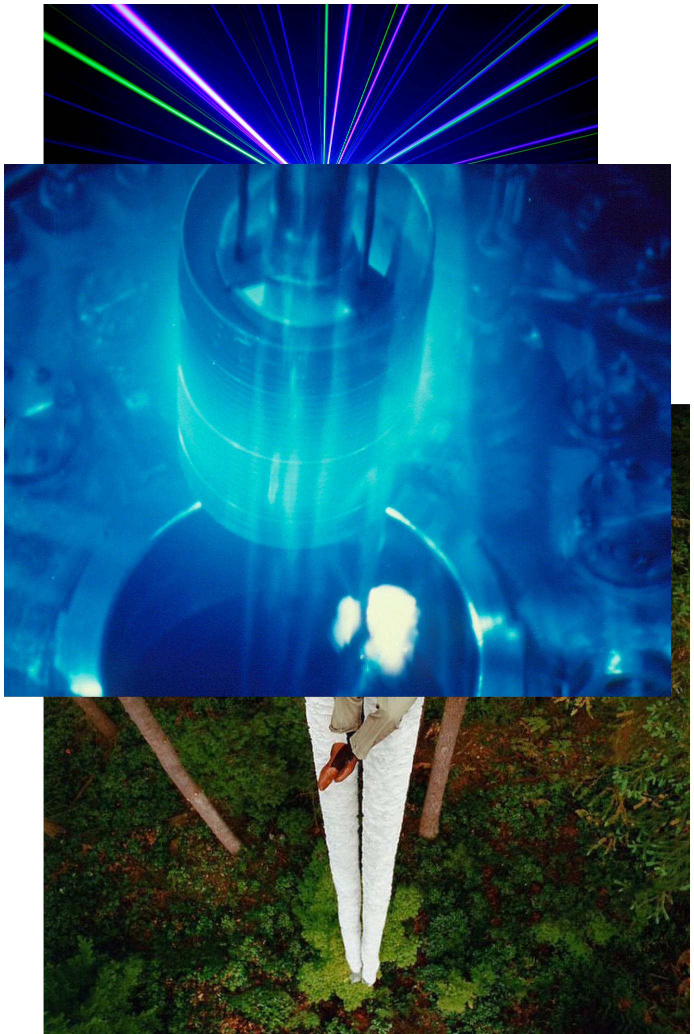

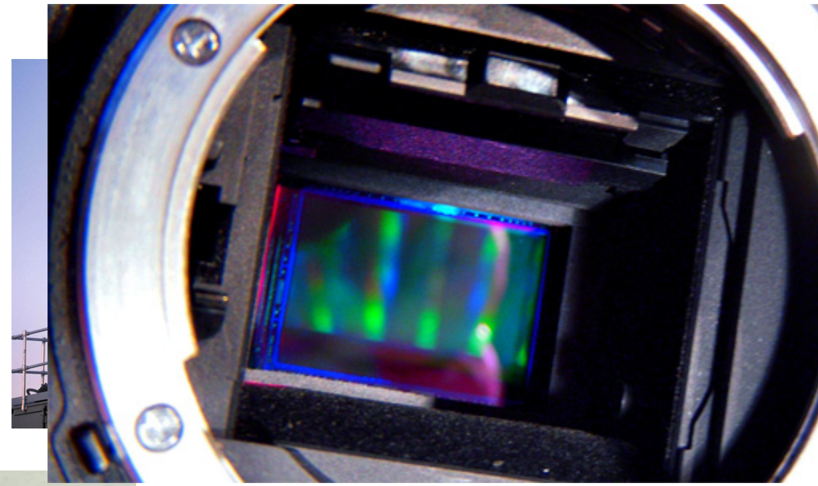

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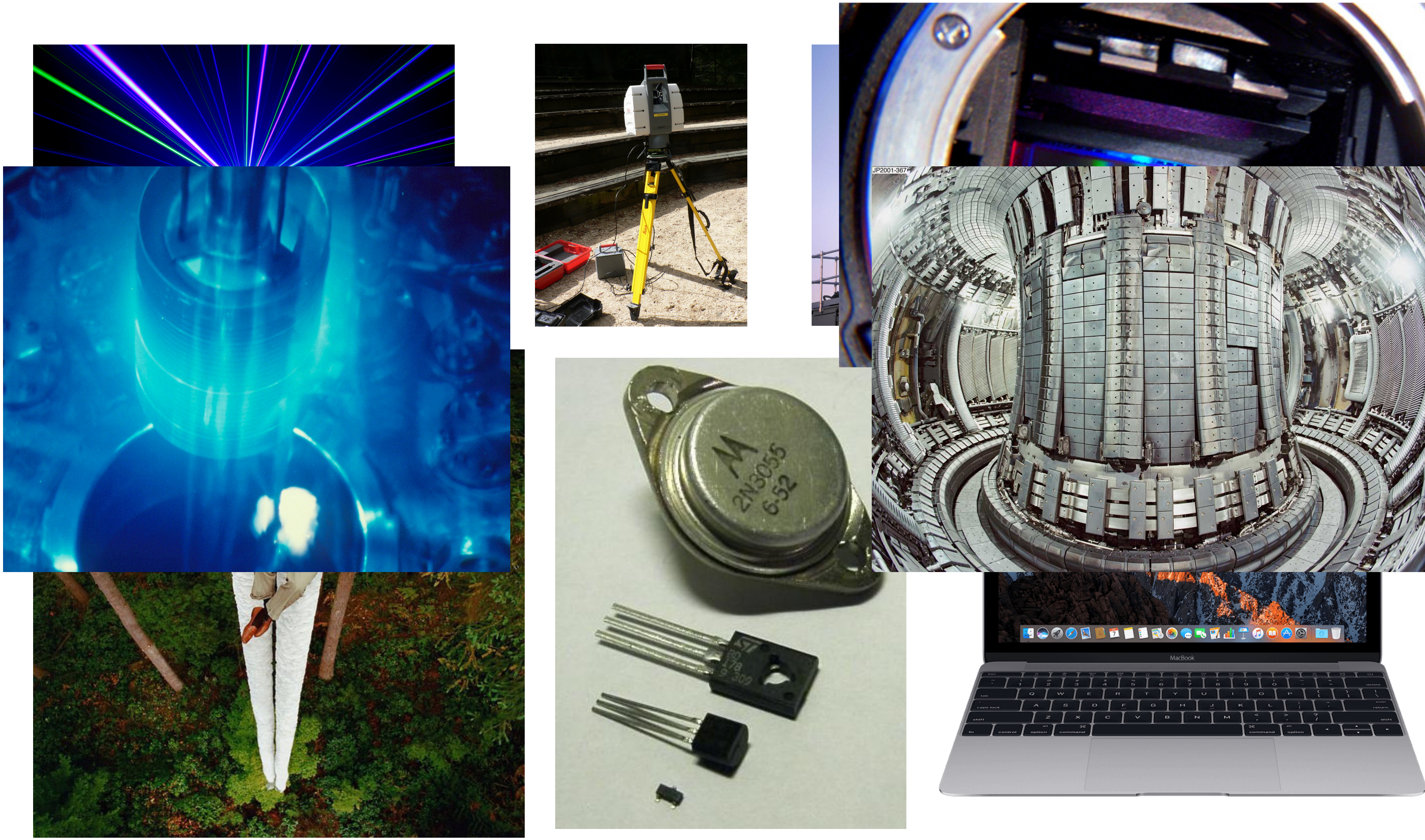

What's up with quantum theory?

Technological Applications

What's up with quantum theory?

What's up with quantum theory?

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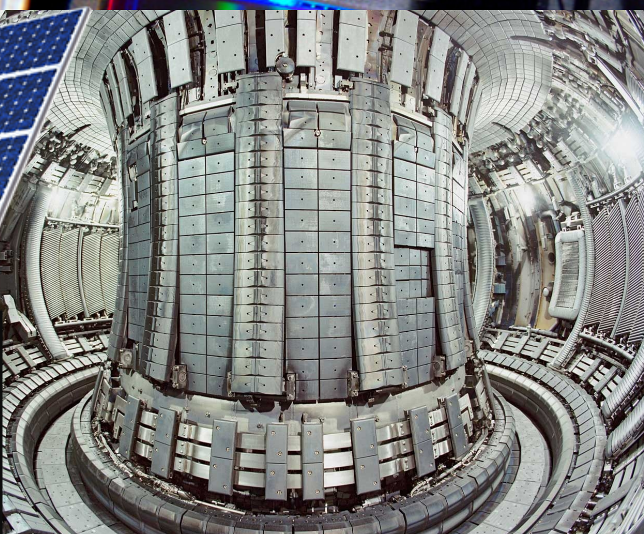

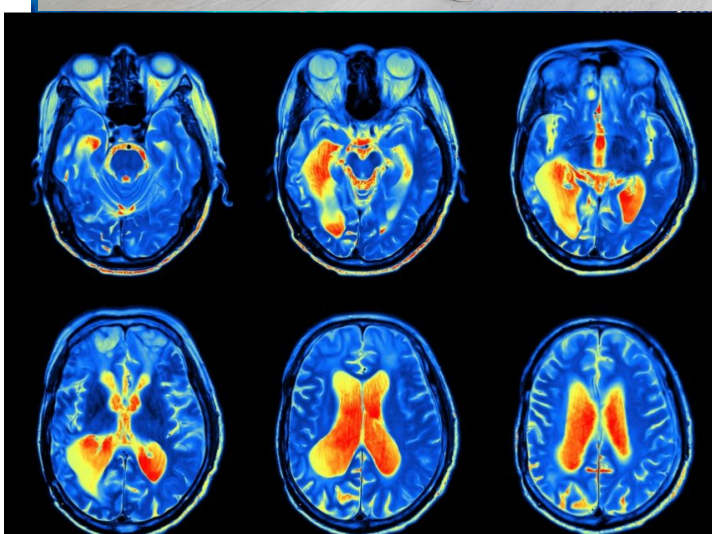

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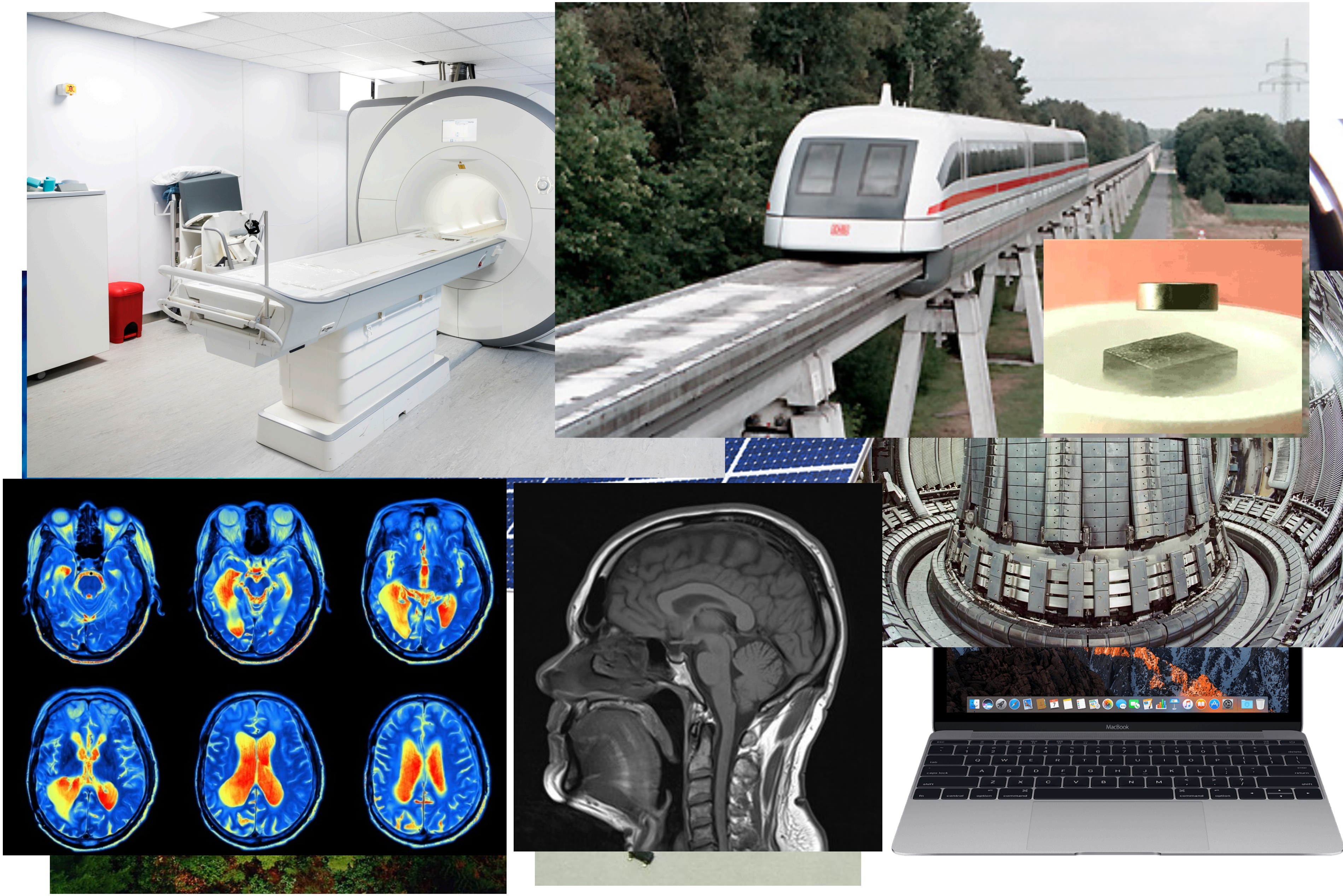

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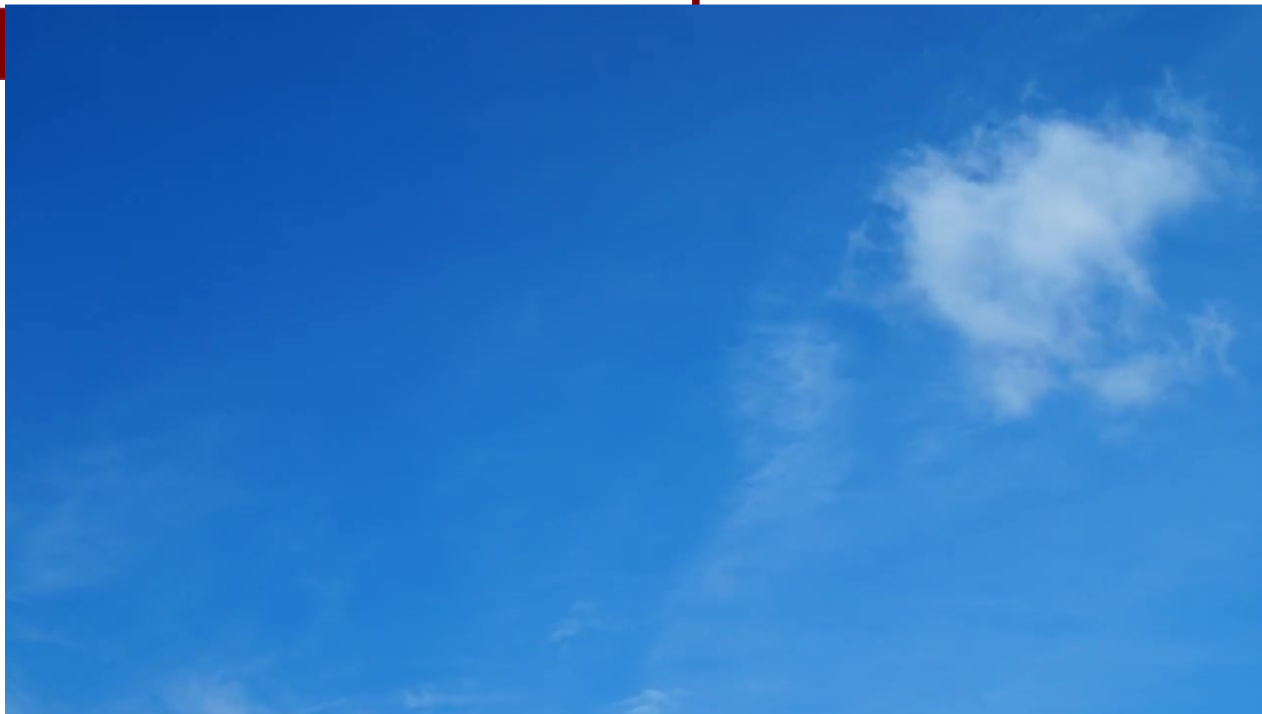

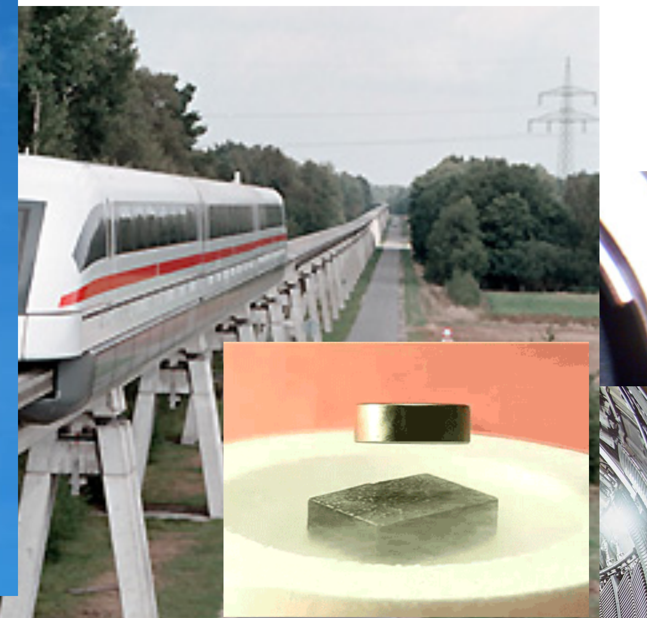

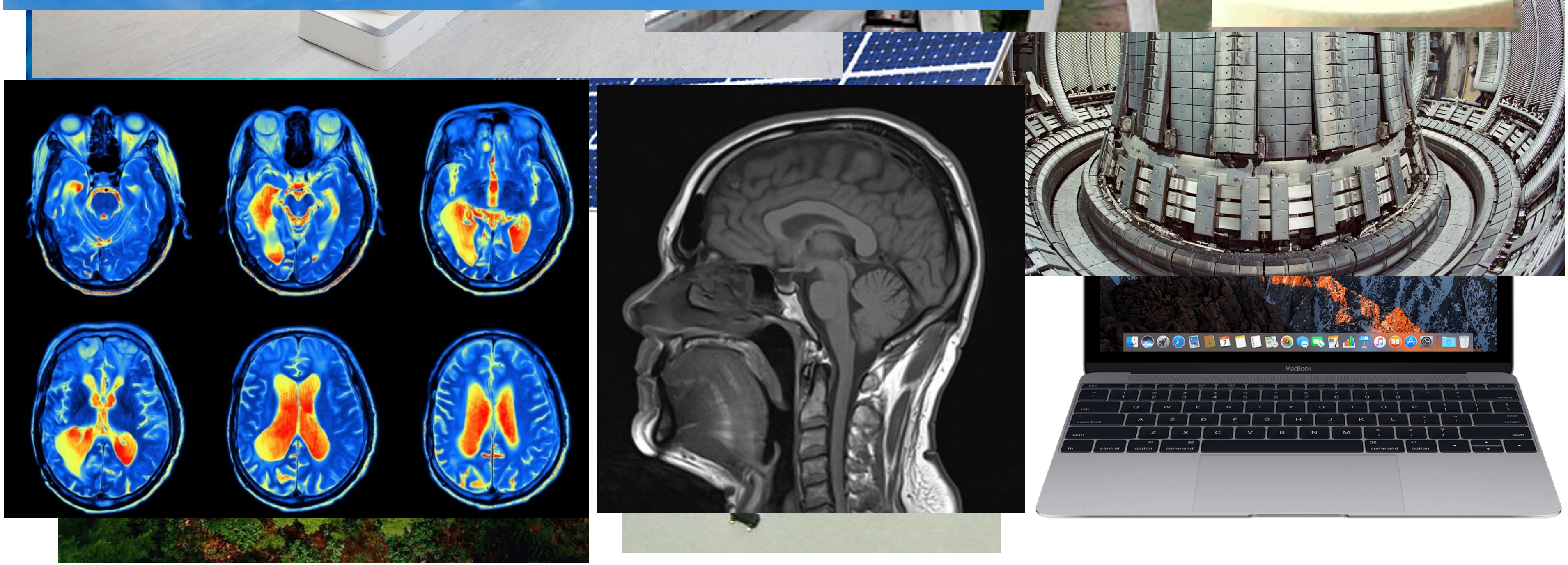

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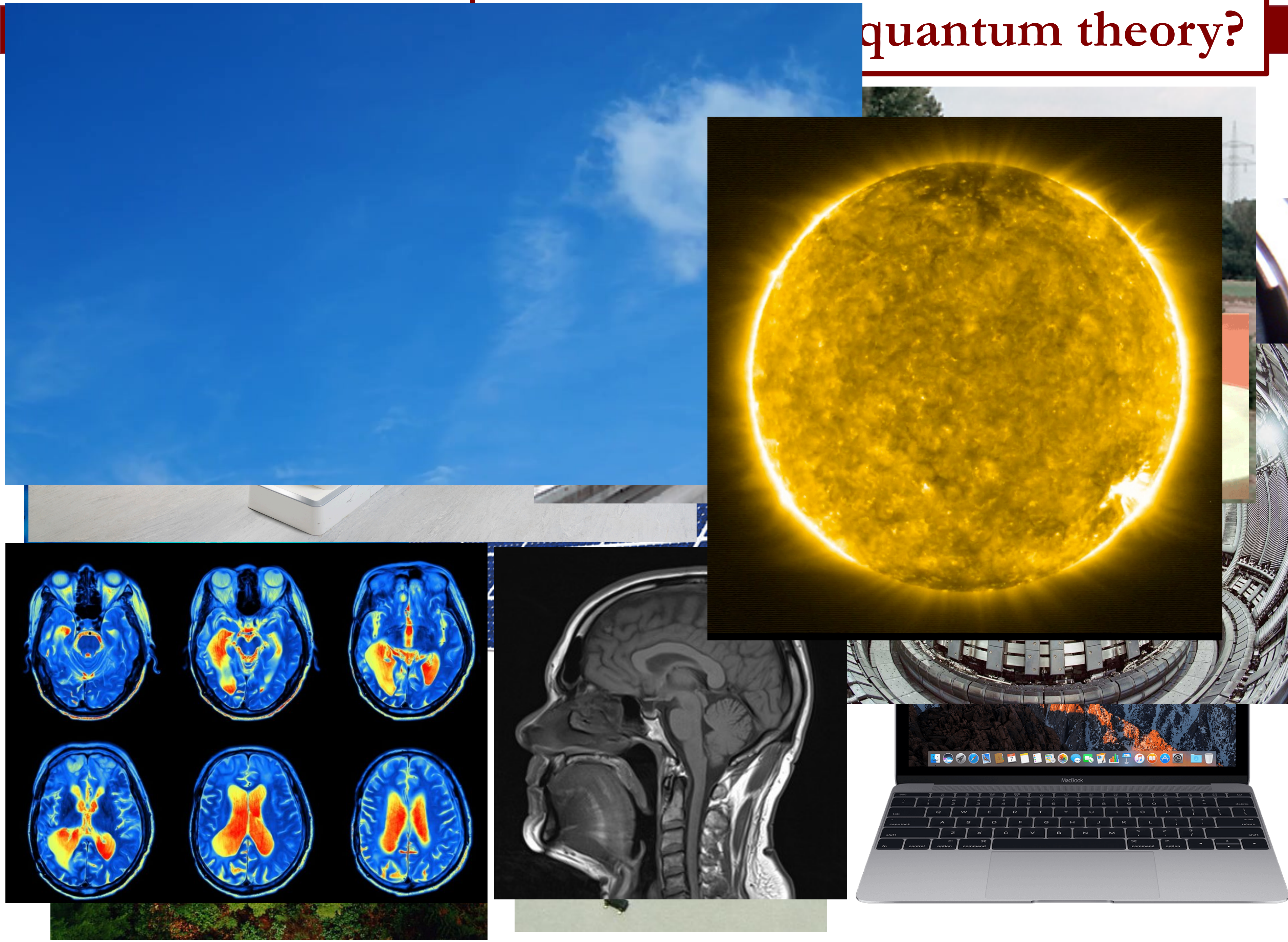

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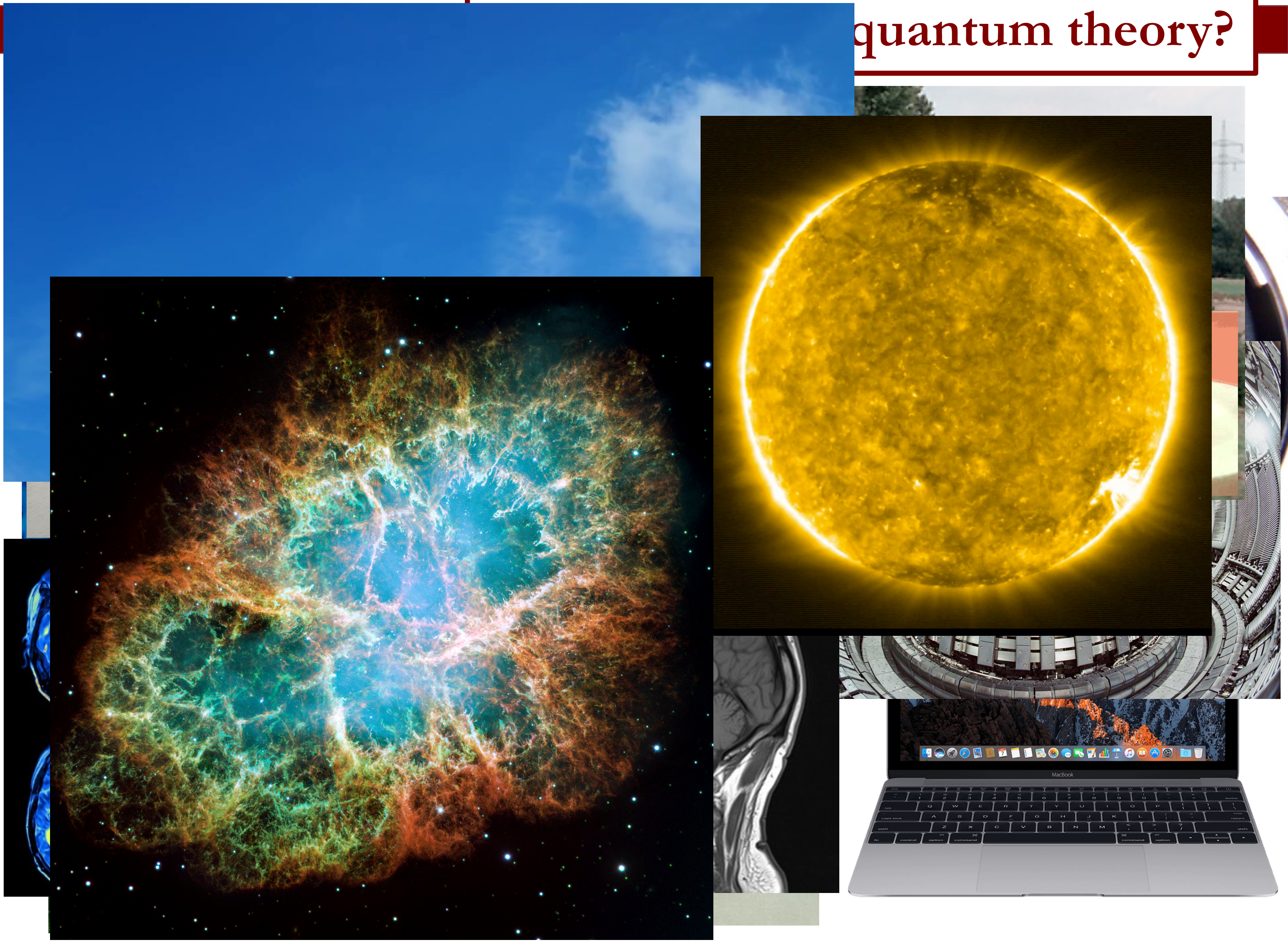

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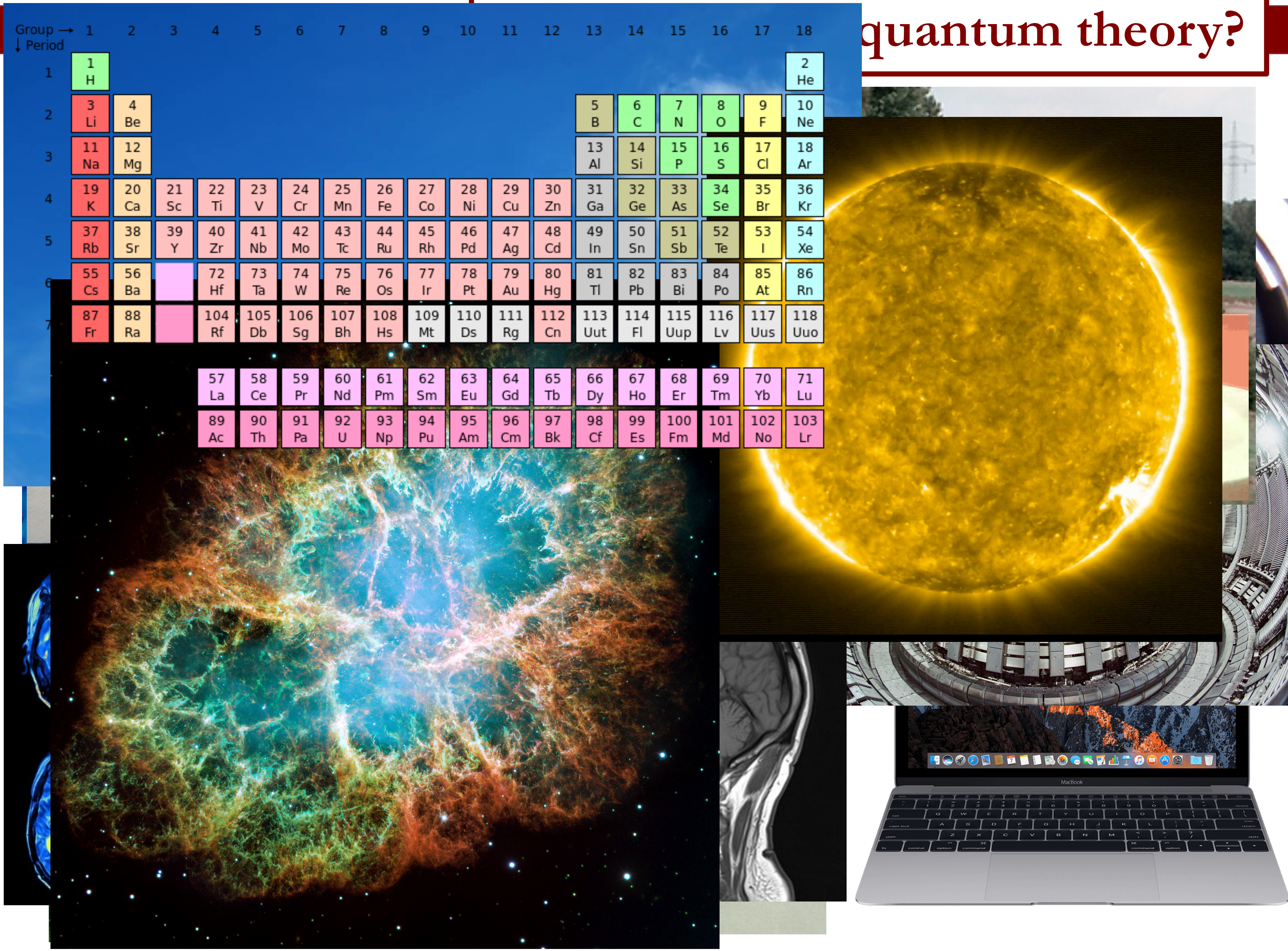

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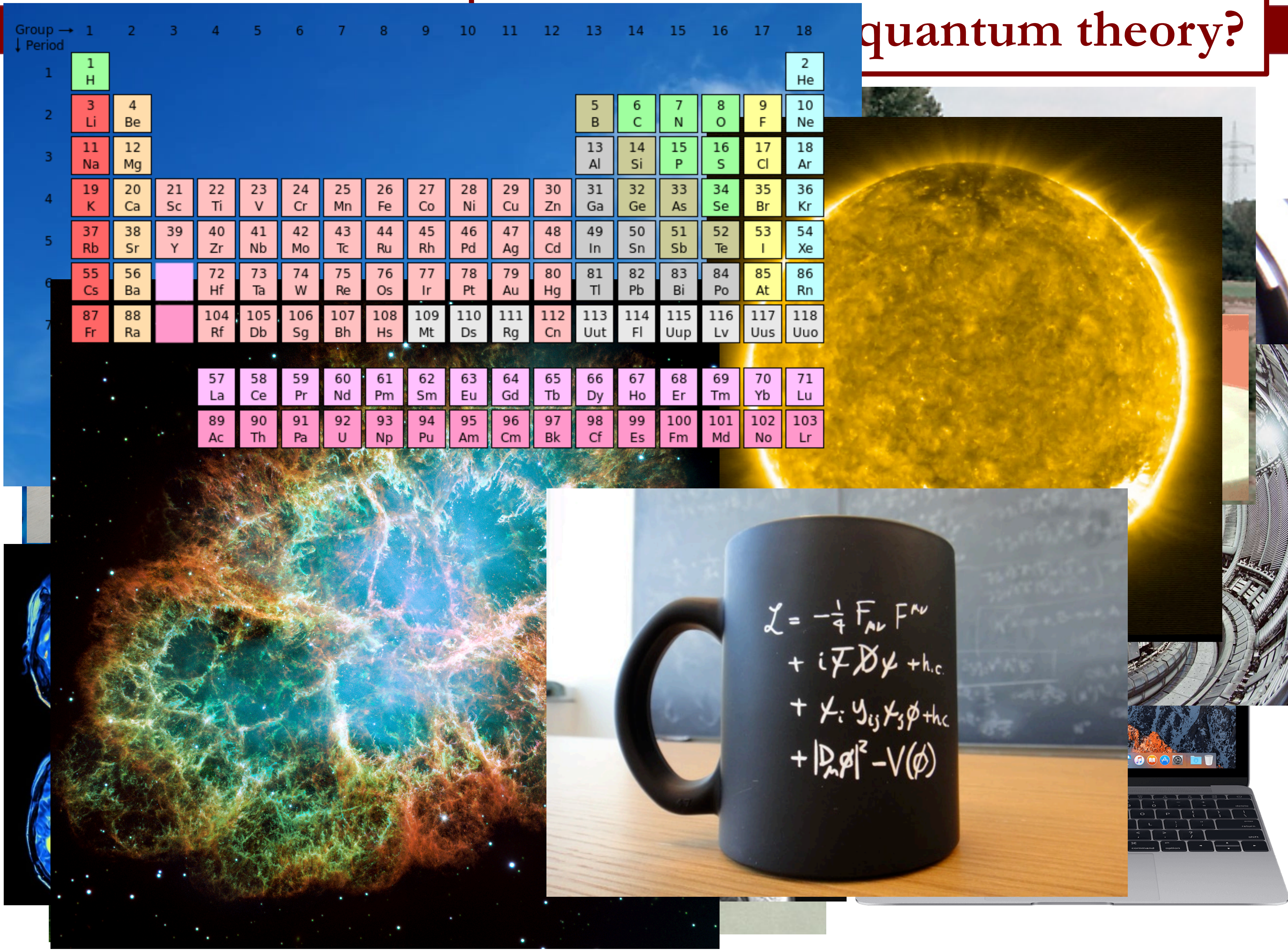

What's up with quantum theory?

David Mermin
2012

Časlav Brukner
2020

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Yet today, nearly 90 years after its formulation, disagreement about the meaning of the theory is stronger than ever.

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Quantum mechanics: Fixing the shifty split (2012)

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Quantum mechanics: Fixing the shifty split (2012)

Can this be believed? It's as if reality... didn't exist...

Časlav Brukner
2020

C. Rovelli, Helgoland (2020)

What's up with quantum theory?

A Fraction of the Quantum Foundations Meetings since 1972

1972	The Development of the Physicist's Conception of Nature, Trieste, Italy
1973	Foundations of Quantum Mechanics and Ordered Linear Spaces, Marbourg, Germany
1974	Quantum Mechanics, a Half Century Later, Strasbourg, Germany
1975	Foundational Problems in the Special Sciences, London, Canada
1976	International Symposium on Fifty Years of the Schrödinger Equation, Vienna, Austria
1977	International School of Physics "Enrico Fermi", Course LXXII: Problems in the Foundations of Physics, Varenna, Italy
1978	Stanford Seminar on the Foundations of Quantum Mechanics, Stanford, USA
1979	Interpretations and Foundations of Quantum Theory, Marburg, Germany
1980	Quantum Theory and the Structures of Time and Space, Tutzing, Germany
1981	NATO Advanced Study Institute on Quantum Optics, Experimental Gravitation, and Measurement Theory, Bad Windsheim, Germany
1982	The Wave-Particle Dualism: a Tribute to Louis de Broglie, Perugia, Italy
1983	Foundations of Quantum Mechanics in the Light of New Technology, Tokyo, Japan
1984	Fundamental Questions in Quantum Mechanics, Albany, New York
1985	Symposium on the Foundations of Modern Physics: 50 Years of the Einstein-Podolsky-Rosen Gedankenexperiment, Joensuu, Finland
1986	New Techniques and Ideas in Quantum Measurement Theory, New York, USA
1987	Symposium on the Foundations of Modern Physics 1987: The Copenhagen Interpretation 60 Years after the Como Lecture, Joensuu, Finland
1988	Bell's Theorem, Quantum Theory, and Conceptions of the Universe, Washington, DC, USA
1989	Sixty-two Years of Uncertainty: Historical, Philosophical and Physical Inquiries into the Foundations of Quantum Mechanics, Erice, Italy
1990	Symposium on the Foundations of Modern Physics 1990: Quantum Theory of Measurement and Related Philosophical Problems, Joensuu, Finland
1991	Bell's Theorem and the Foundations of Modern Physics, Cesena, Italy
1992	Symposia on the Foundations of Modern Physics 1992: The Copenhagen Interpretation and Wolfgang Pauli, Helsinki, Finland
1993	International Symposium on Fundamental Problems in Quantum Physics, Oviedo, Spain
1994	Fundamental Problems in Quantum Theory, Baltimore, USA
1995	The Dilemma of Einstein, Podolsky and Rosen, 60 Years Later, Haifa, Israel
1996	2nd International Symposium on Fundamental Problems in Quantum Physics, Oviedo, Spain
1997	Sixth UK Conference on Conceptual and Mathematical Foundations of Modern Physics, Hull, England
1998	Mysteries, Puzzles, and Paradoxes in Quantum Mechanics, Garda Lake, Italy
1999	2nd Workshop on Fundamental Problems in Quantum Theory, Baltimore, USA
2000	NATO Advanced Research Workshop on Decoherence and its Implications in Quantum Computation and Information Transfer, Mykonos, Greece
2001	Quantum Theory: Reconsideration of Foundations, Växjö, Sweden

C. Fuchs (2002) https://arxiv.org/abs/quant-ph/0205039

What's up with quantum theory?

A

Interpretation	Year published	Author(s)	Deterministic?	Ontic wave-function?	Unique history?	Hidden variables?	Collapsing wave-functions?	Observer role?	Local dynamics?	Counter-factually definite?	Extant universal wave-function?
Ensemble interpretation	1926	Max Born	Agnostic	No	Yes	Agnostic	No	No	No	No	No
Copenhagen interpretation	1927	Niels Bohr, Werner Heisenberg	No	No[a]	Yes	No	Yes[b]	Causal	Yes	No	No
de Broglie–Bohm theory	1927–1952	Louis de Broglie, David Bohm	Yes	Yes[c]	Yes[d]	Yes	Phenomenological	No	No	Yes	Yes
Quantum logic	1936	Garrett Birkhoff	Agnostic	Agnostic	Yes[e]	No	No	Interpretational[f]	Agnostic	No	No
Time-symmetric theories	1955	Satosi Watanabe	Yes	No	Yes	Yes	No	No	No[55]	No	Yes
Many-worlds interpretation	1957	Hugh Everett	Yes	Yes	No	No	No	No	Yes	Ill-posed	Yes
Consciousness causes collapse	1961–1993	John von Neumann, Eugene Wigner, Henry Stapp	No	Yes	Yes	No	Yes	Causal	No	No	Yes
Stochastic interpretation	1966	Edward Nelson	No	No	Yes	Yes[g]	No	No	No	Yes[g]	No
Many-minds interpretation	1970	H. Dieter Zeh	Yes	Yes	No	No	No	Interpretational[h]	Yes	Ill-posed	Yes
Consistent histories	1984	Robert B. Griffiths	No	No	No	No	No[i]	No	Yes	No	Yes
Transactional interpretation	1986	John G. Cramer	No	Yes	Yes	No	Yes[j]	No	No[k]	Yes	No
Objective collapse theories	1986–1989	Ghirardi–Rimini–Weber, Penrose interpretation	No	Yes	Yes	No	Yes	No	No	No	No
Relational interpretation	1994	Carlo Rovelli	No[56]	No	Agnostic[l]	No	Yes[m]	Intrinsic[n]	Yes[57]	No	No
QBism	2010	Christopher Fuchs, Ruediger Schack	No	No[o]	Agnostic[p]	No	Yes[q]	Intrinsic[r]	Yes	No	No

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In				Ontic wave-function?	Unique history?	Hidden variables?	Collapsing wave-functions?	Observer role?	Local dynamics?	Counterfactually definite?	Extant universal wave-function?
i				No	Yes	Agnostic	No	No	No	No	No
C i				No[a]	Yes	No	Yes[b]	Causal	Yes	No	No
E				Yes[c]	Yes[d]	Yes	Phenomenological	No	No	Yes	Yes
Q				Agnostic	Yes[e]	No	No	Interpretational[f]	Agnostic	No	No
sym				No	Yes	Yes	No	No	No[55]	No	Yes
M i				Yes	No	No	No	No	Yes	Ill-posed	Yes
C ca				Yes	Yes	No	Yes	Causal	No	No	Yes
Stochastic interpretation	1966	Edward Nelson	No	No	Yes	Yes[g]	No	No	No	Yes[g]	No
Many-minds interpretation	1970	H. Dieter Zeh	Yes	Yes	No	No	No	Interpretational[h]	Yes	Ill-posed	Yes
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Objective collaps... theories								No	No	No	No
Relational interpretation								Intrinsic[n]	Yes[57]	No	No
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What's up with quantum theory?

...interpretations_of_quantum_mechanics#Comparisons

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Two missions of science

Science offers two things:

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1. Control

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2. Understanding

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QM was a success on both counts, so what's all the fuss about?

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We'll take a fast-track route to the core of the problem.

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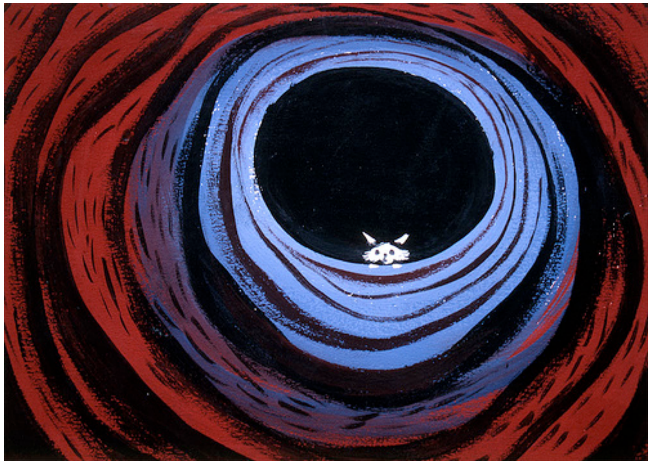
Plan

- What is quantum mechanics?
- The double slit experiment
- Electron Spin & qubits
- Entanglement



Mary Blair

QM is our theory of matter...

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- **Originally: the theory of the atom**

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- Then the nucleus, then chemistry

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What is Quantum Mechanics?

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… with uncomfortable features:

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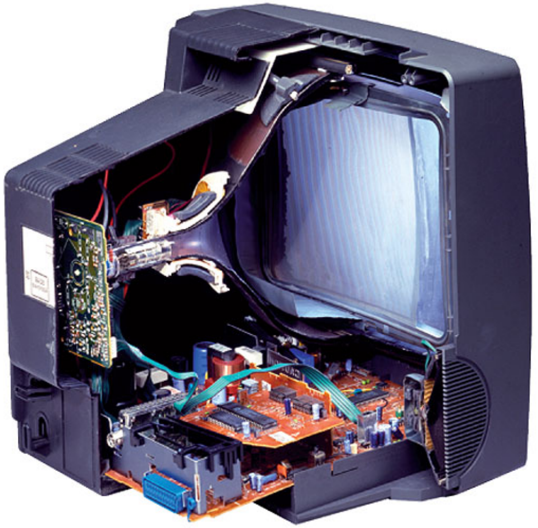
... with uncomfortable features:

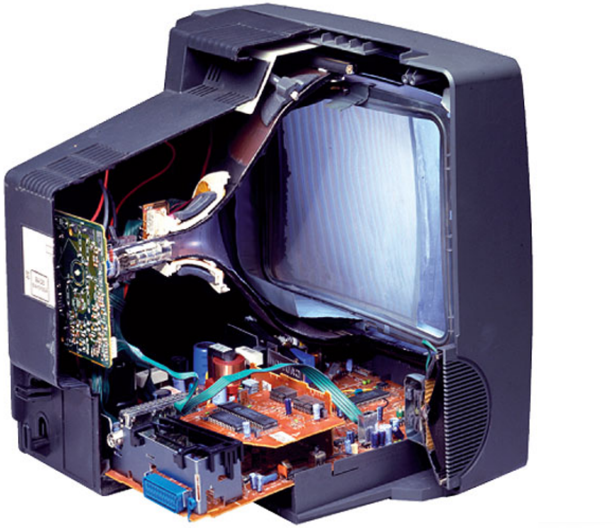
- Predicts only probabilities of the result of interactions
- A split: system / observer
- No intuitive picture of what happens between interactions

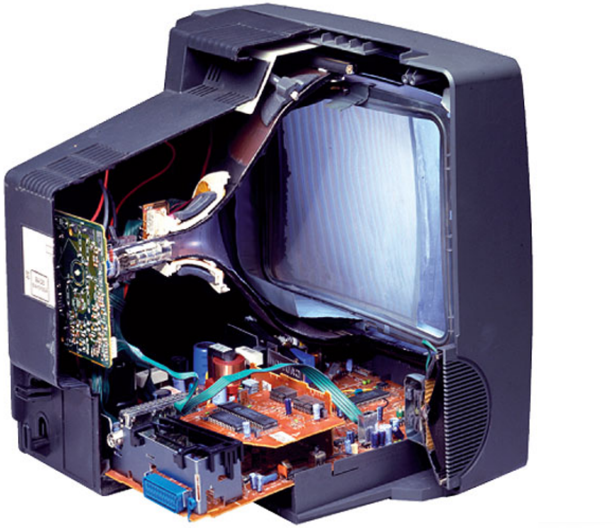
Electron

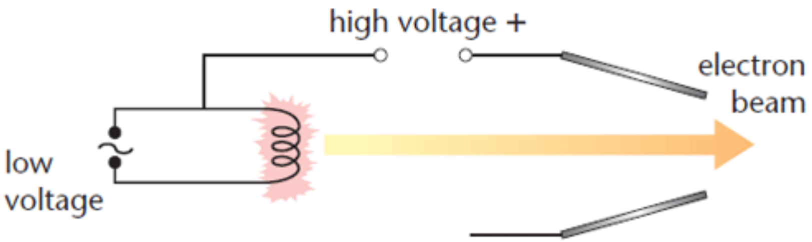
Electron



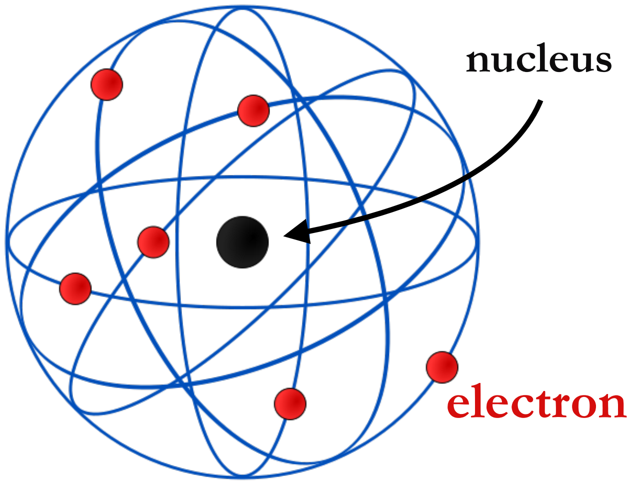
Electron

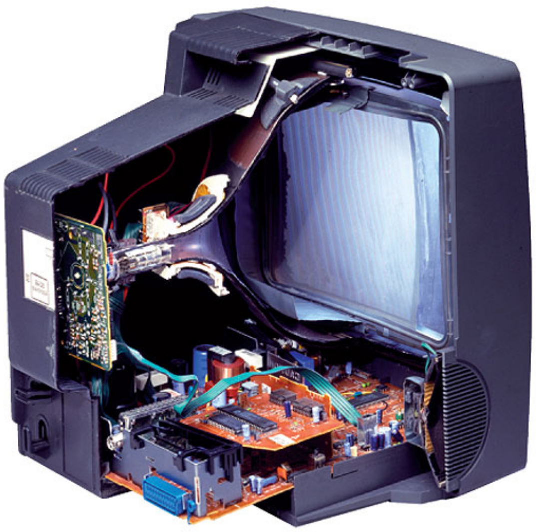


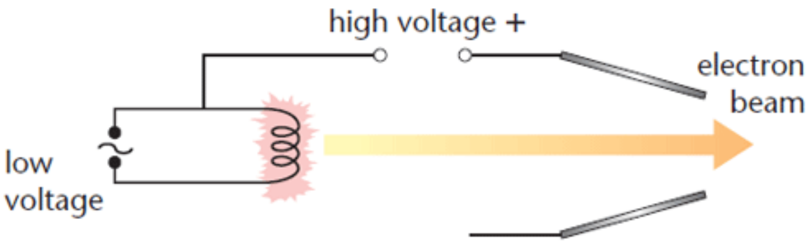




An electron gun

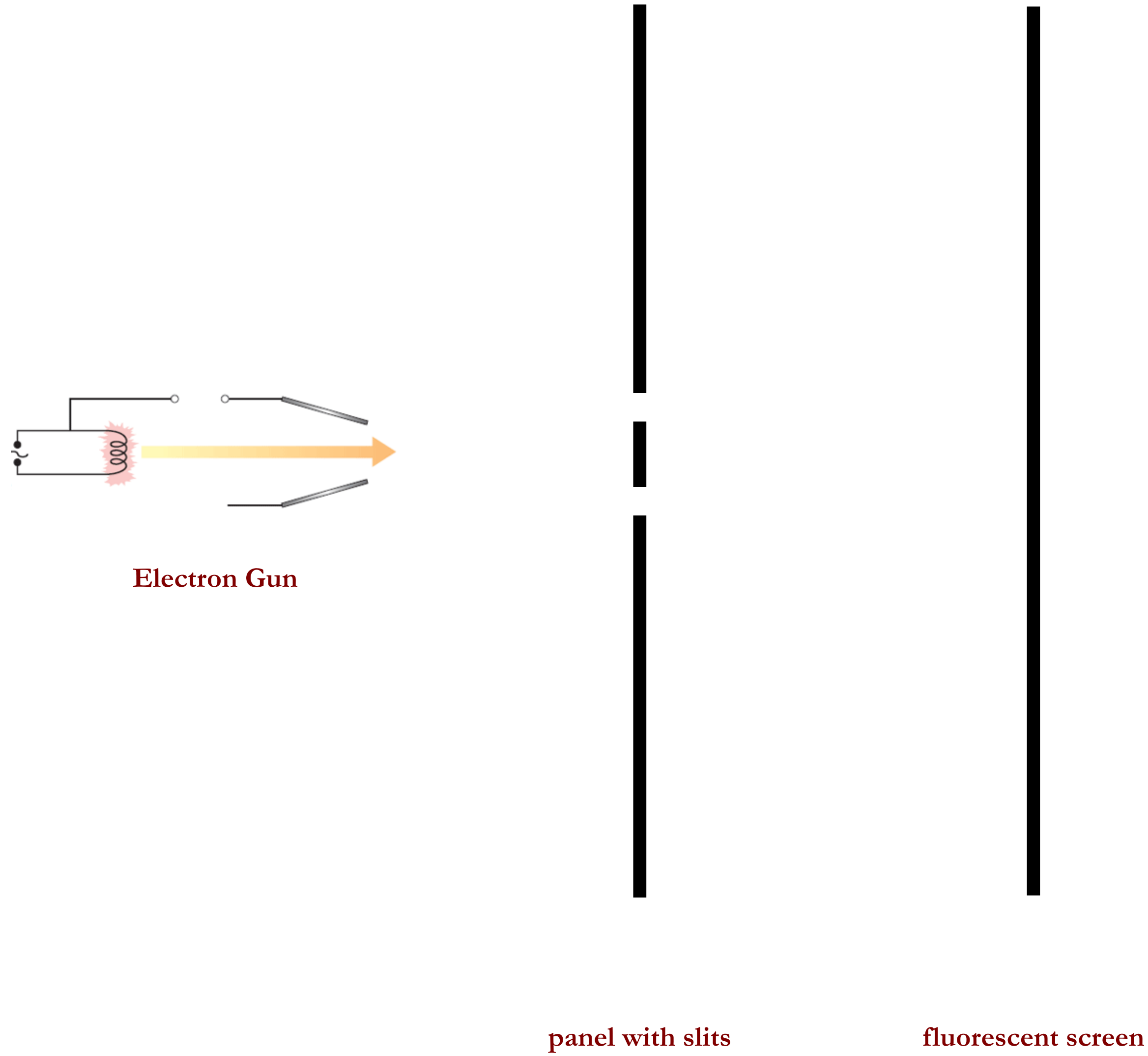




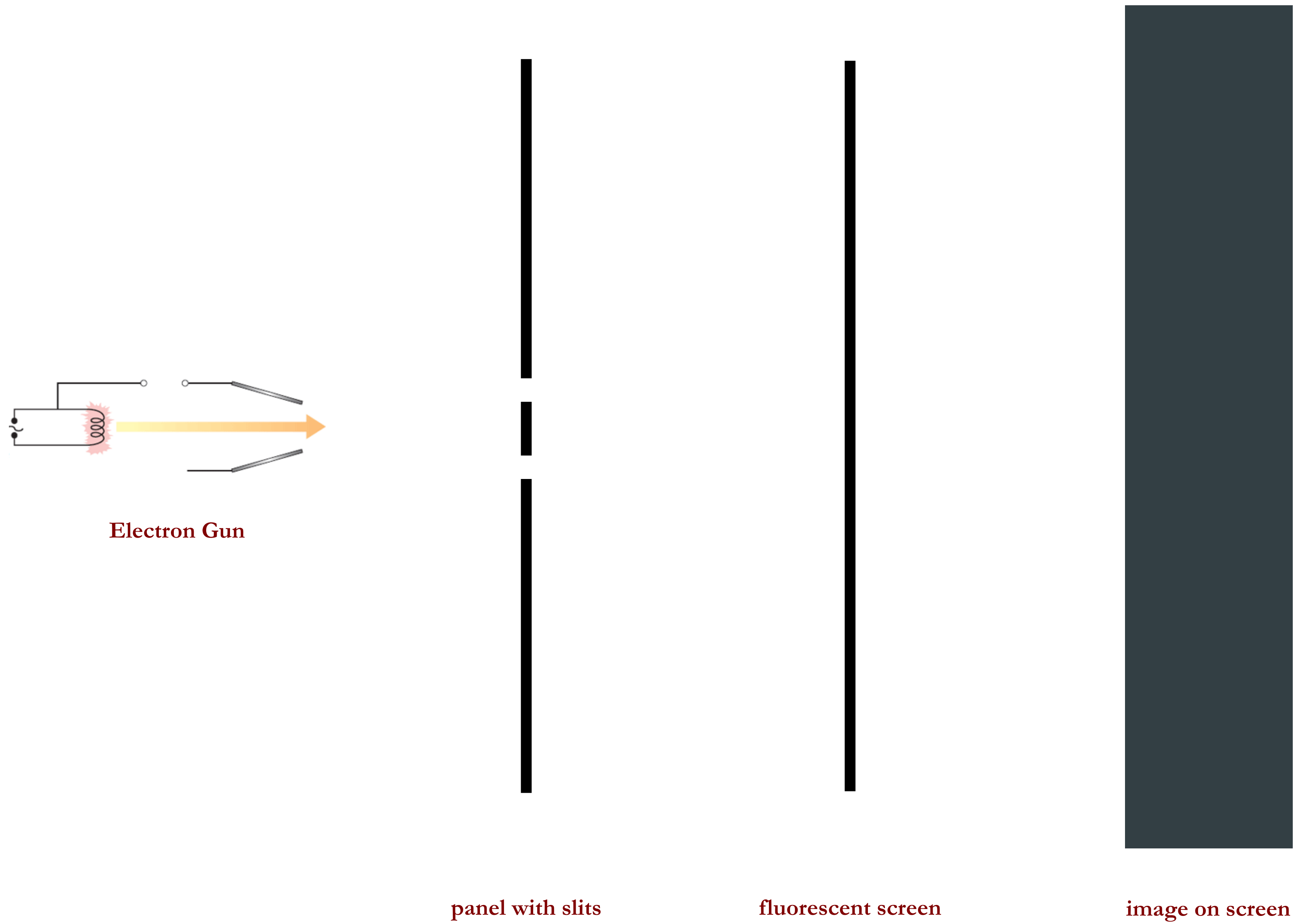


An electron gun

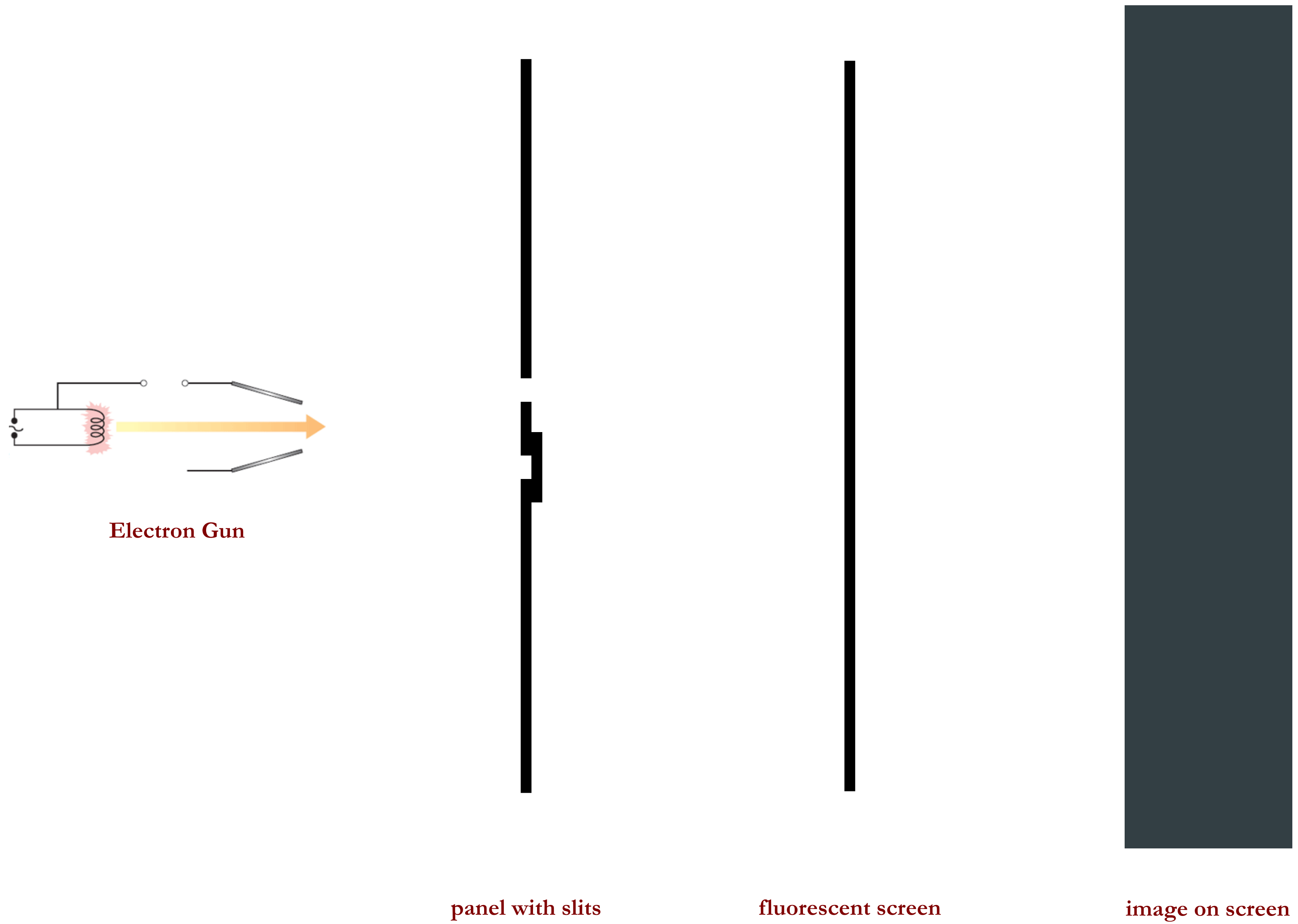
Double Slit Experiment



Double Slit Experiment



Double Slit Experiment



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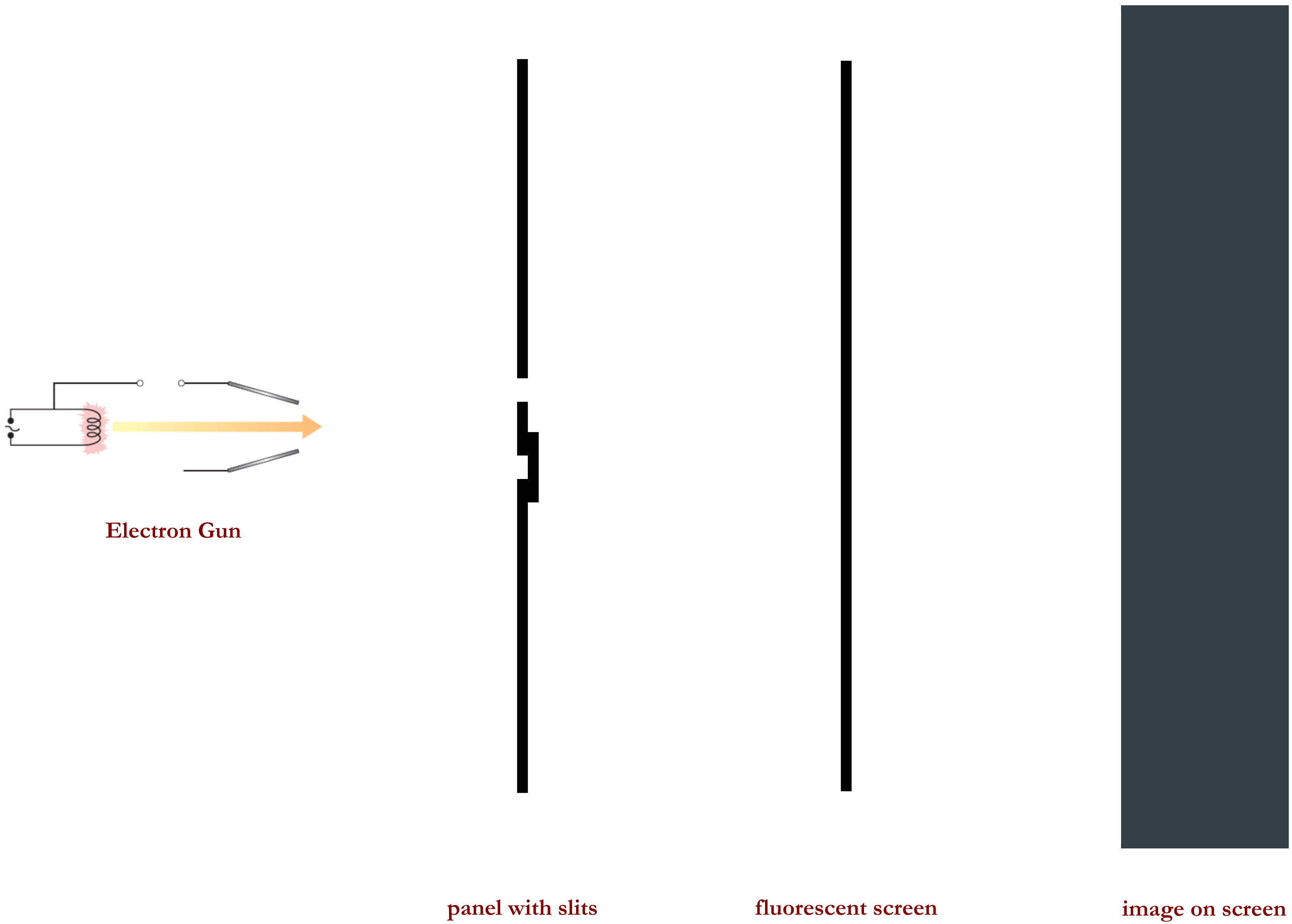

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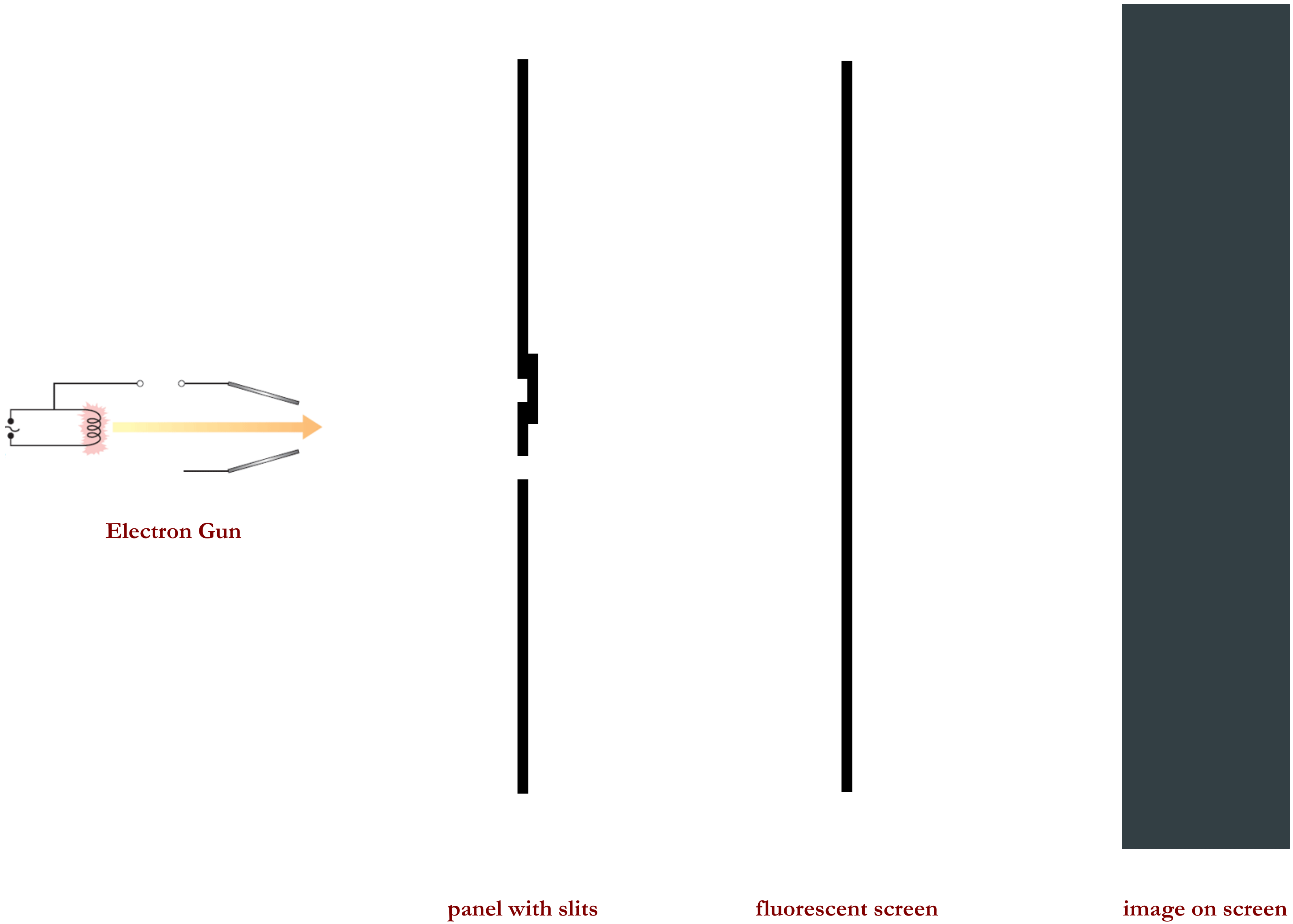

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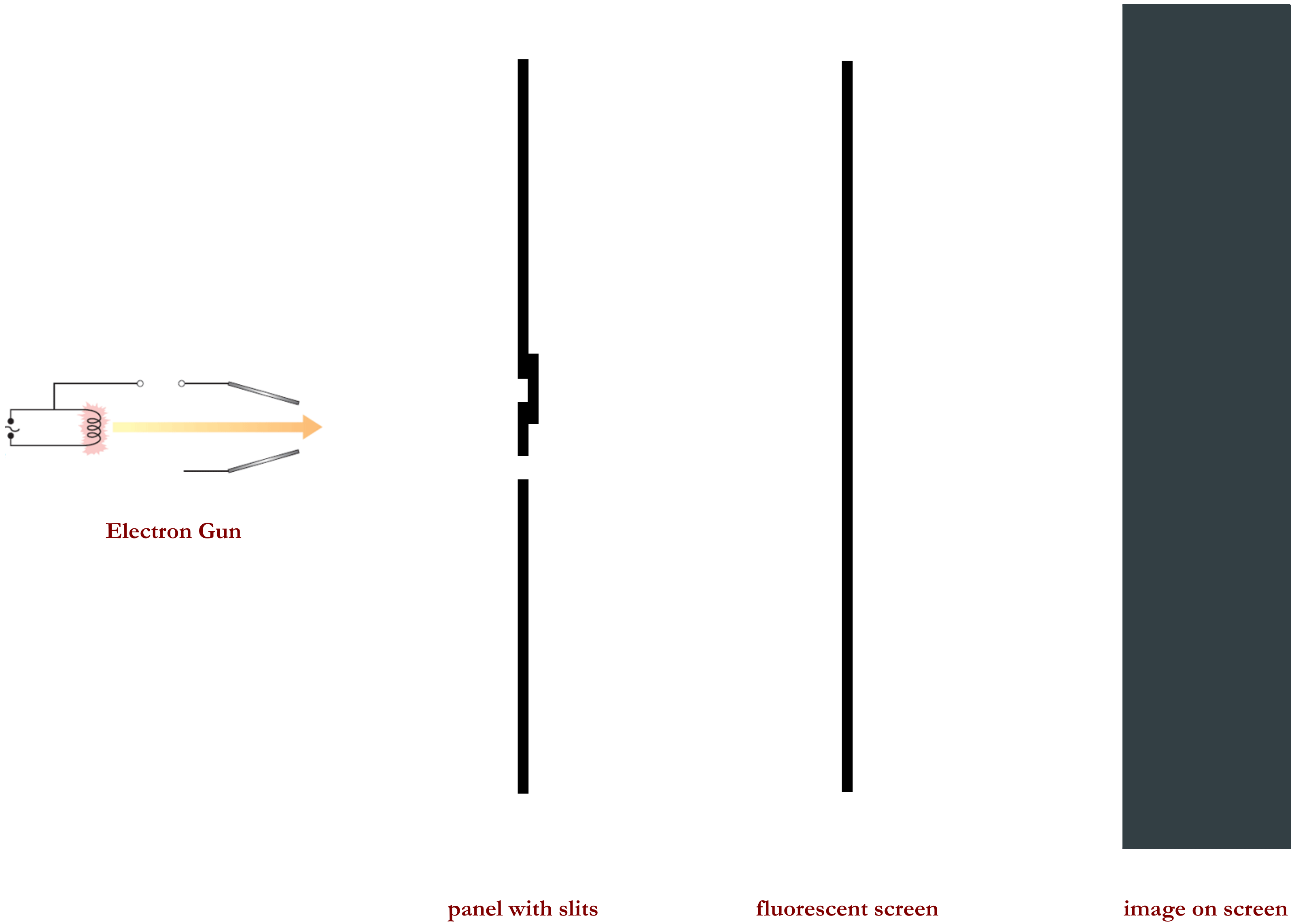

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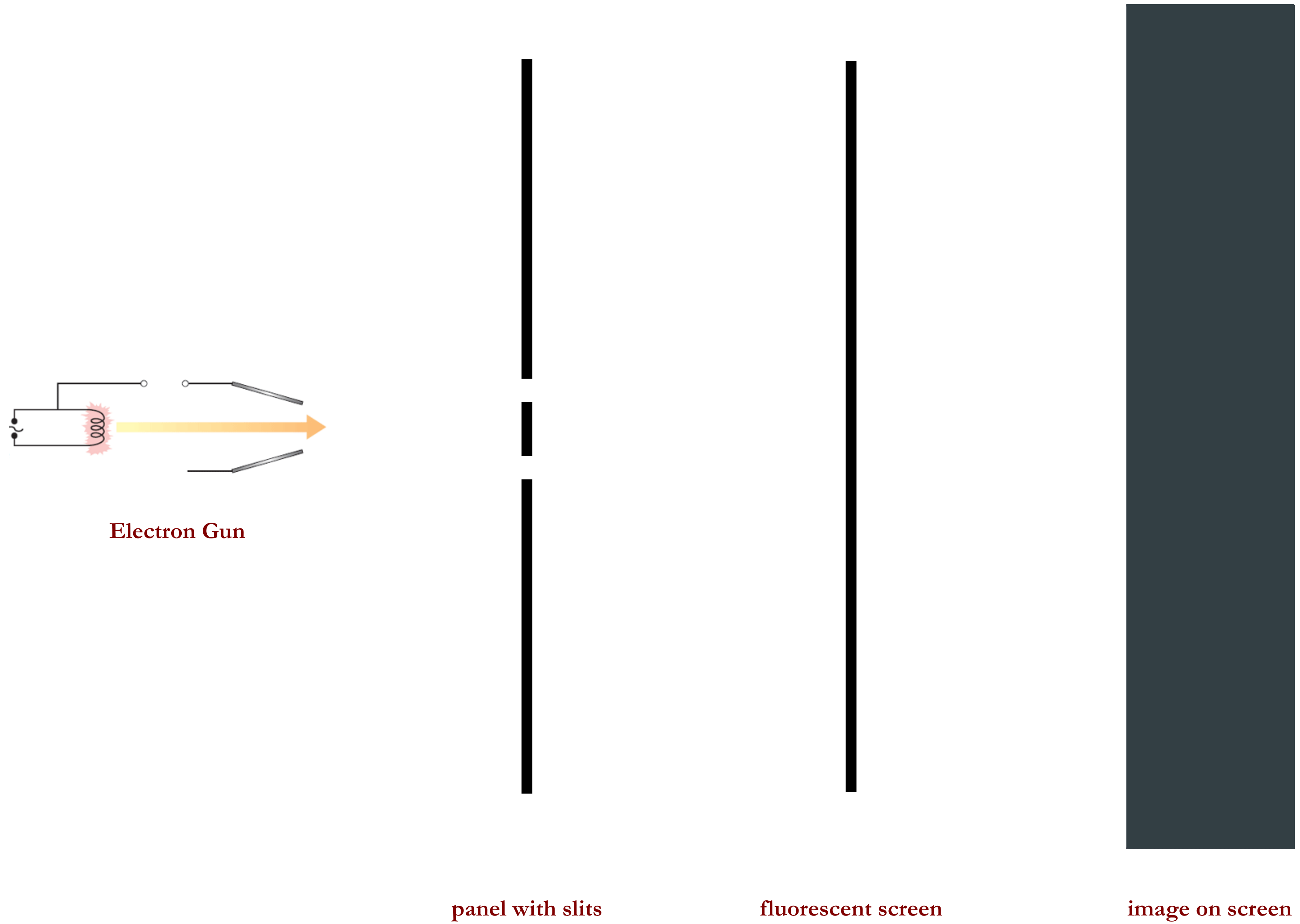

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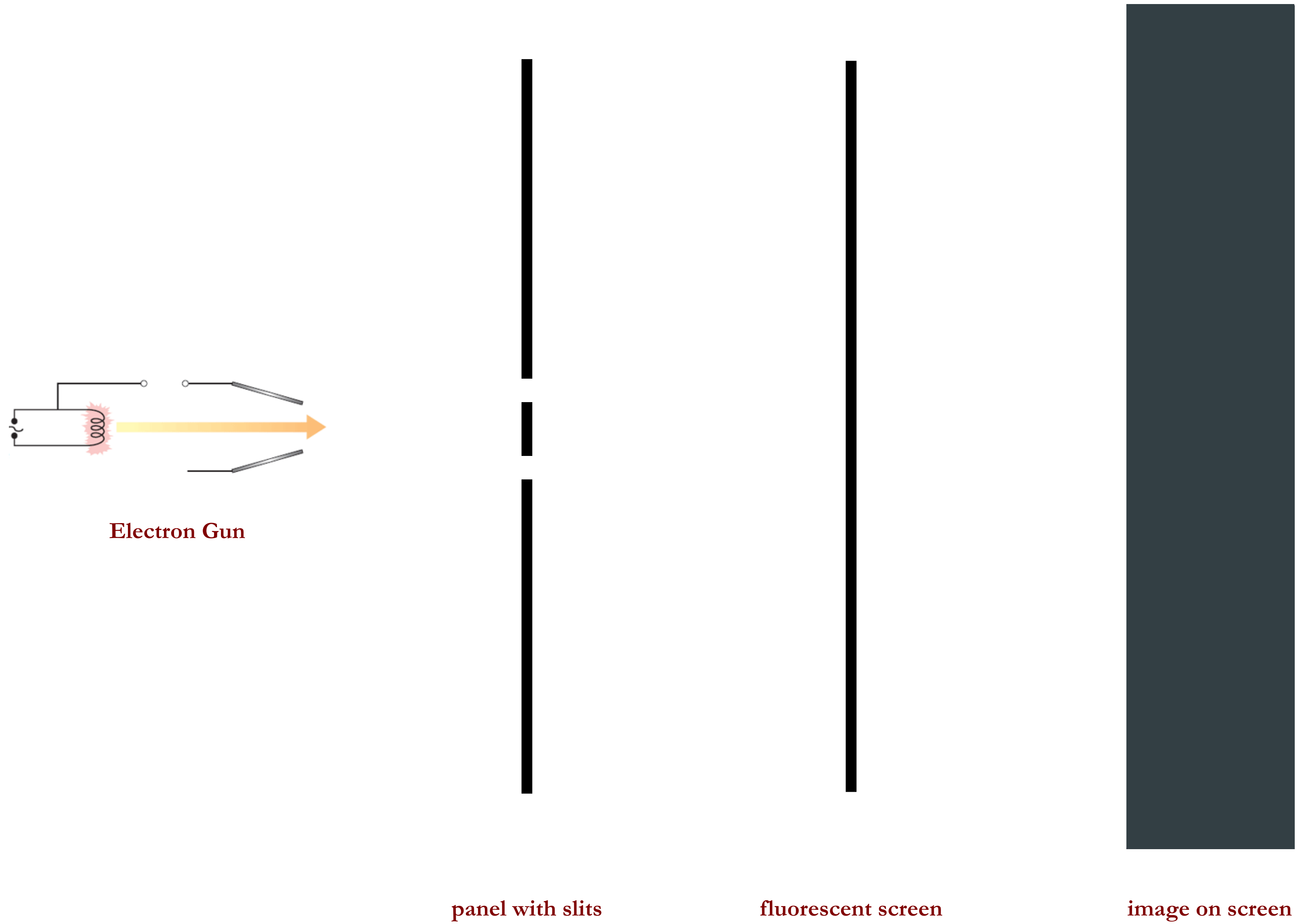

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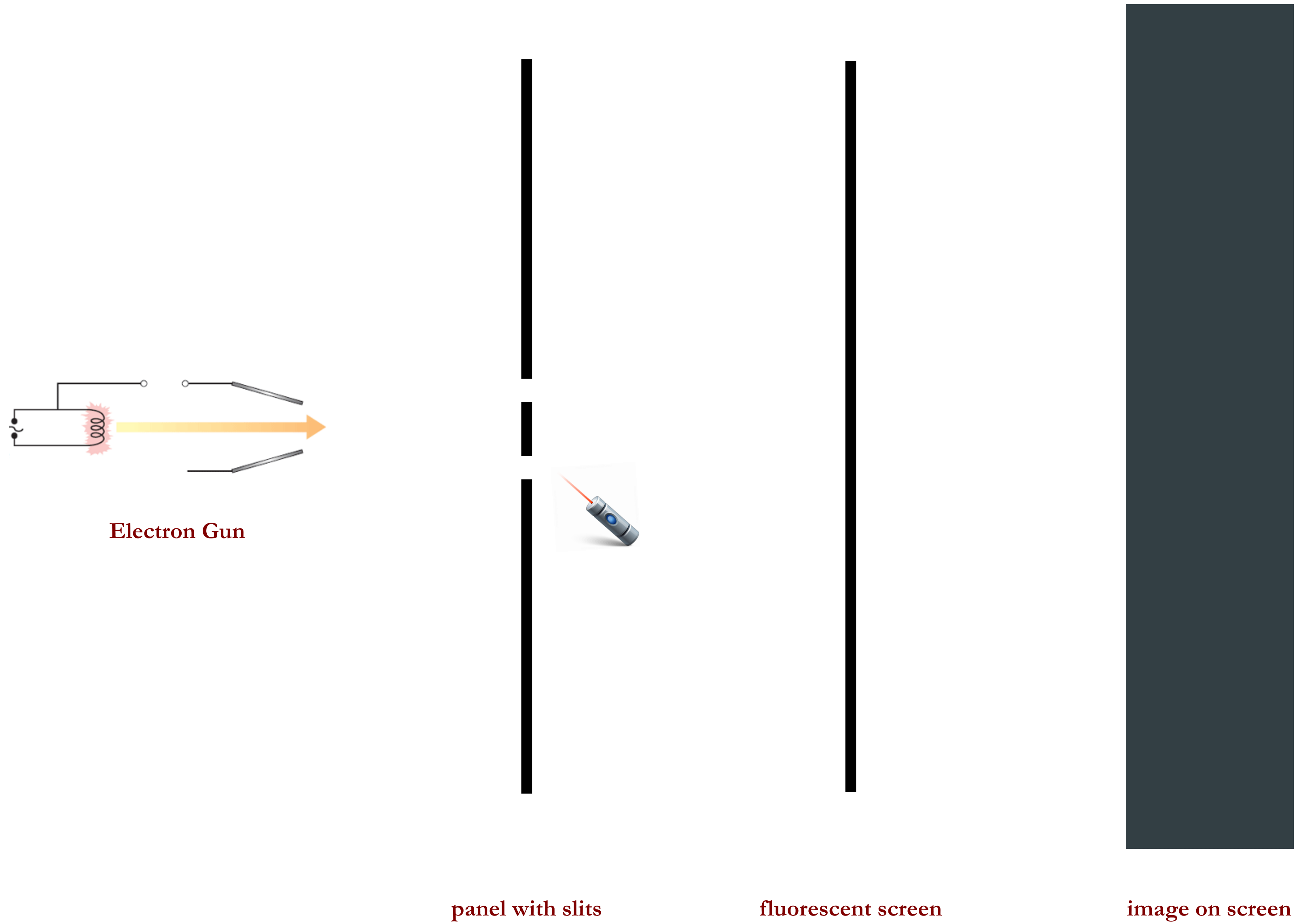

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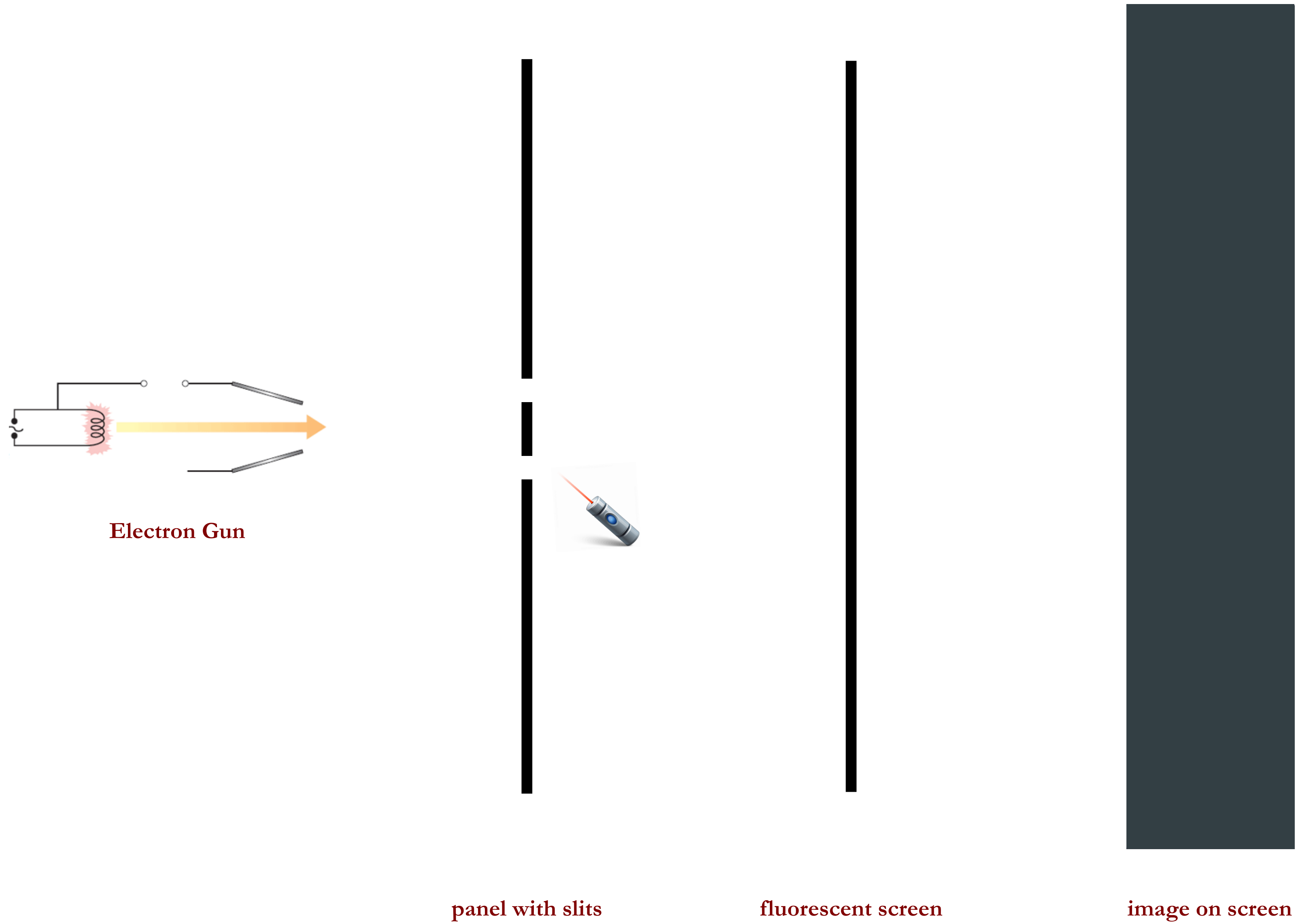

Double Slit Experiment

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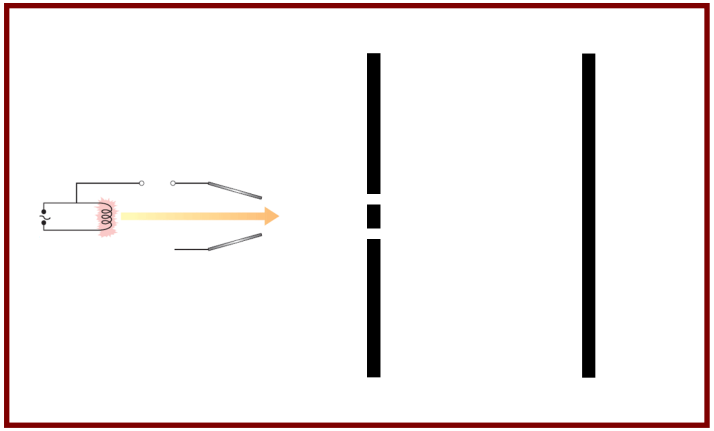

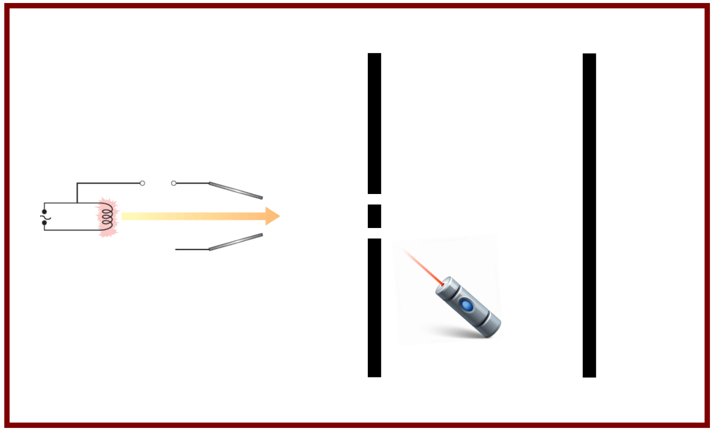

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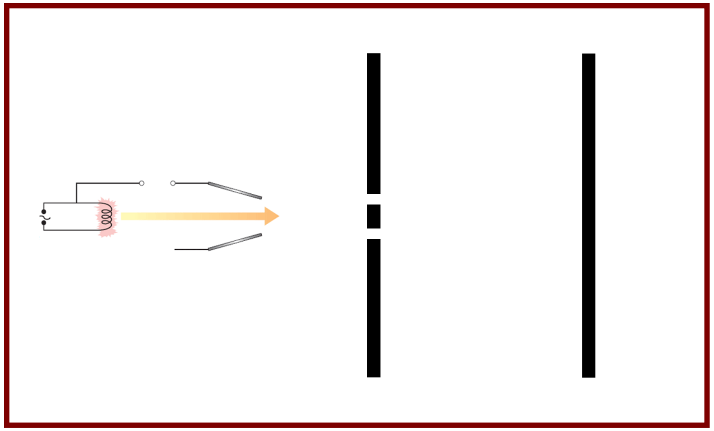

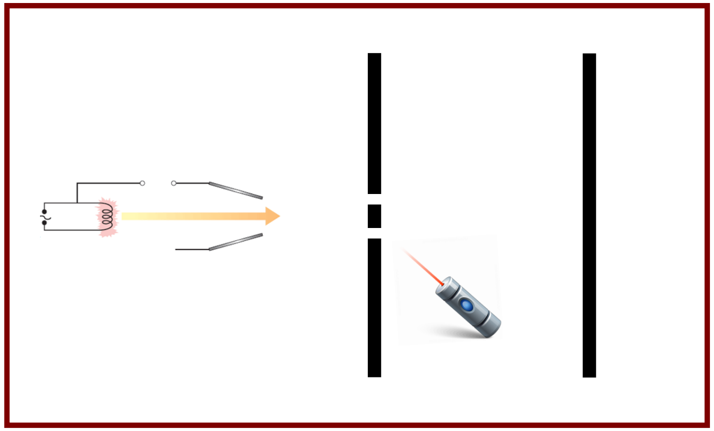

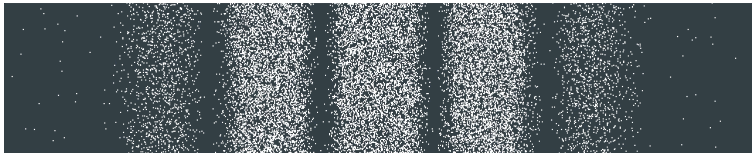

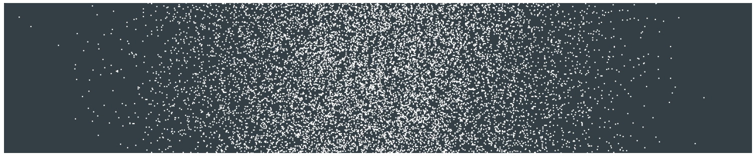

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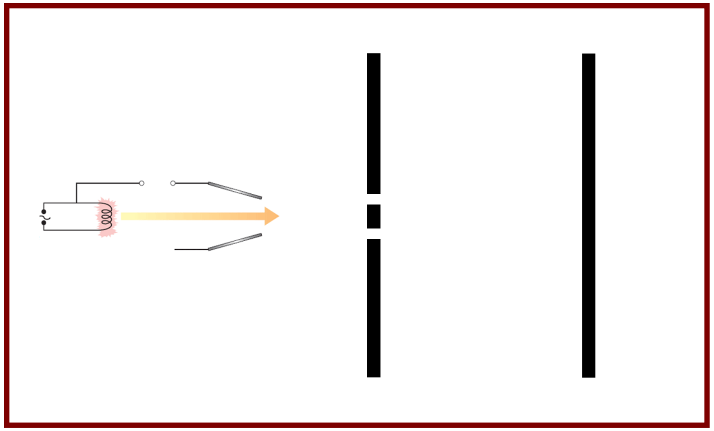

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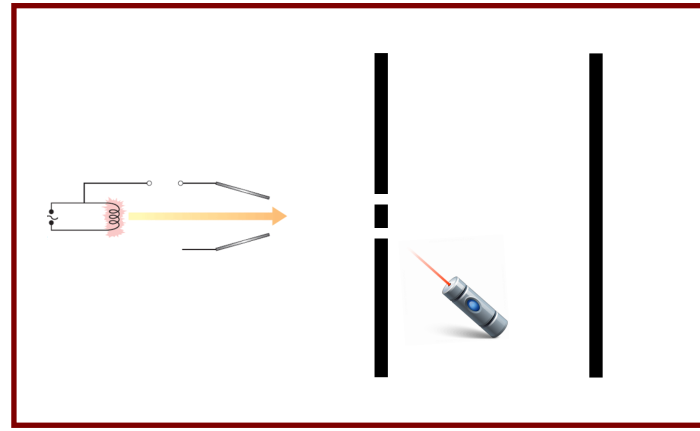

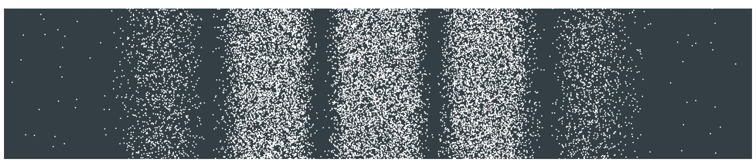

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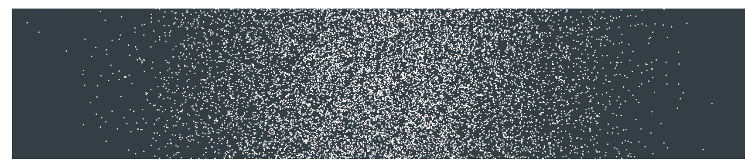

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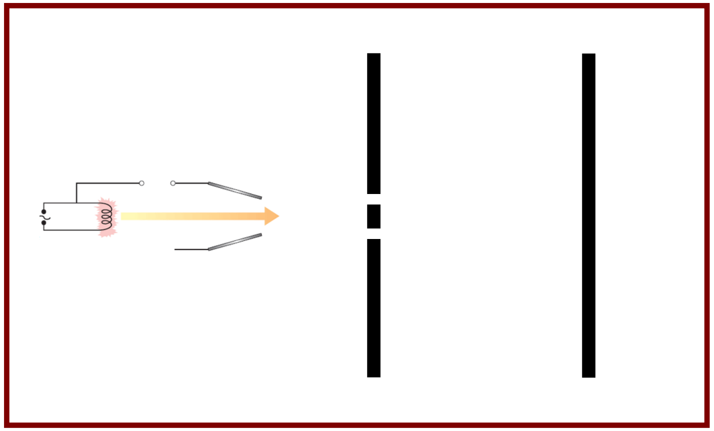

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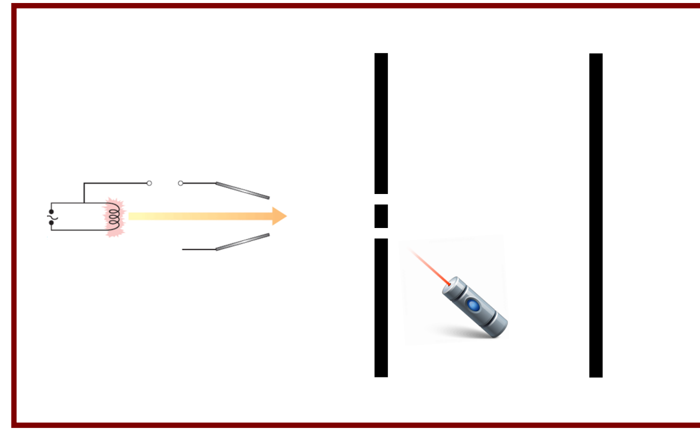

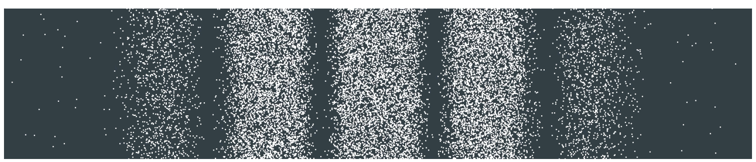

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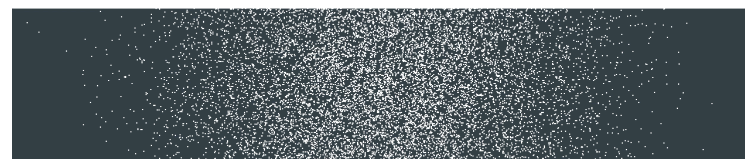
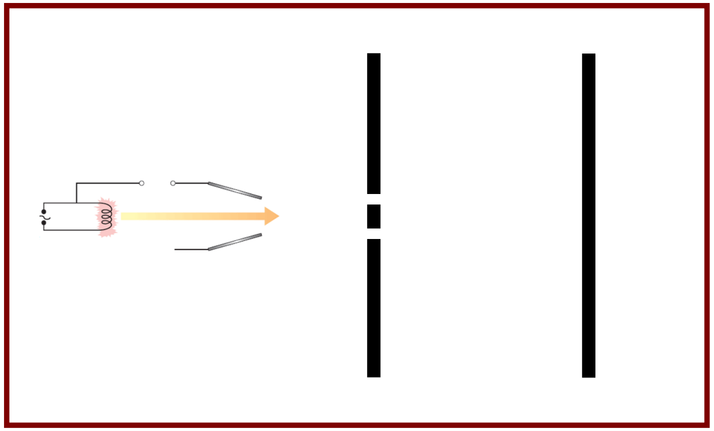


Ask different questions, get different answers.

Double Slit Experiment



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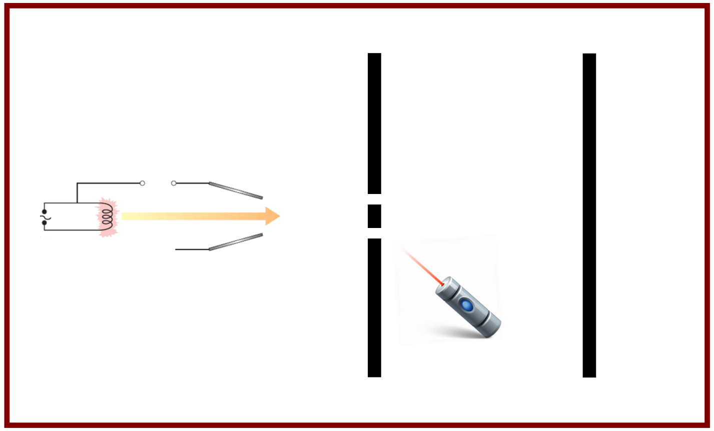

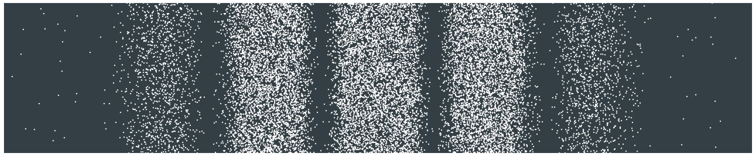

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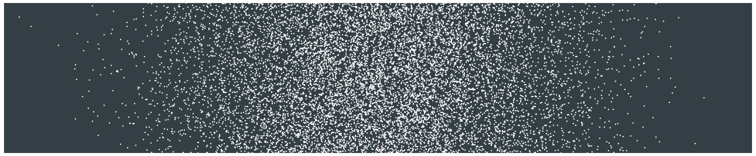

Ask different questions, get different answers.

Questions that aren't asked, don't have answers.

Double Slit Experiment

Demonstration of single-electron buildup of an interference pattern

American Journal of Physics **57**, 117 (1989); https://doi.org/10.1119/1.16104

A. Tonomura, J. Endo, T. Matsuda, *and* T. Kawasaki

- Advanced Research Laboratory, Hitachi, Ltd., Kokubunji, Tokyo 185, Japan

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- Department of Physics, Gakushuin University, Mejiro, Tokyo 171, Japan

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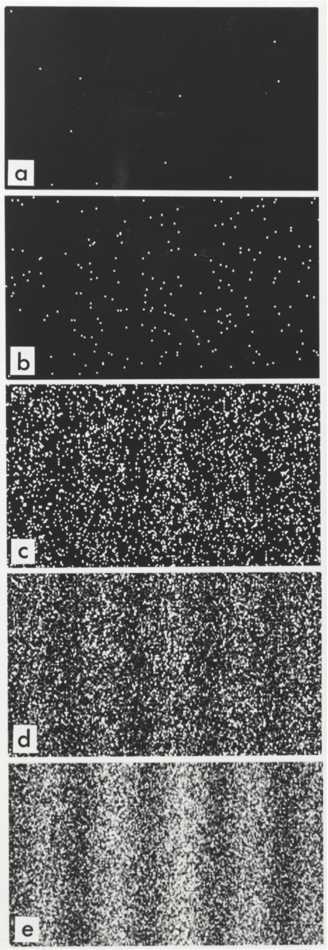

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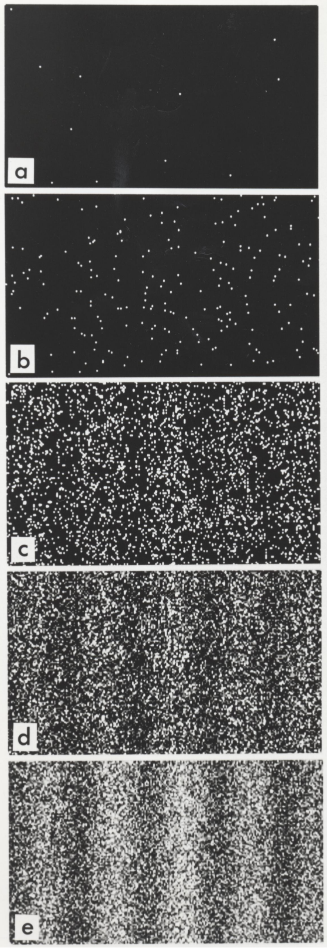

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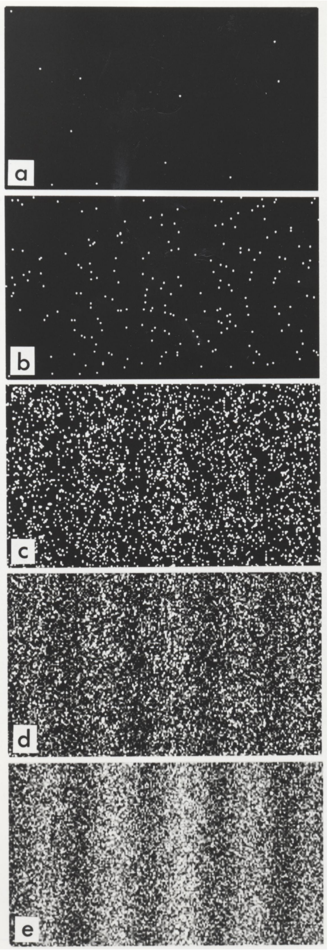

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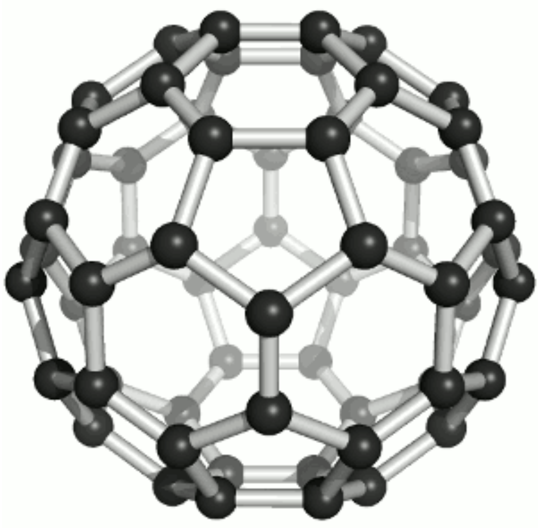
Wave–particle duality of C_{60} molecules

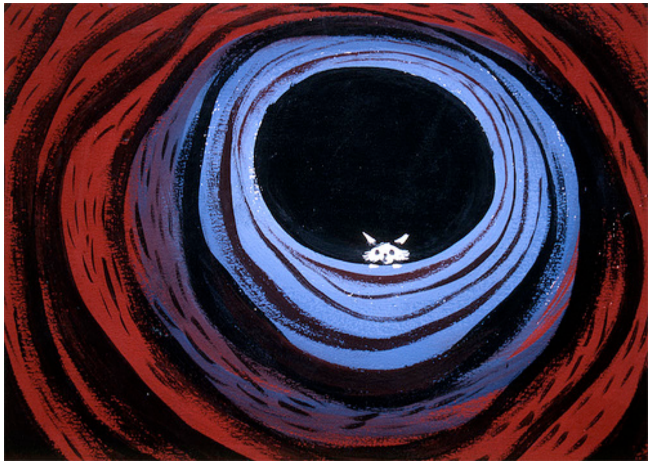
Markus Arndt, Olaf Nairz, Julian Vos-Andreae, Claudia Keller, Gerbrand van der Zouw & Anton Zeilinger

Nature **401**, 680–682(1999) | Cite this article



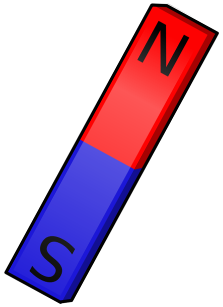
Plan

- What is quantum mechanics?
- The double slit experiment
- **Electron Spin & Qubits**
- Entanglement



Mary Blair

Electron Spin



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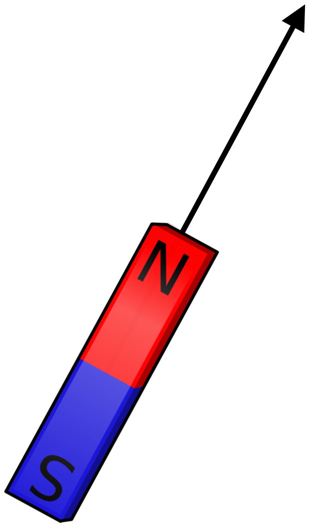

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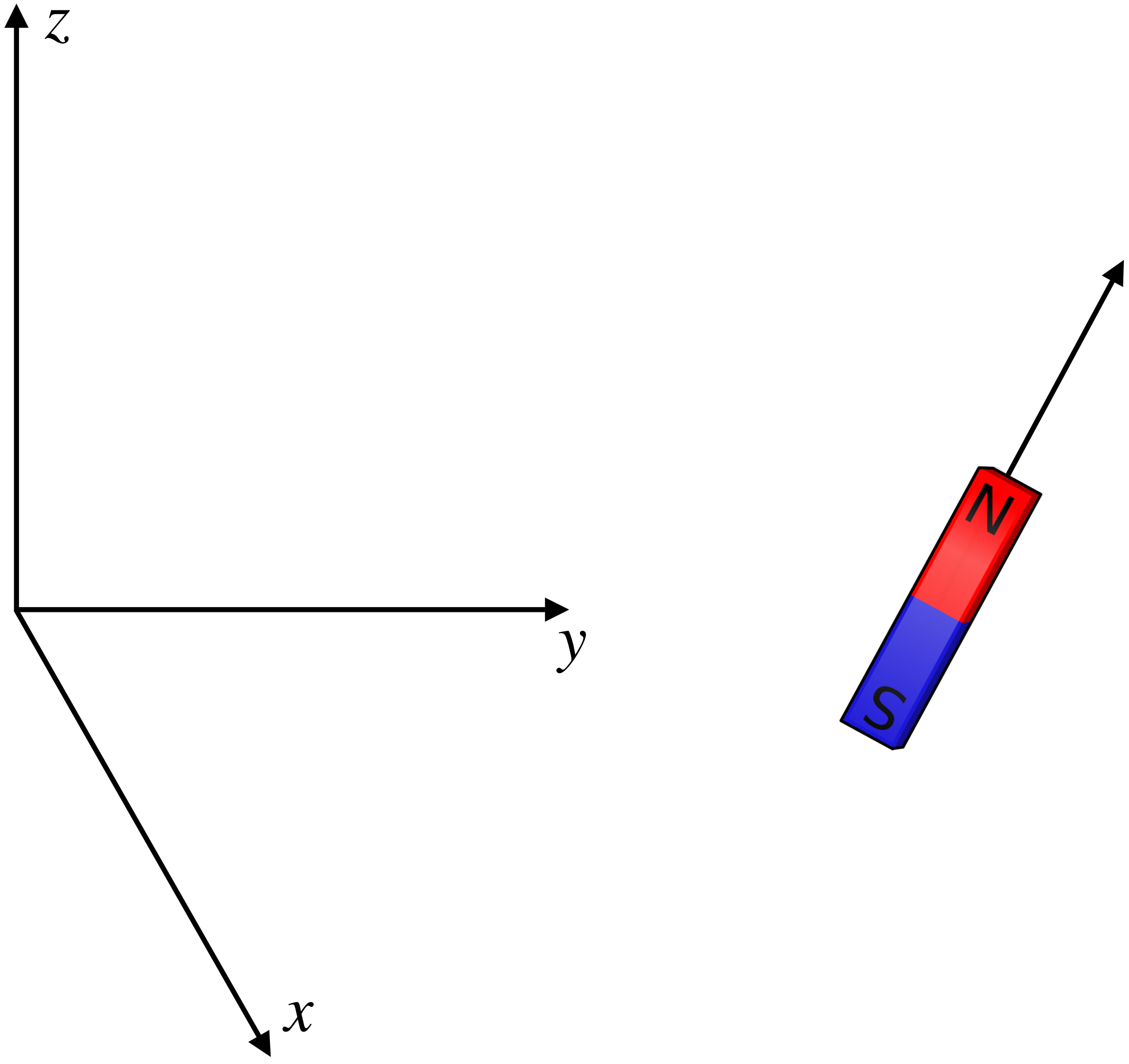
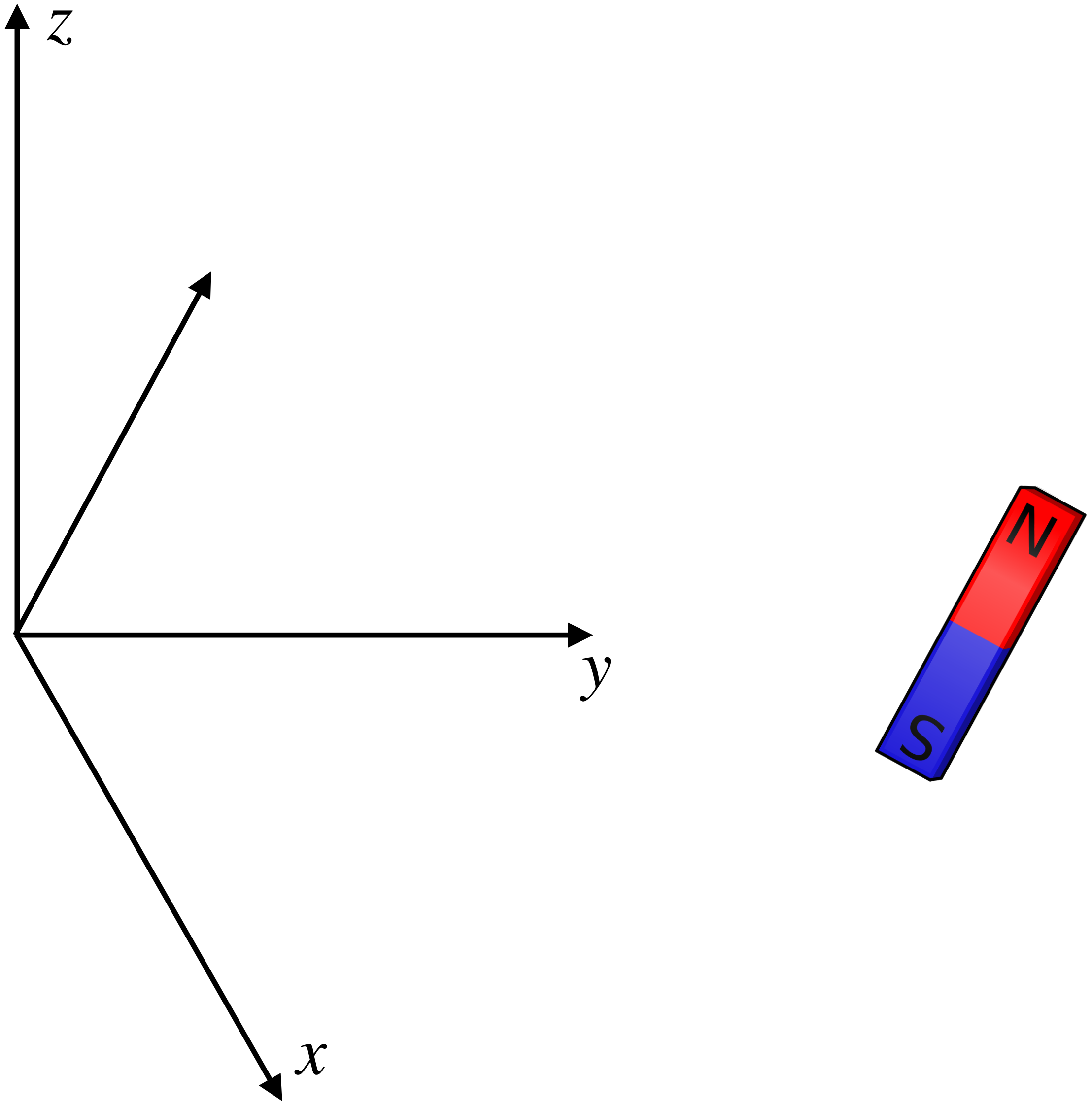
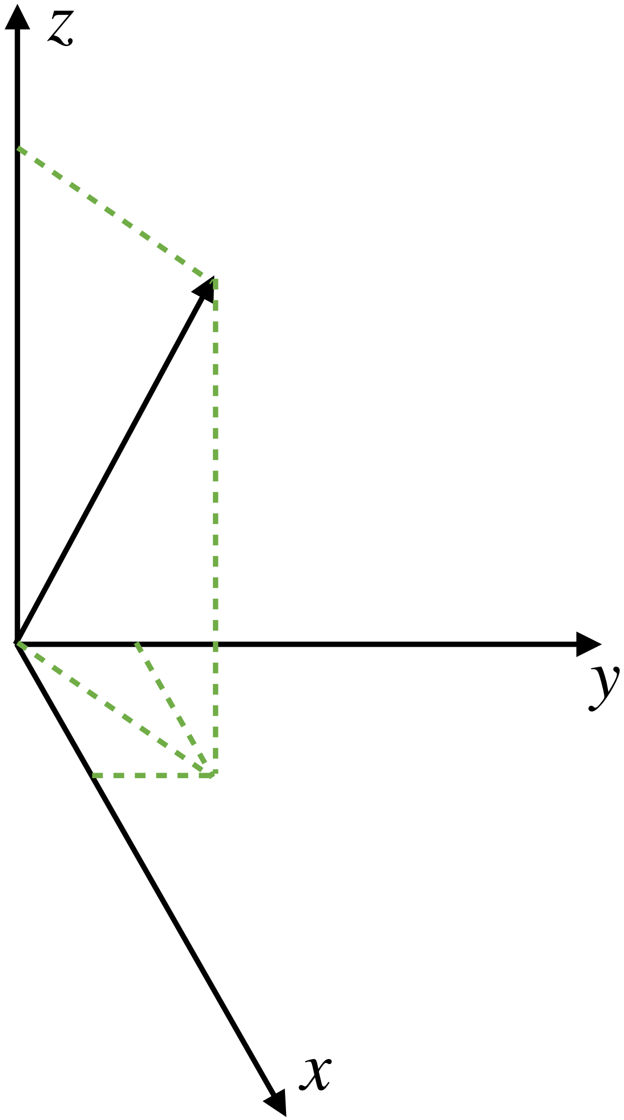
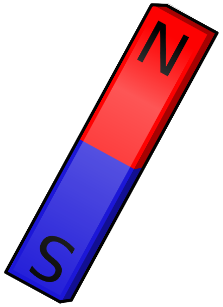
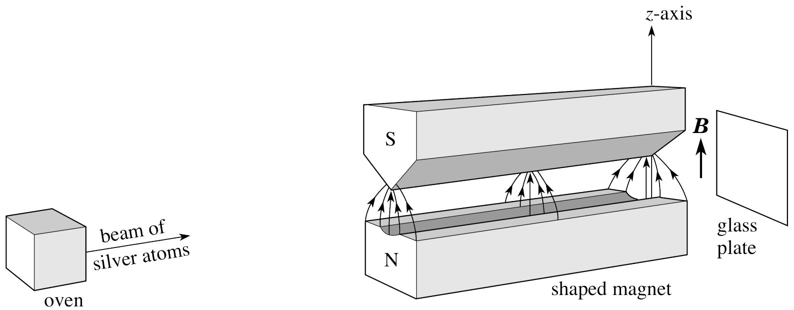


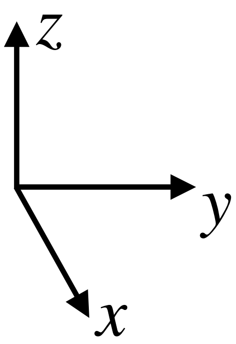
Electron Spin



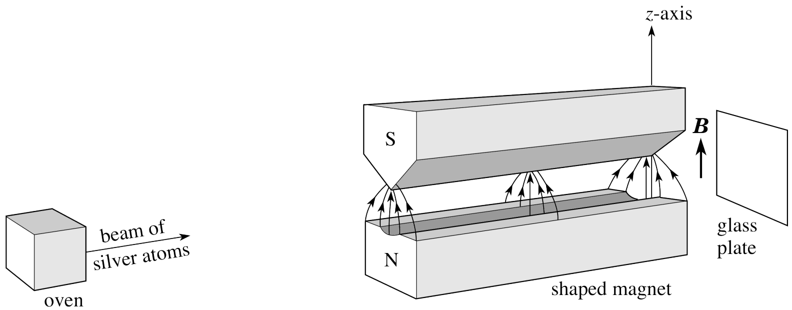

z
y
x

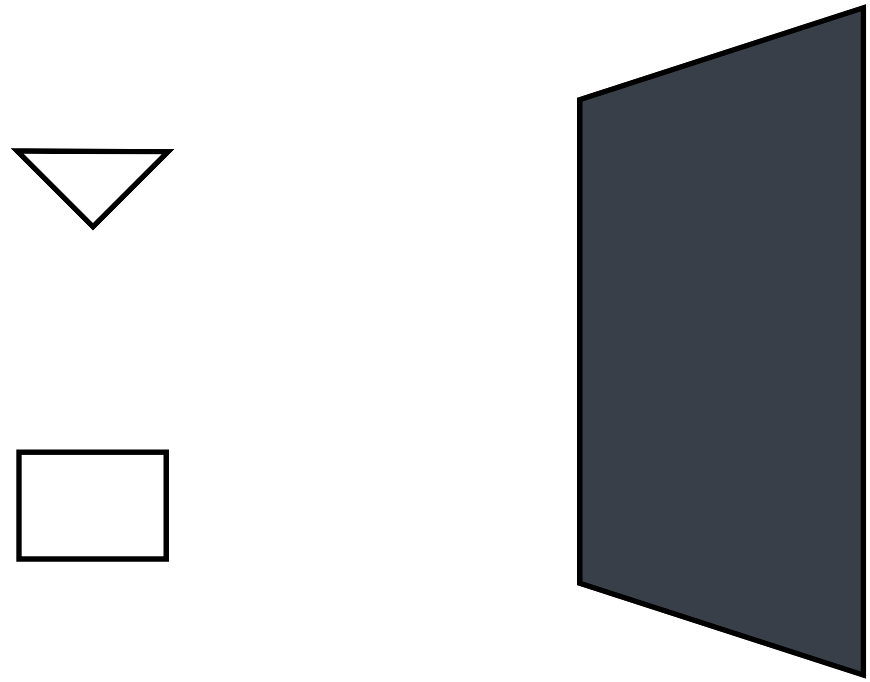

N
S

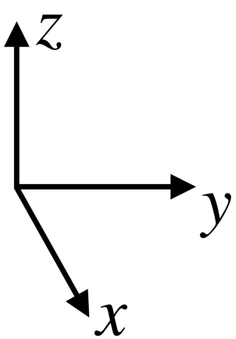

z-axis
S
N
B
beam of
silver atoms
oven
glass
plate
shaped magnet


z
y
x

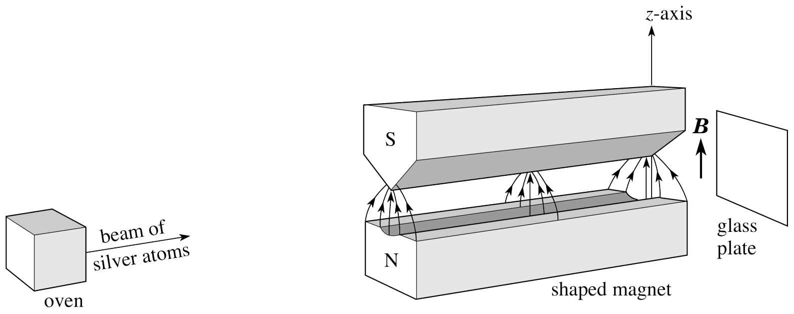
Electron Spin

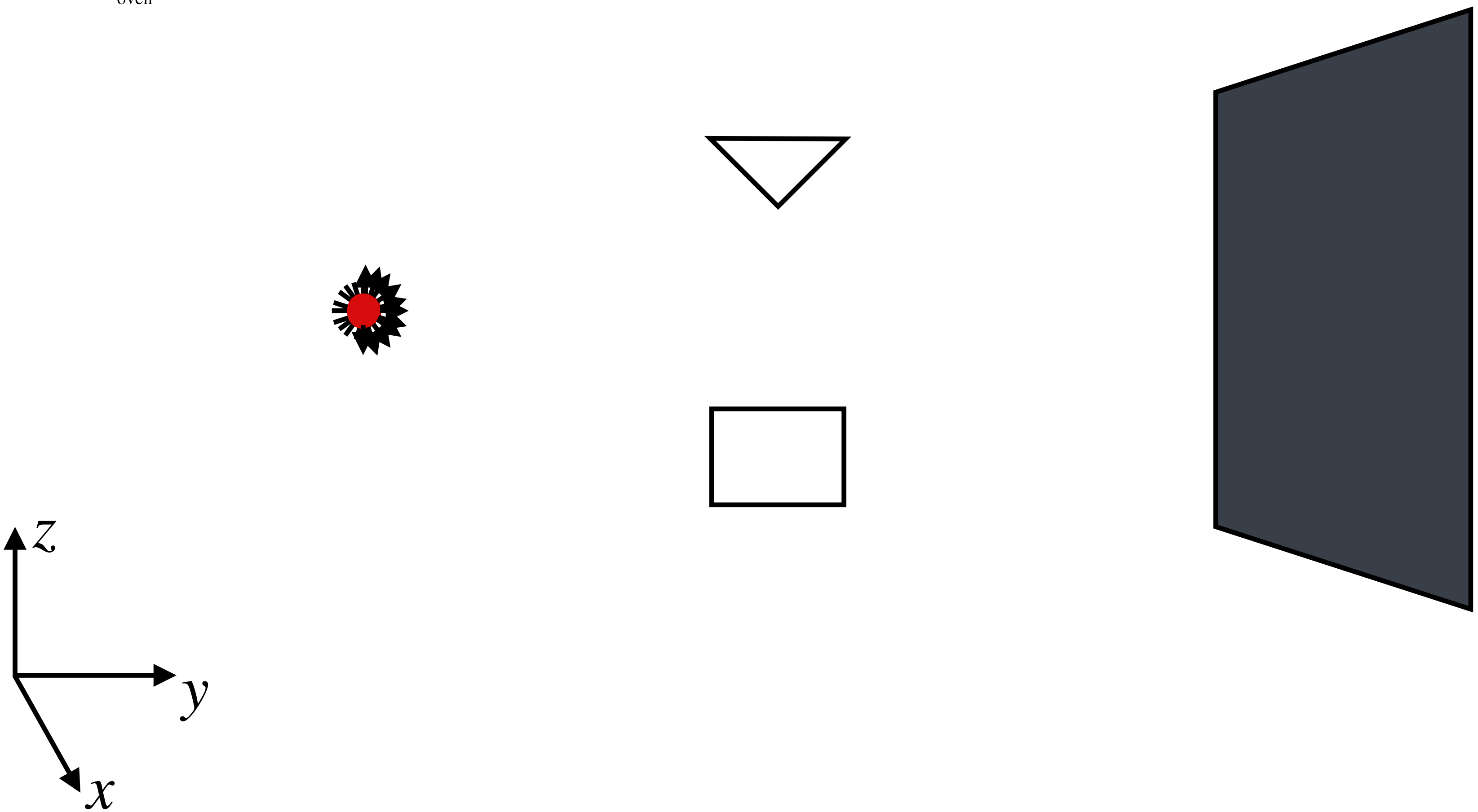






Electron Spin





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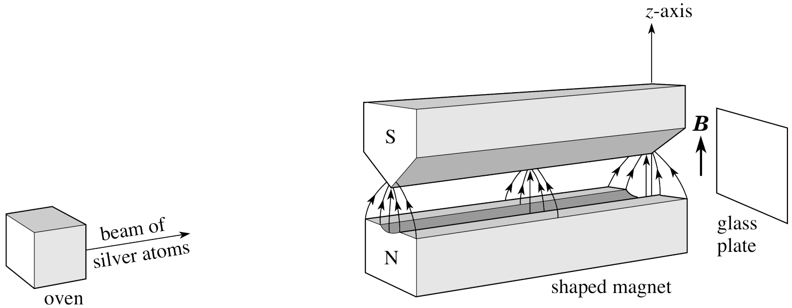

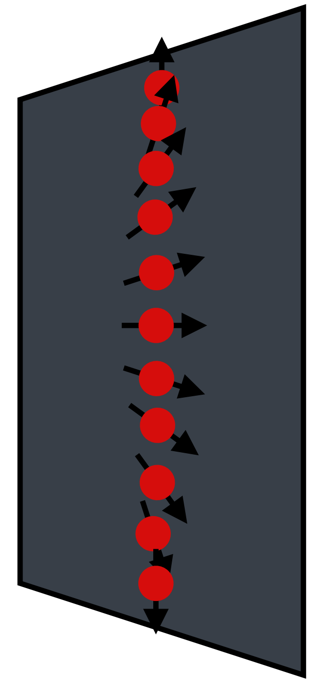

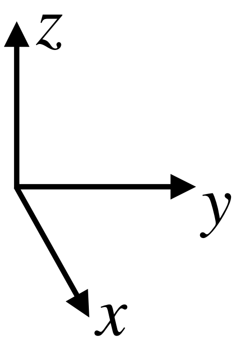

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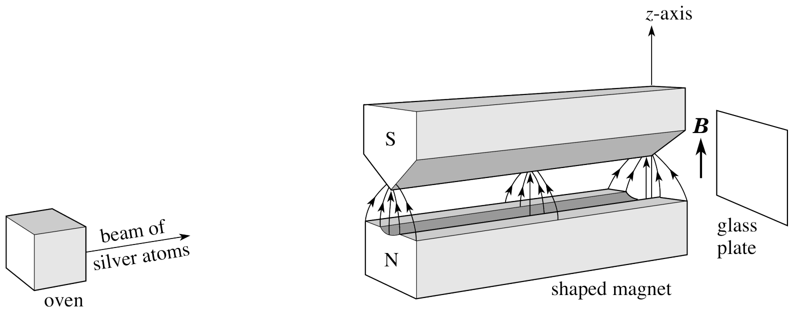
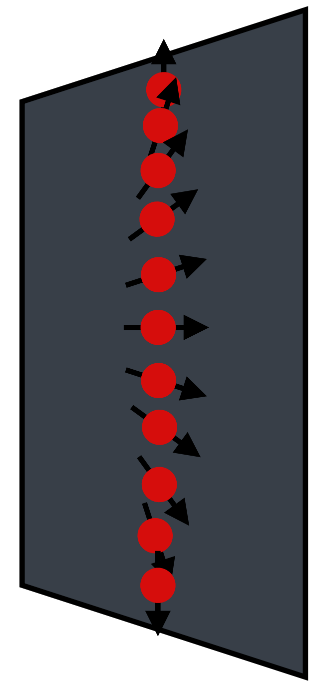
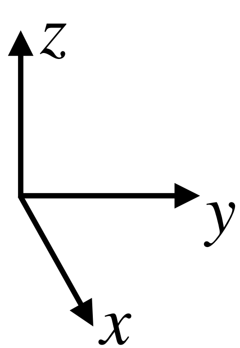
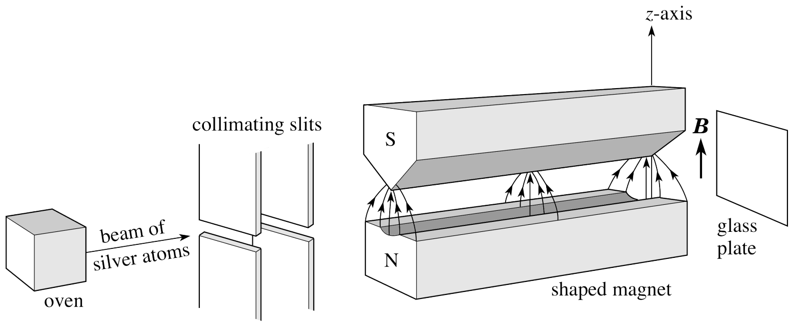


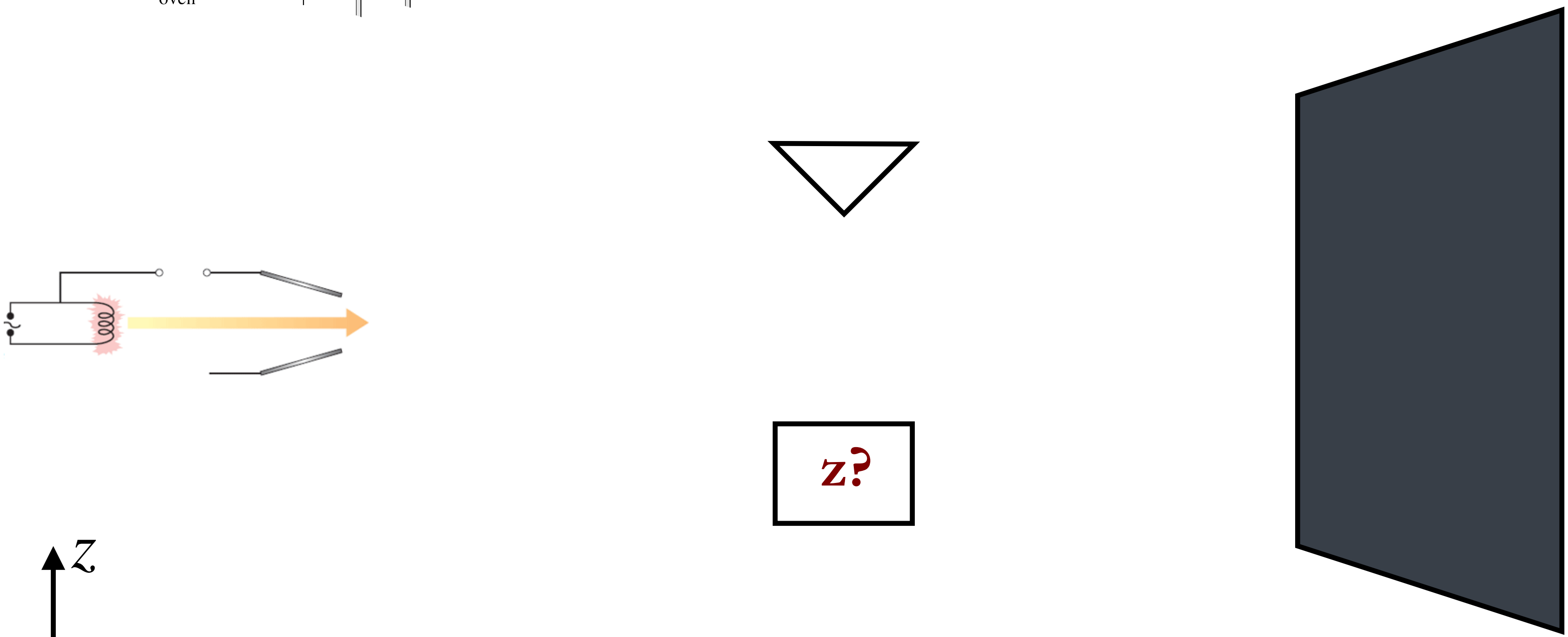


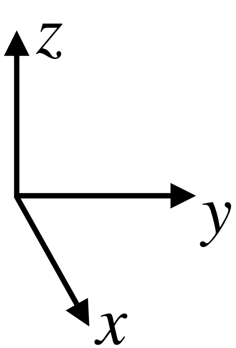
z?



Q: How much are you pointing this way?







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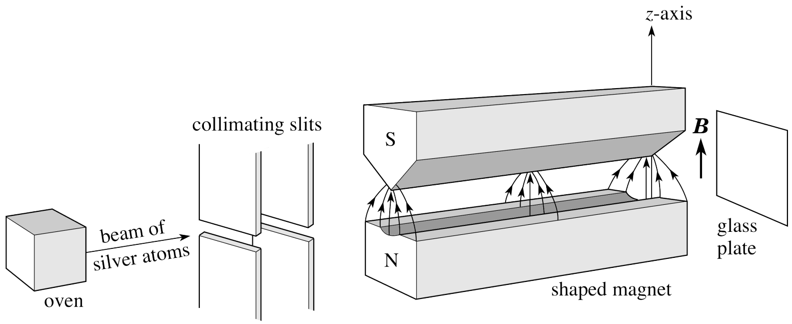
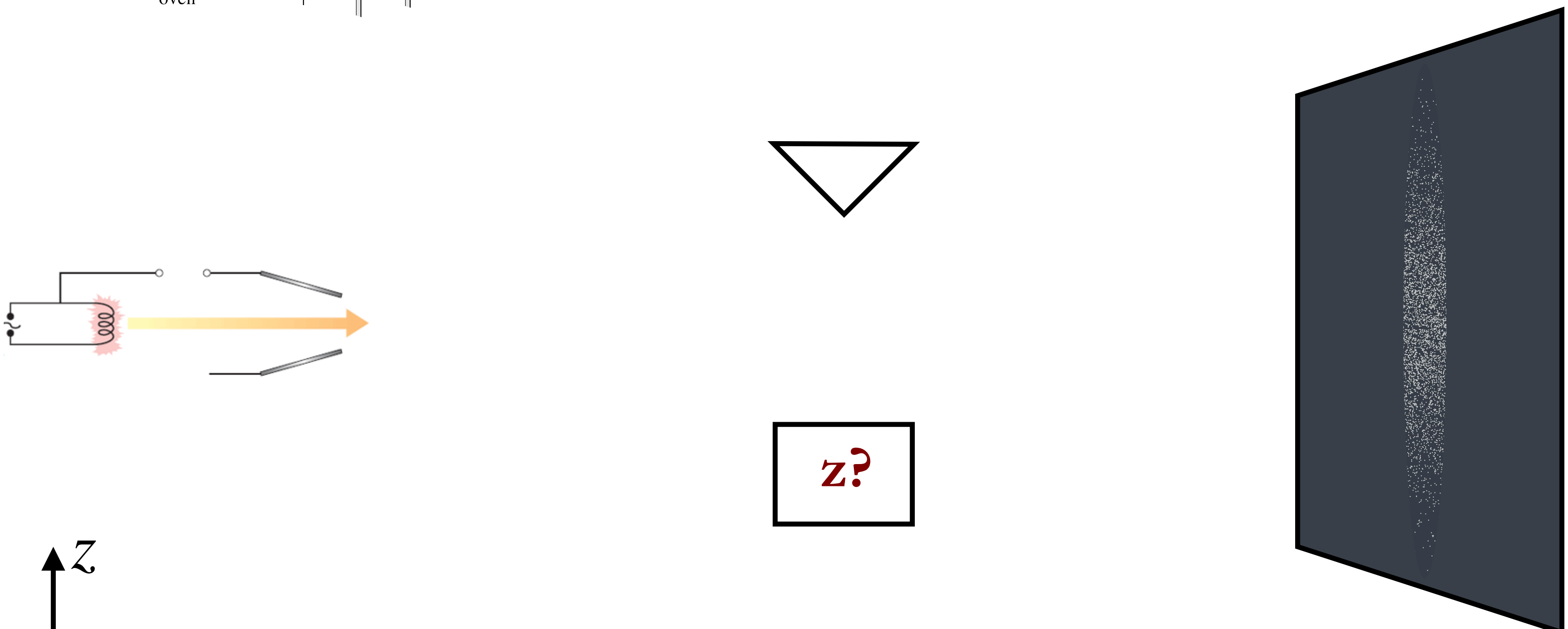
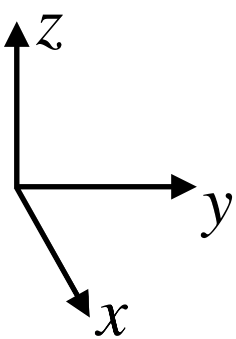
Electron Spin







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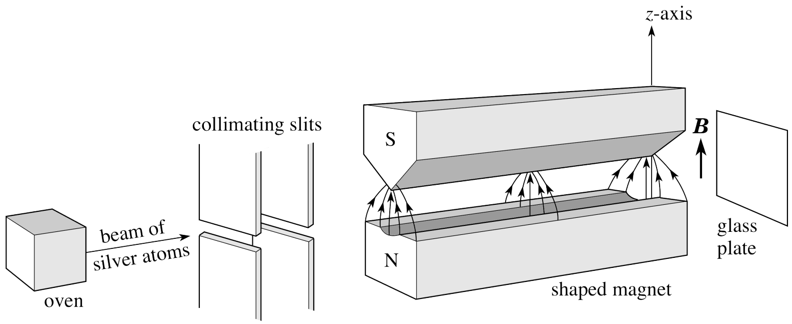
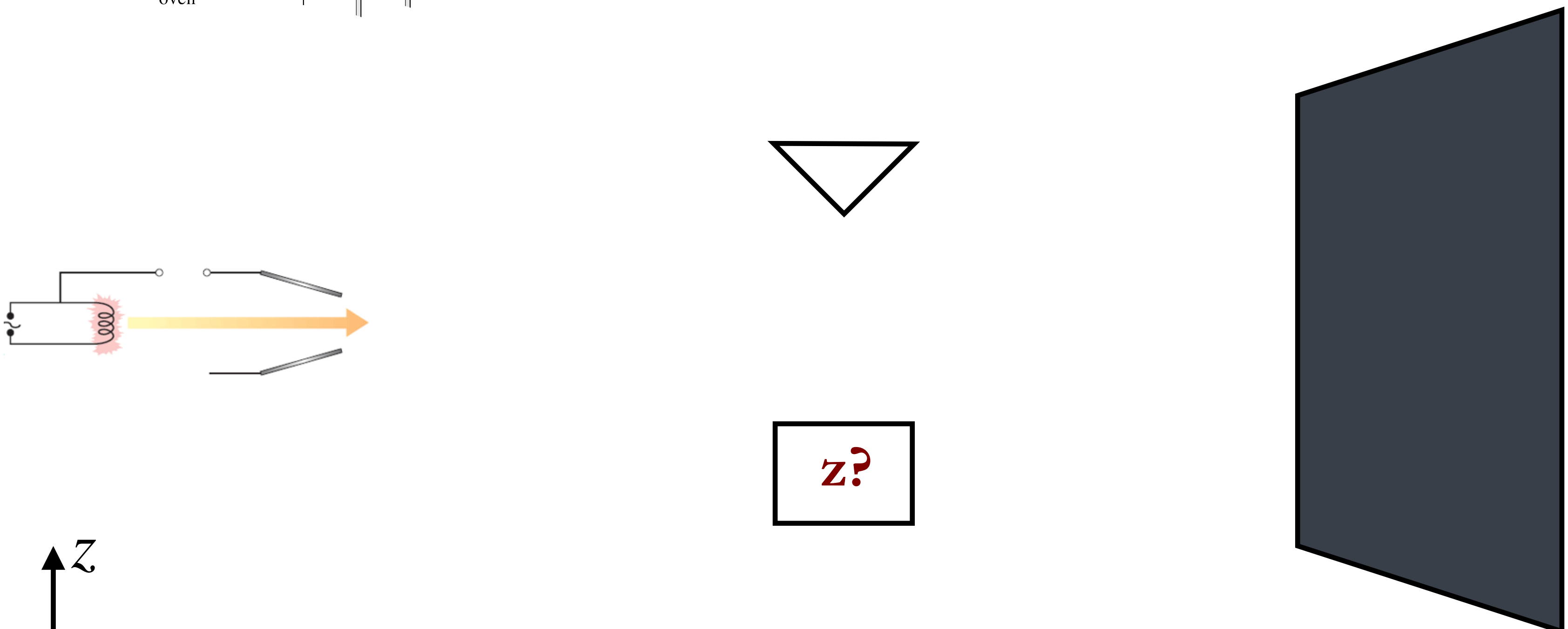
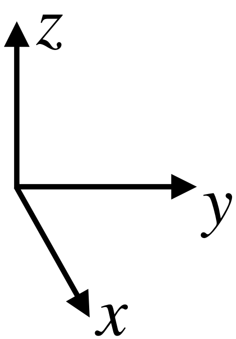
Electron Spin







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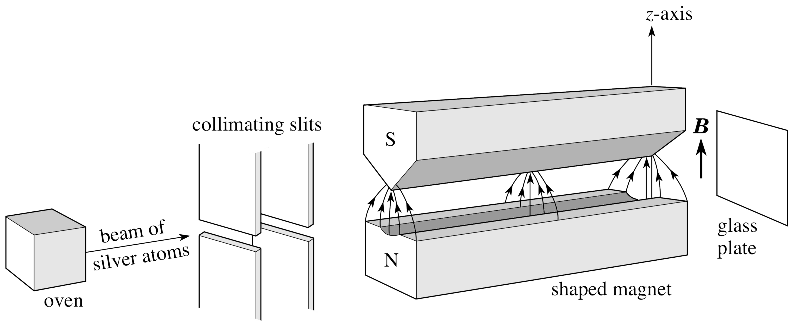
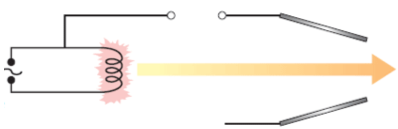
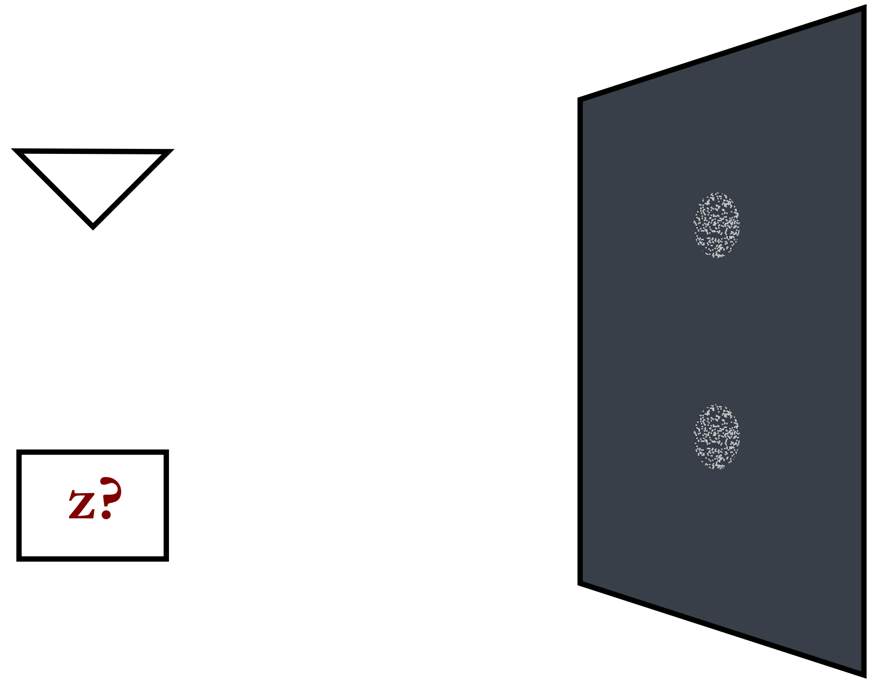
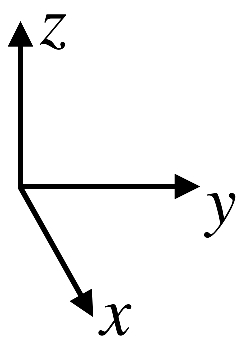


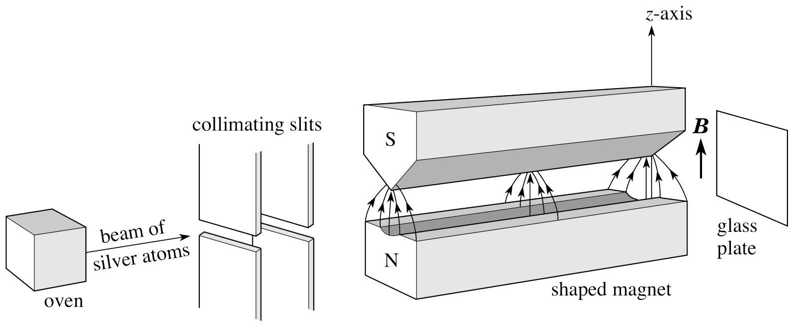


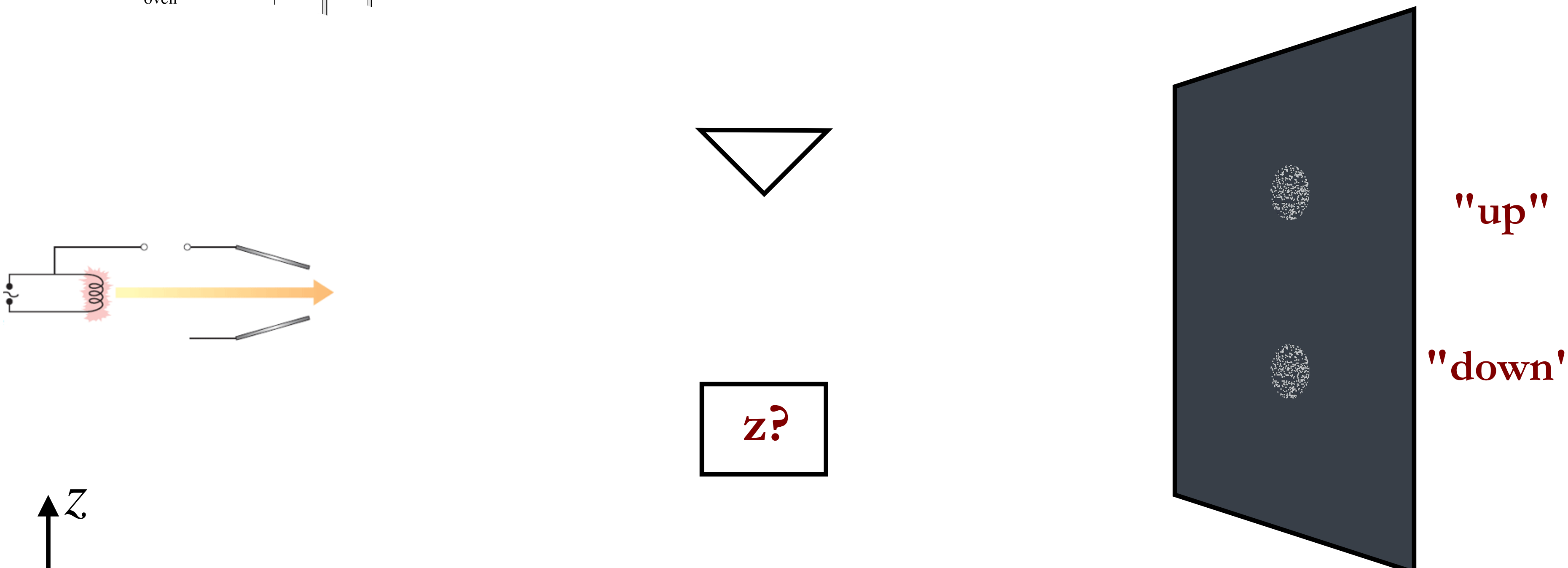


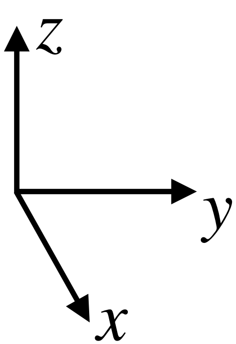


Q: How much are you pointing this way?

Electron Spin



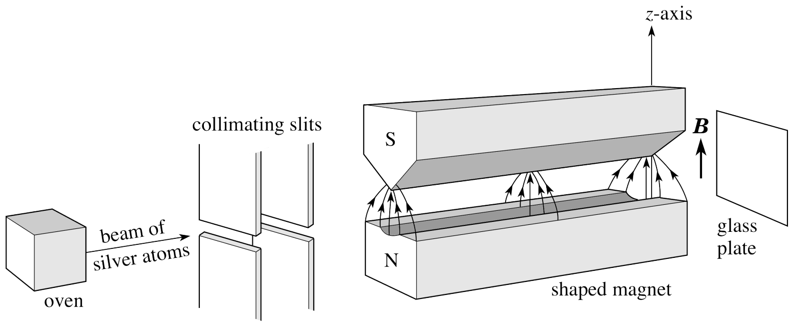


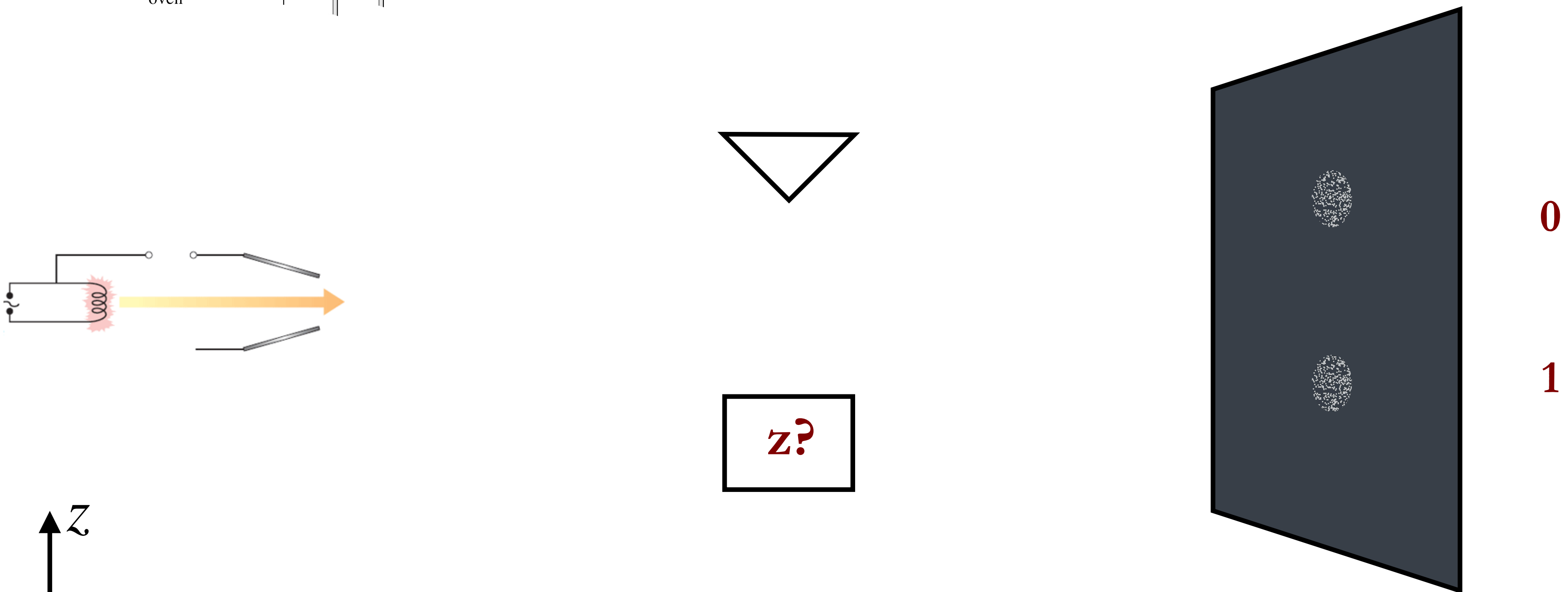


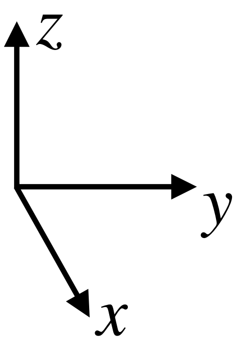
Q: How much are you pointing this way?

Only two possible answers!

Electron Spin



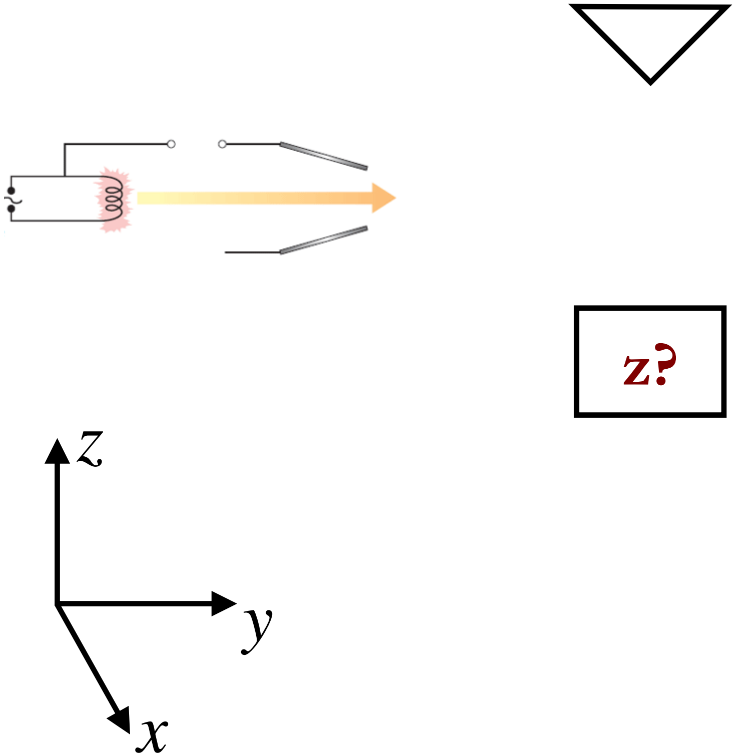


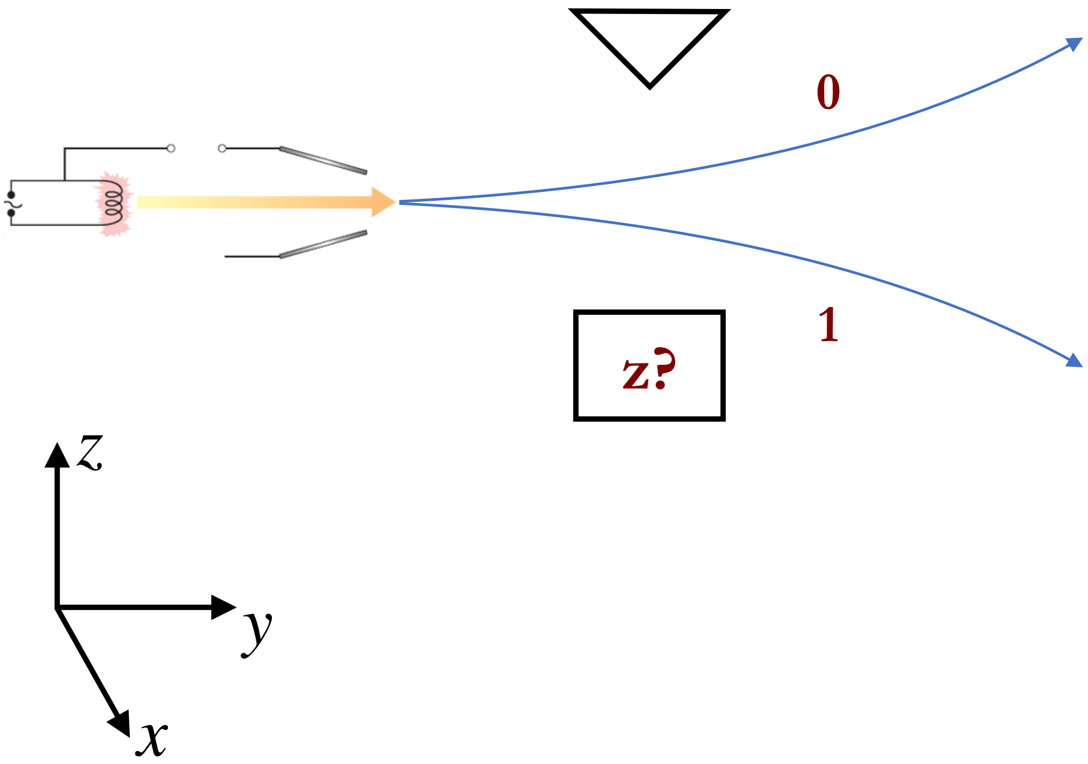


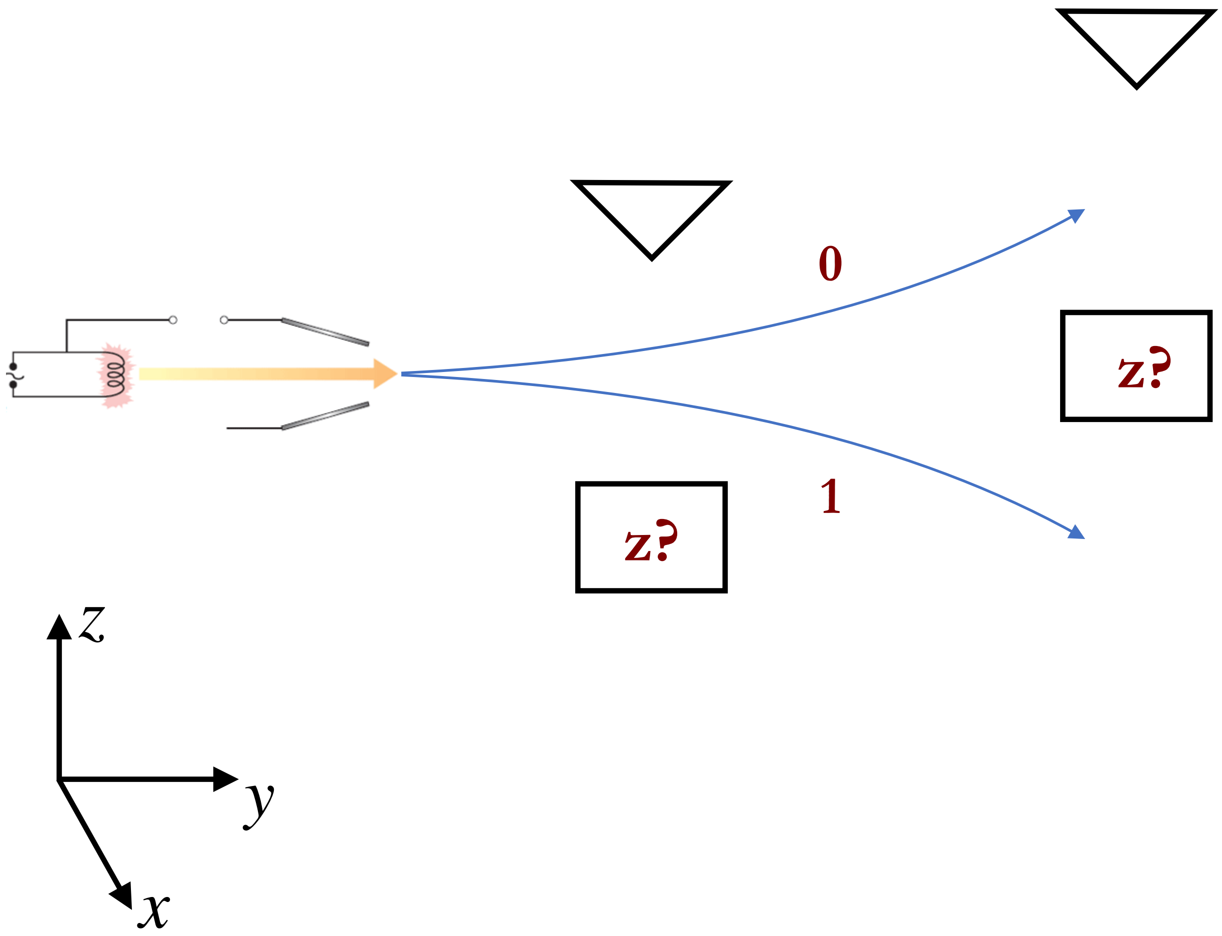
Q: How much are you pointing this way?

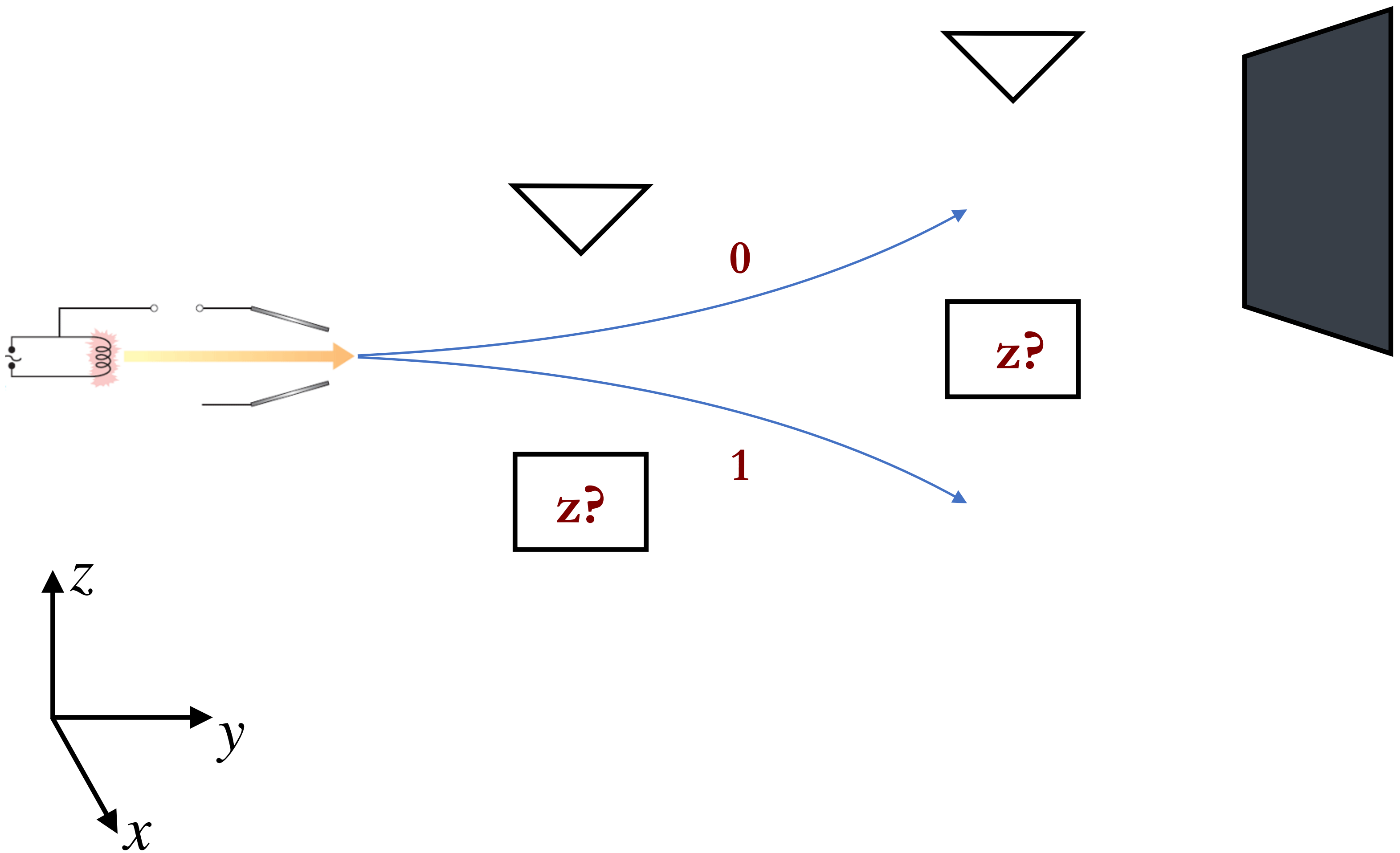
Only two possible answers!

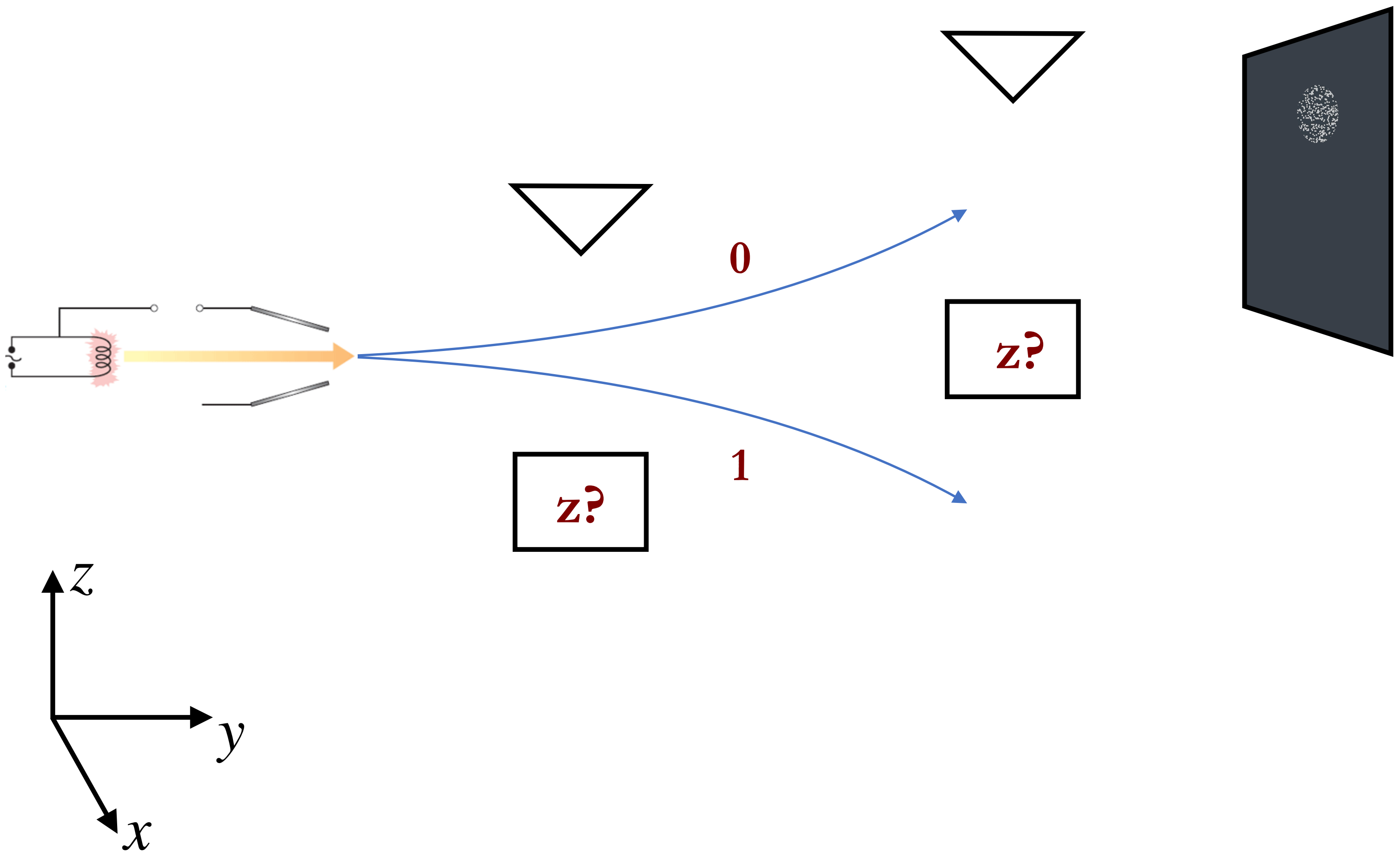
Electron Spin

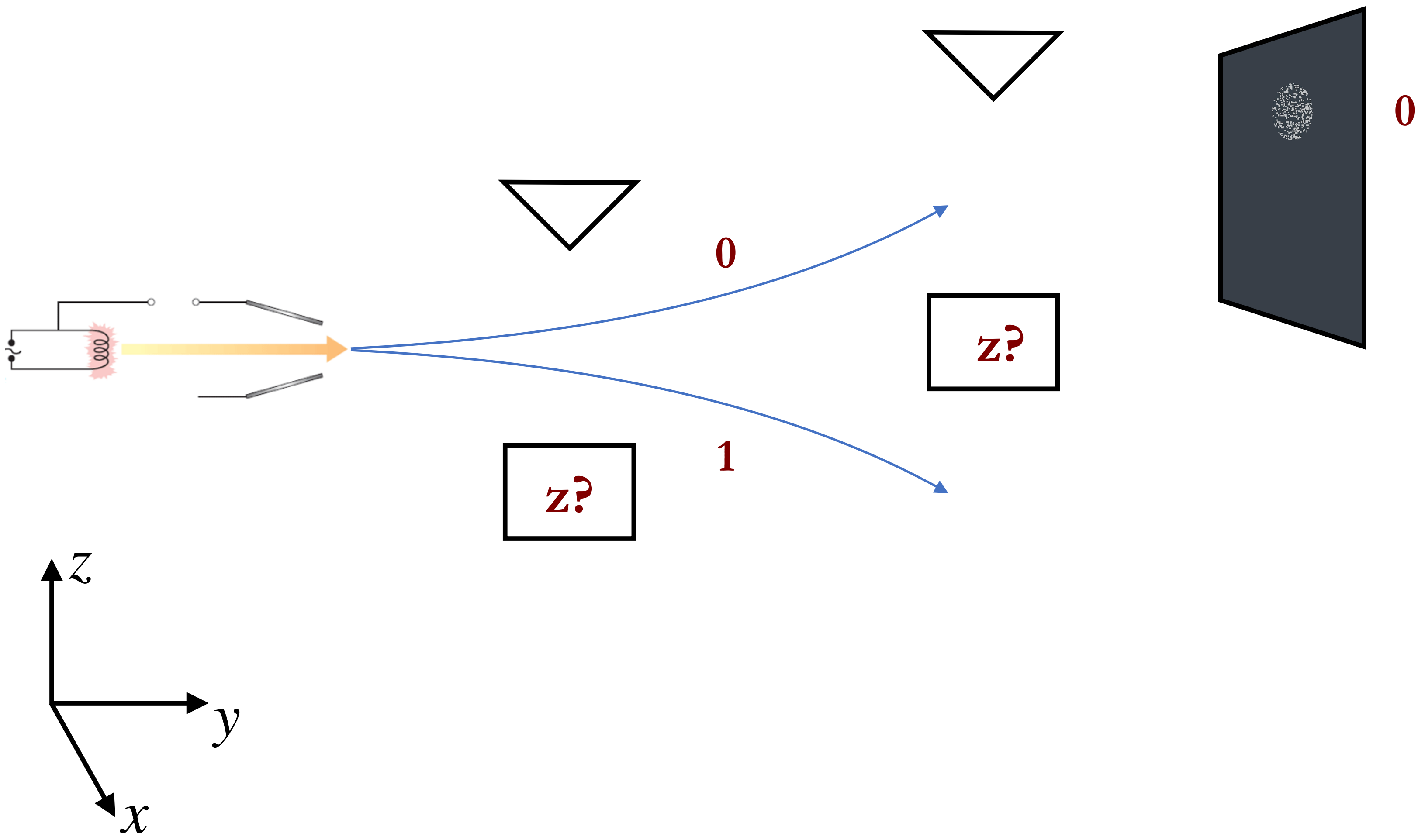


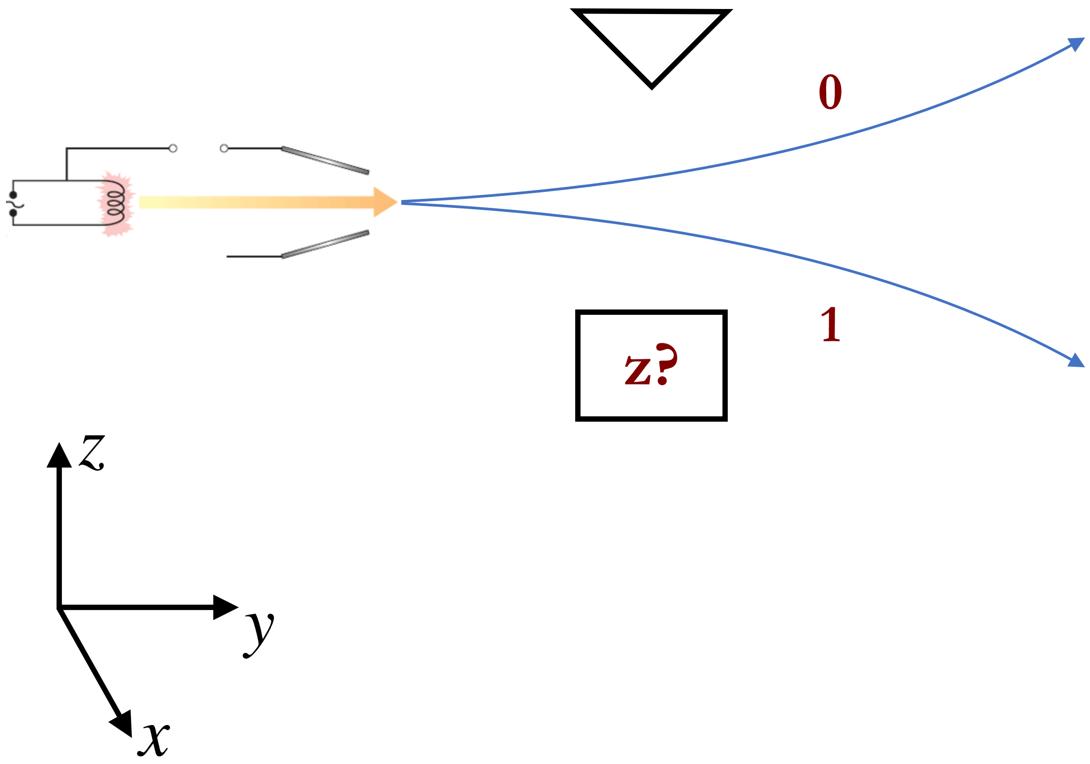

0
1
z?
z
y
x


0
1
z?
z?
z
y
x

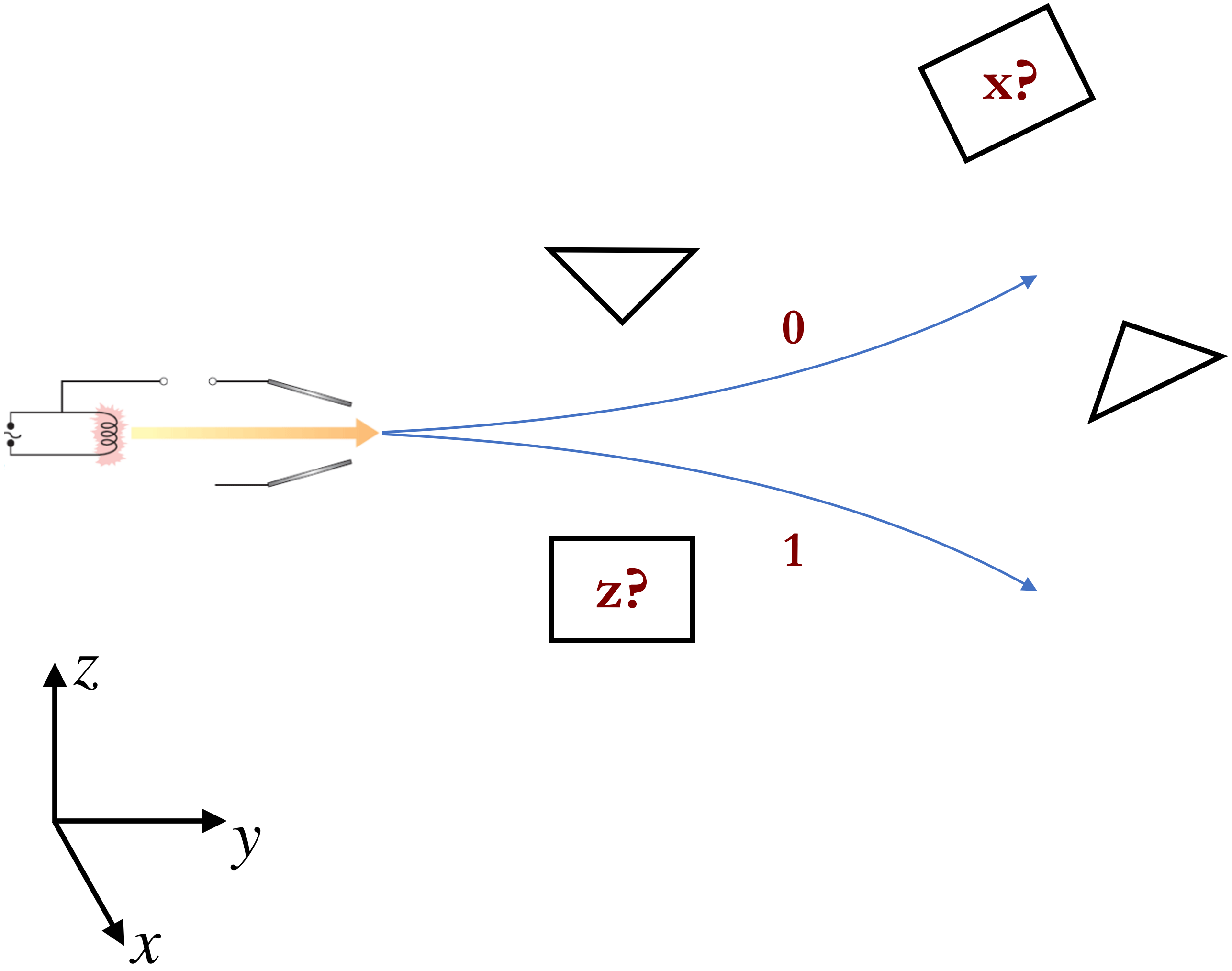

0
1
z?
z?
z
y
x

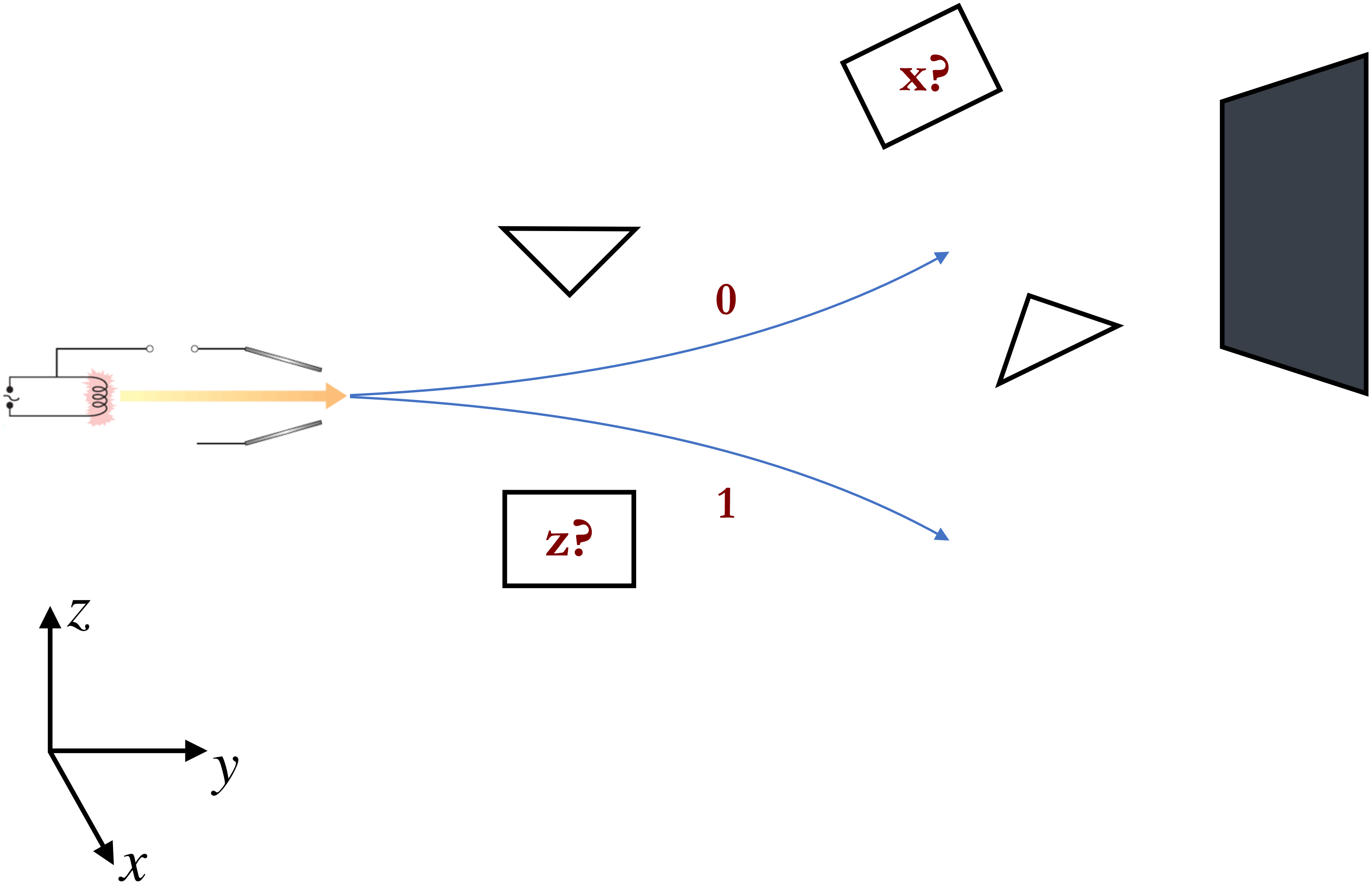

0
1
z?
z?
z
y
x


0
1
z?
z?
0
z
y
x

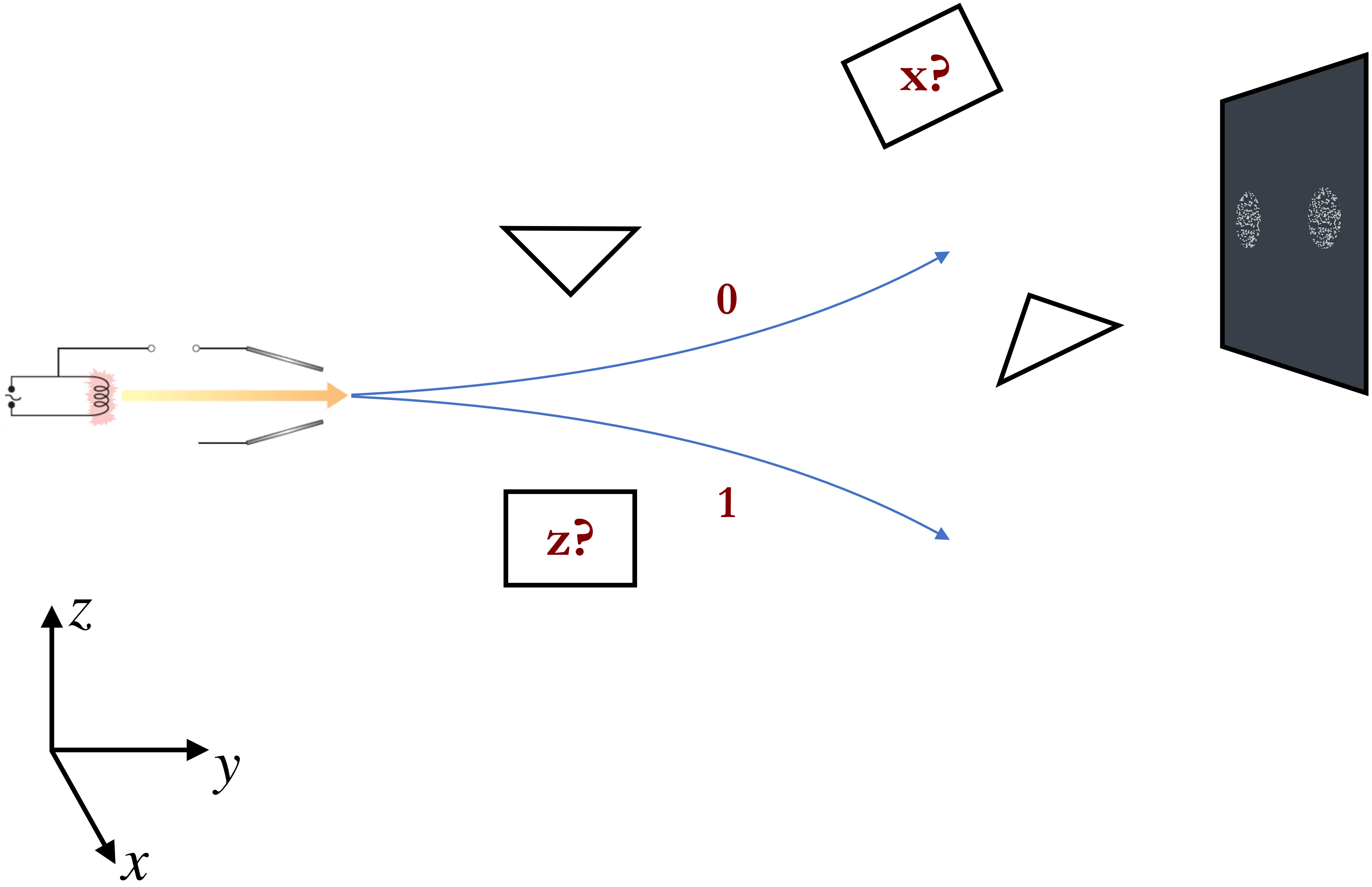

0
1
z?
z
y
x

Electron Spin

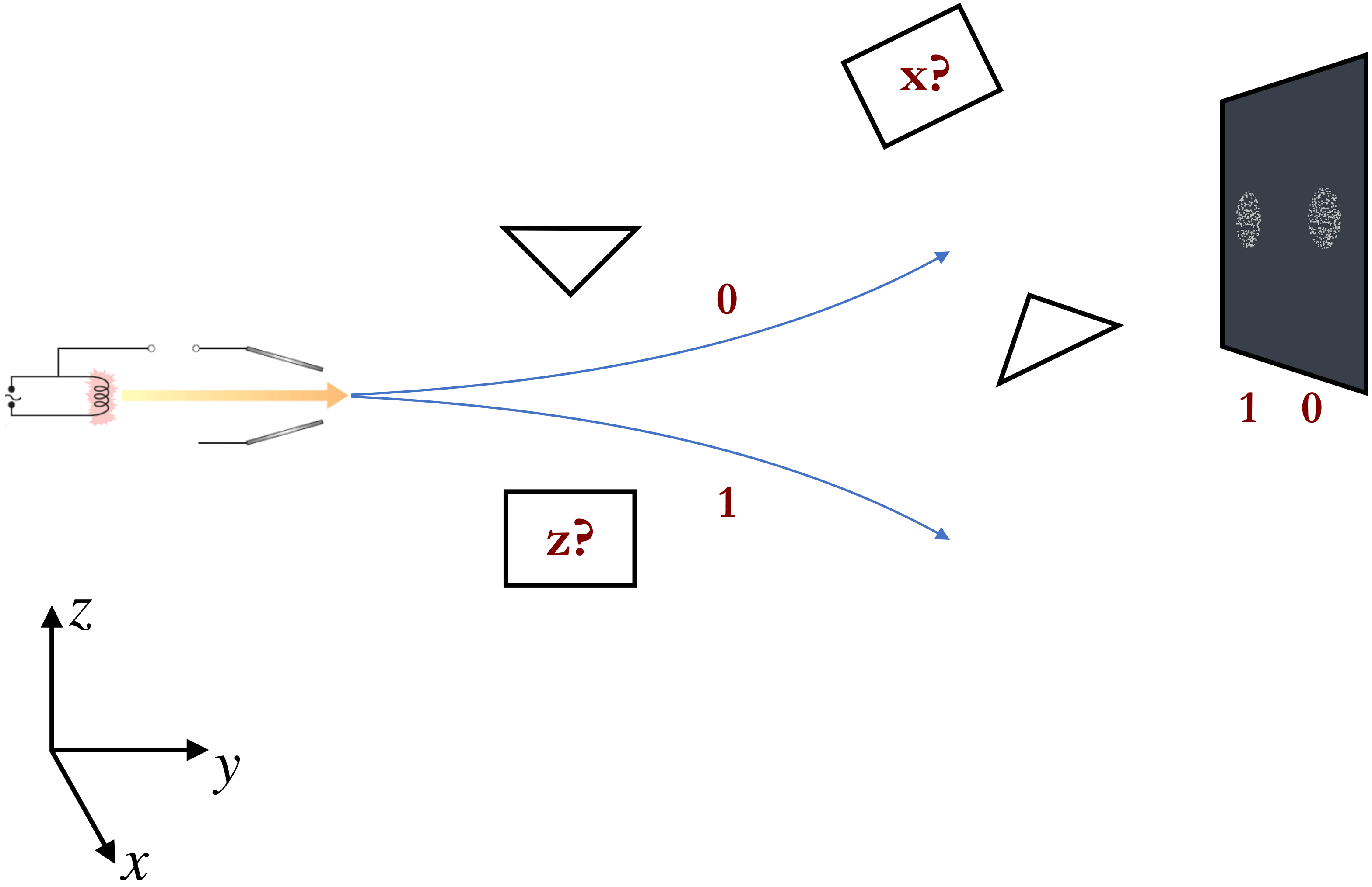


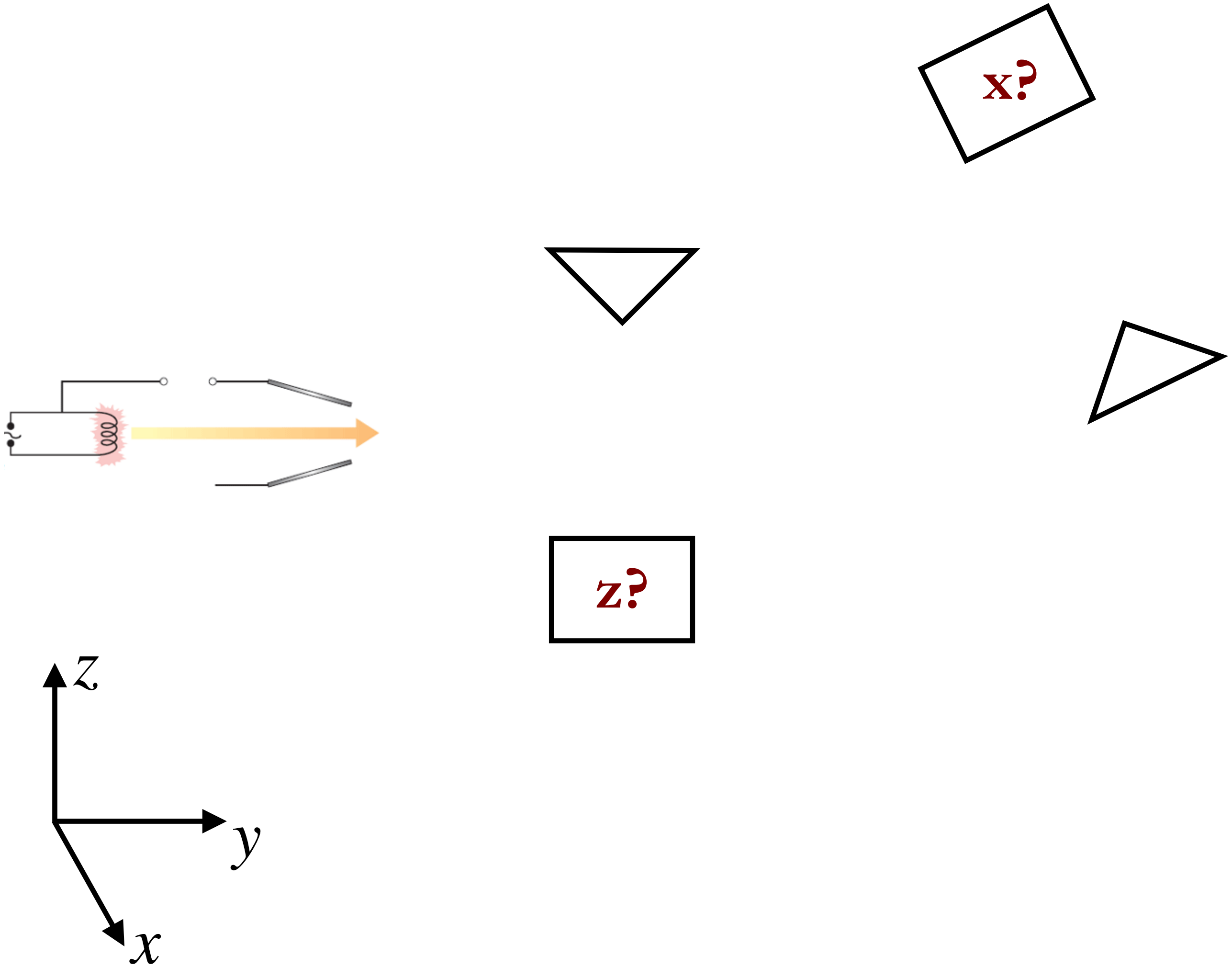

x?
0
1
z?
z
y
x

Electron Spin

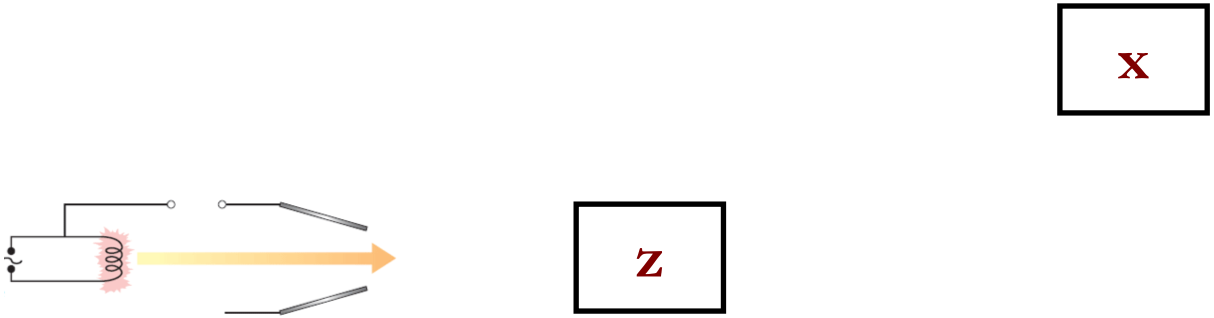


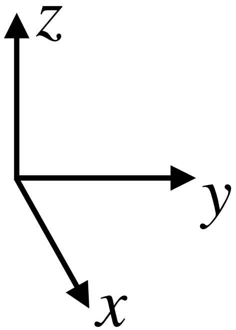
Electron Spin



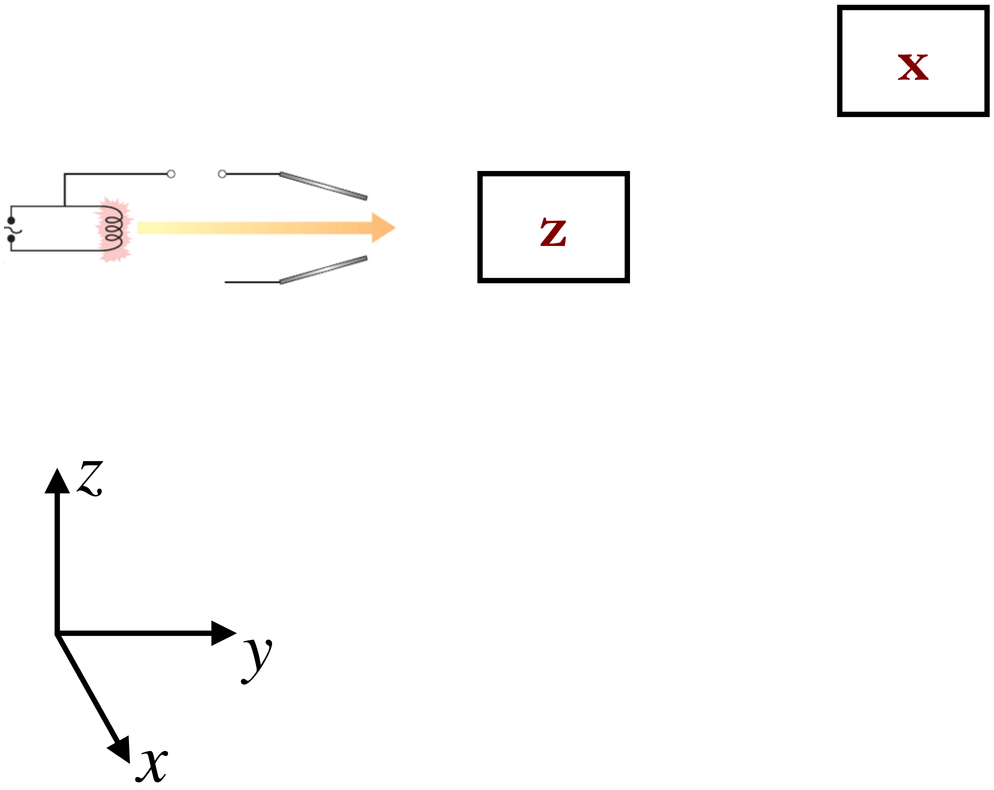

x?
z?
z
y
x

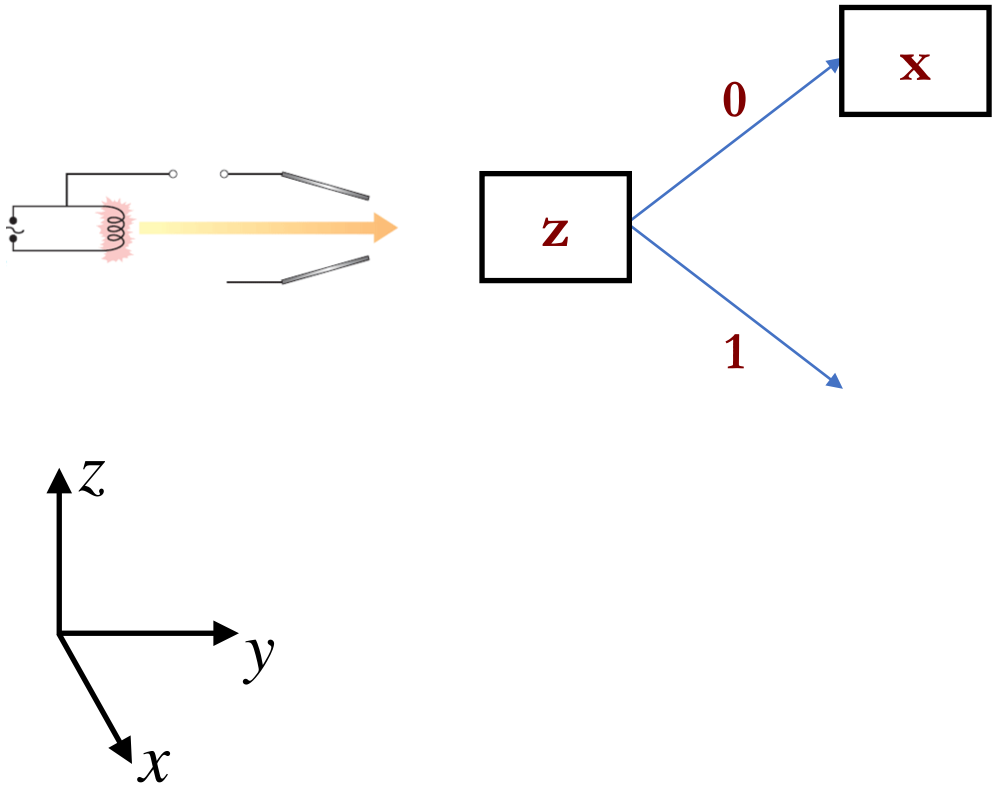
Electron Spin

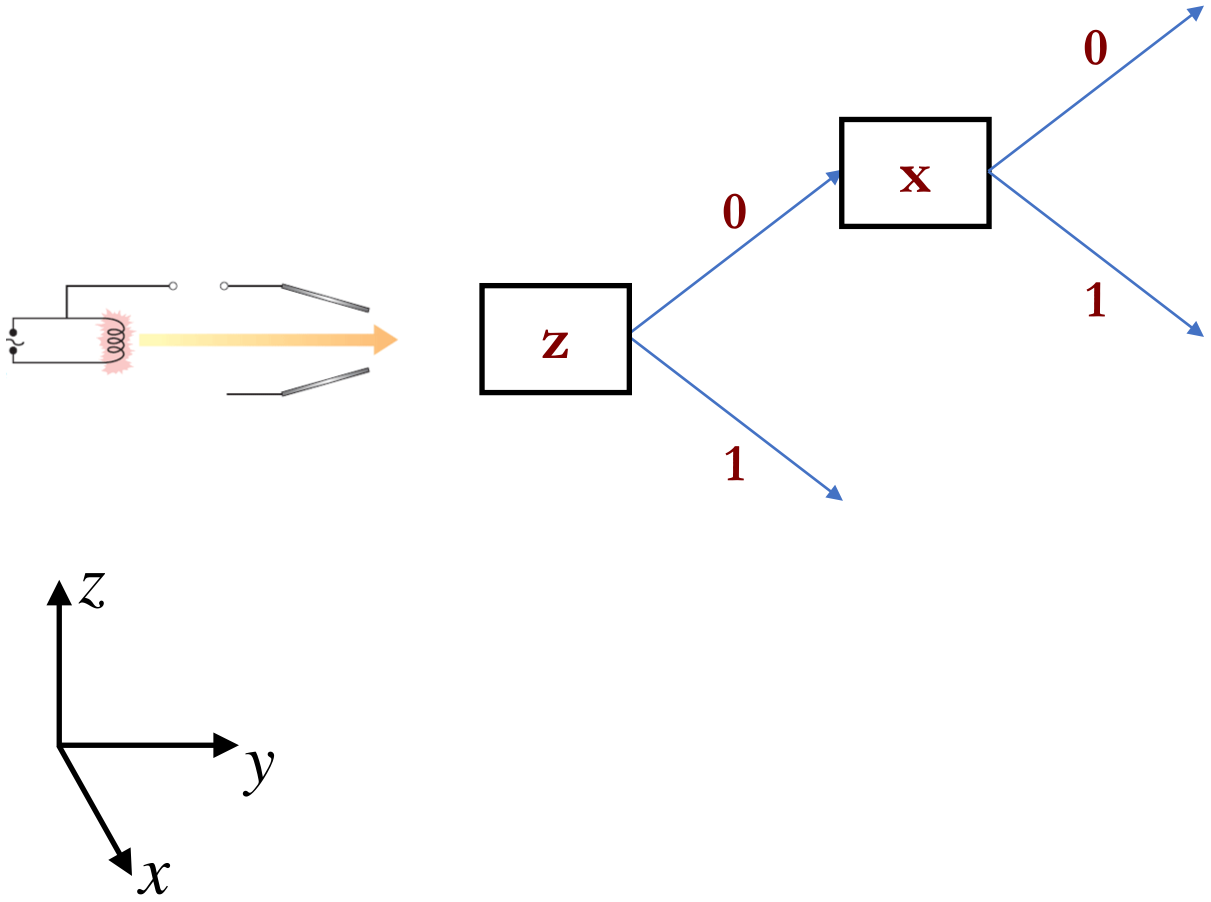


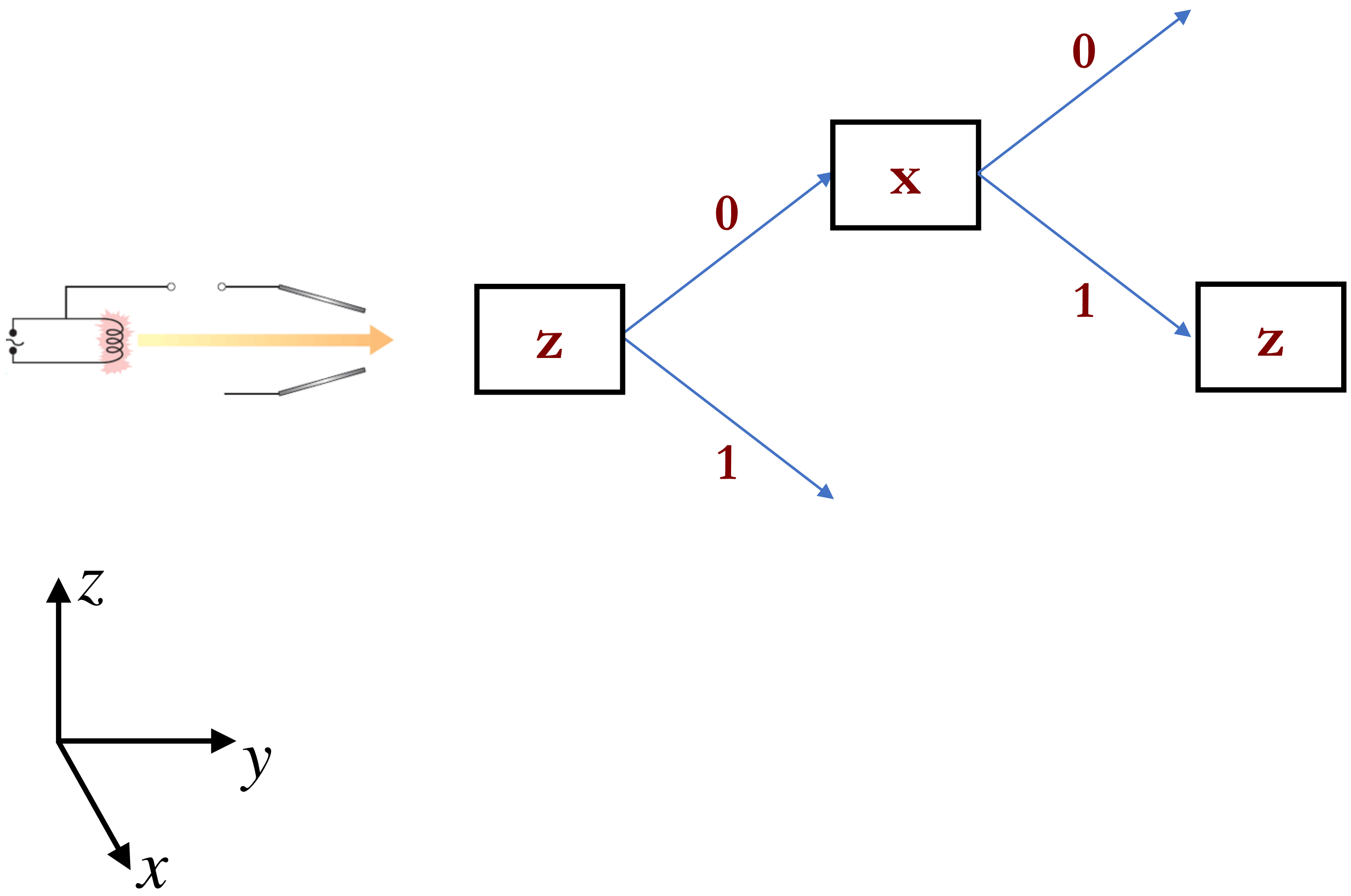


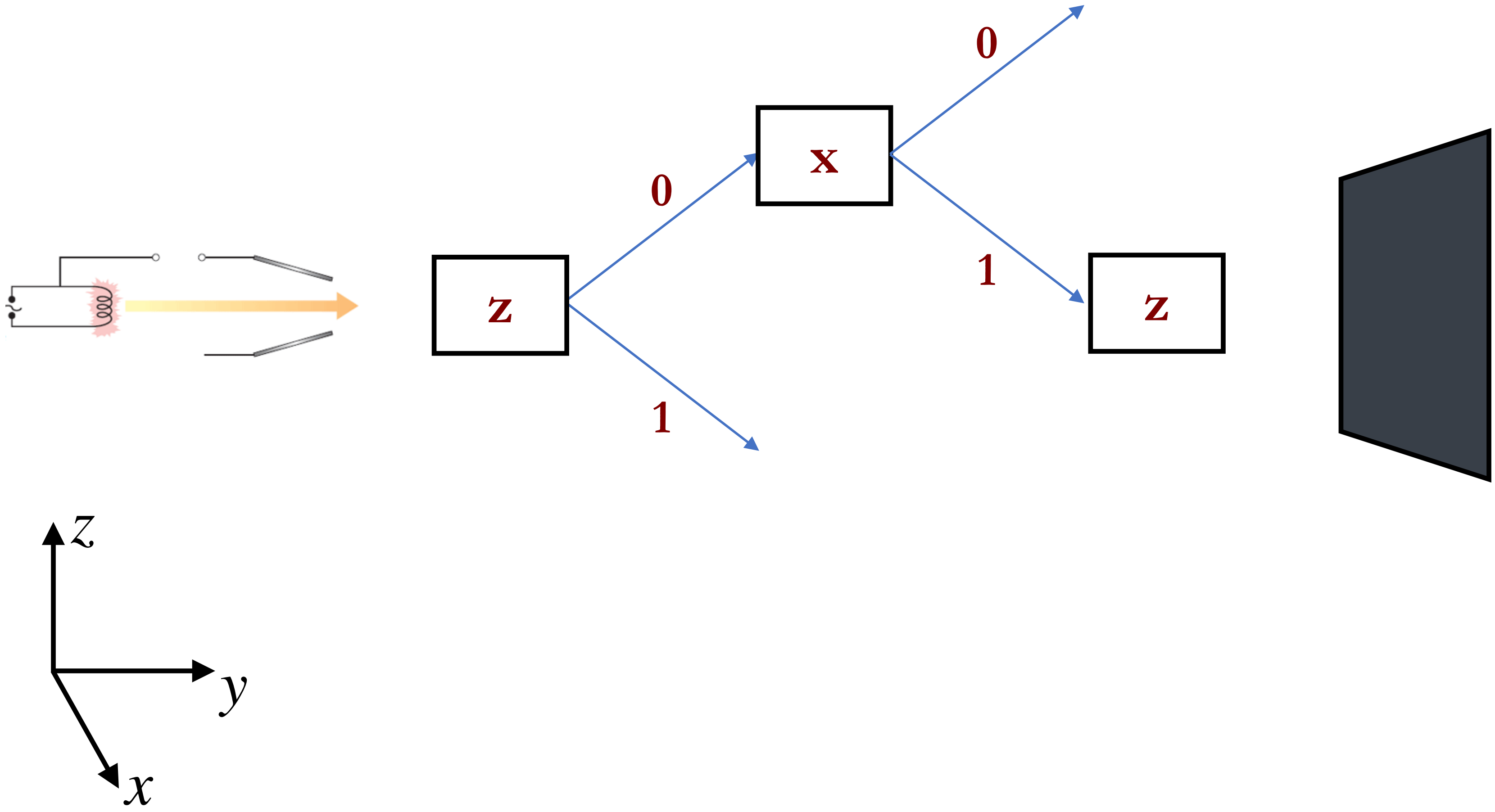
Electron Spin



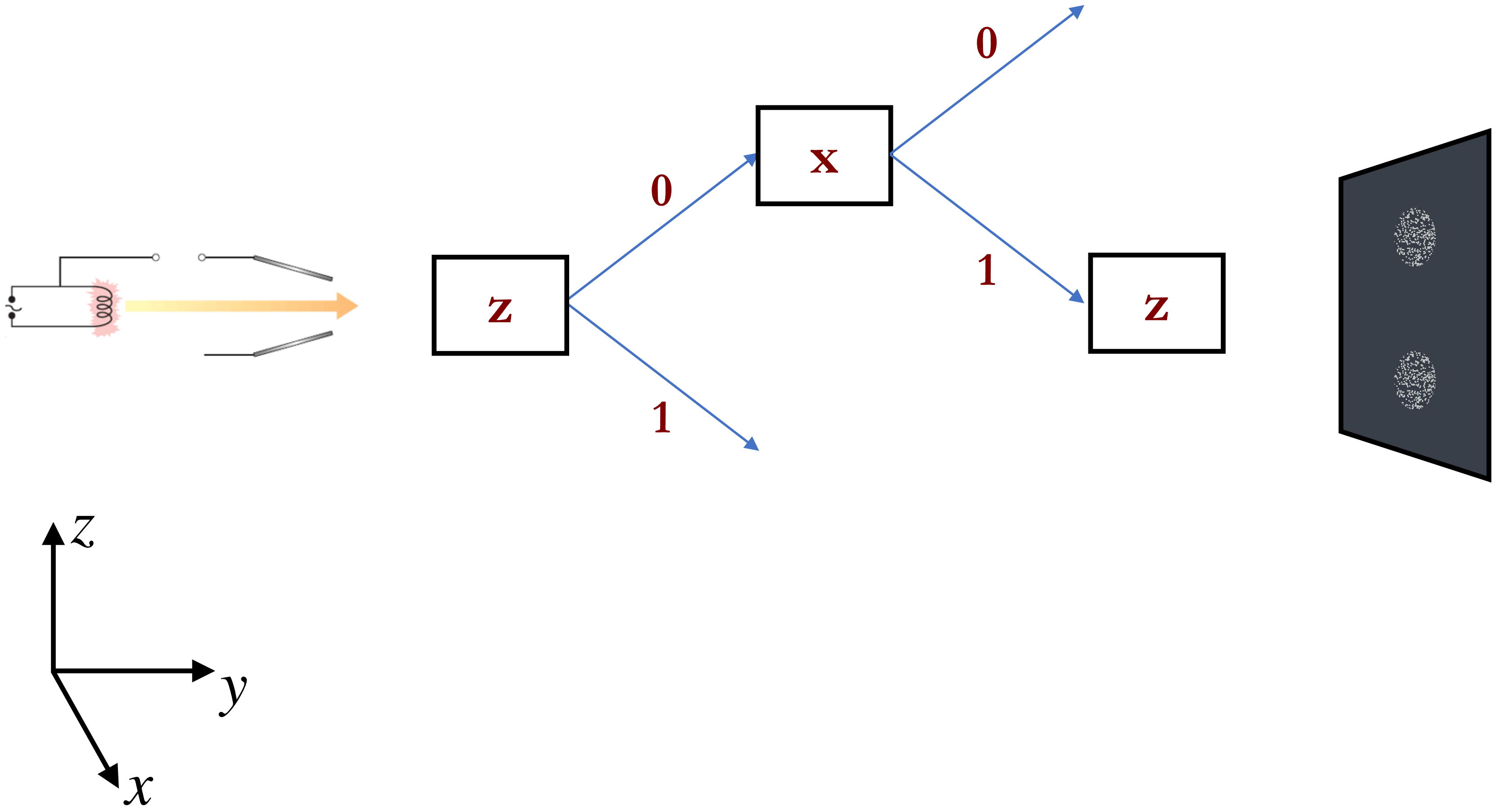

z
0
x
1
z
y
x

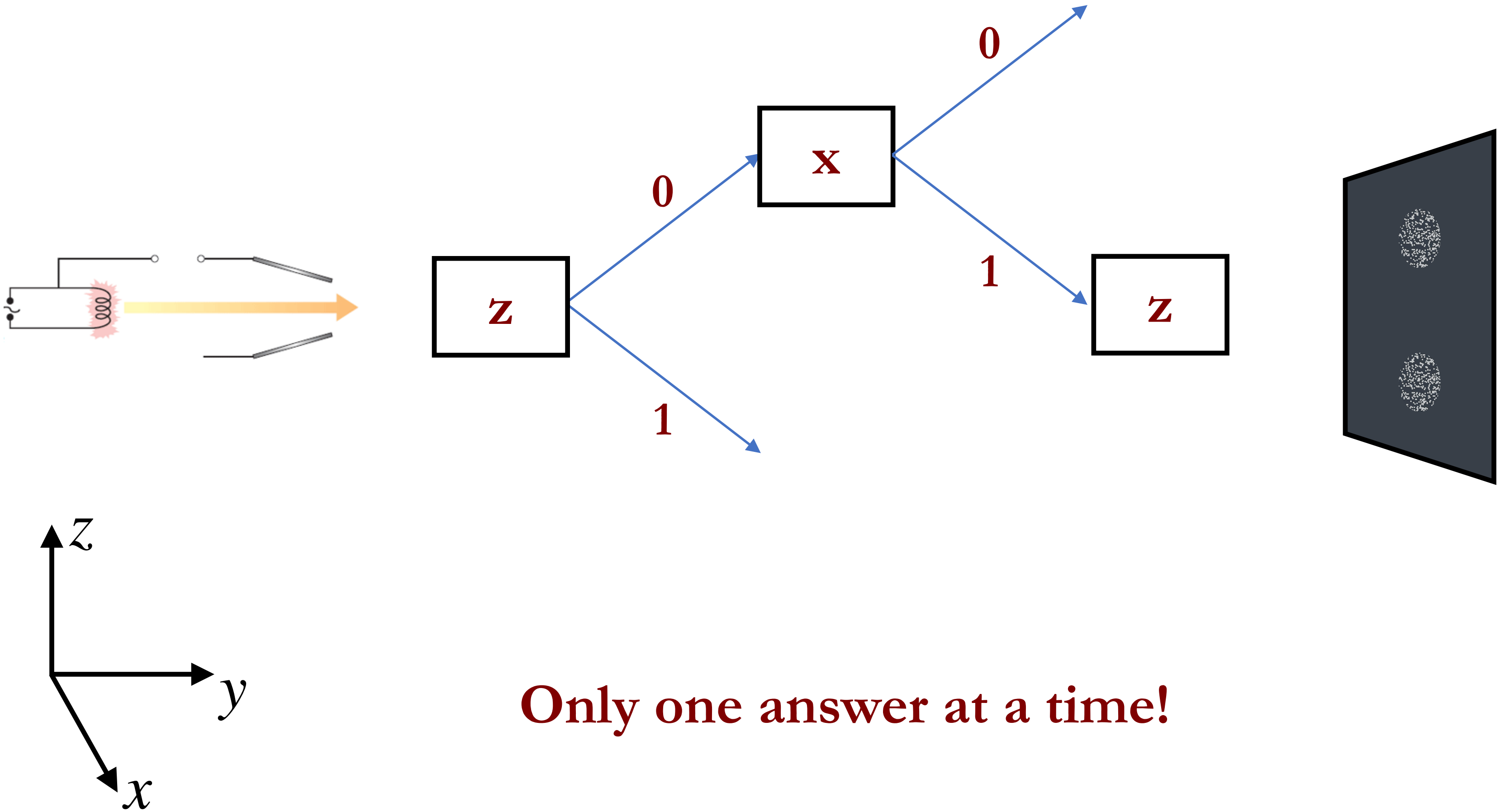

z
0
1
x
0
1
z
y
x


z
0
1
x
0
1
z
z
y
x


z
0
1
x
0
1
z
z
y
x

Electron Spin





Only one answer at a time!

Qubits

Qubits

- Only 2 answers to any question

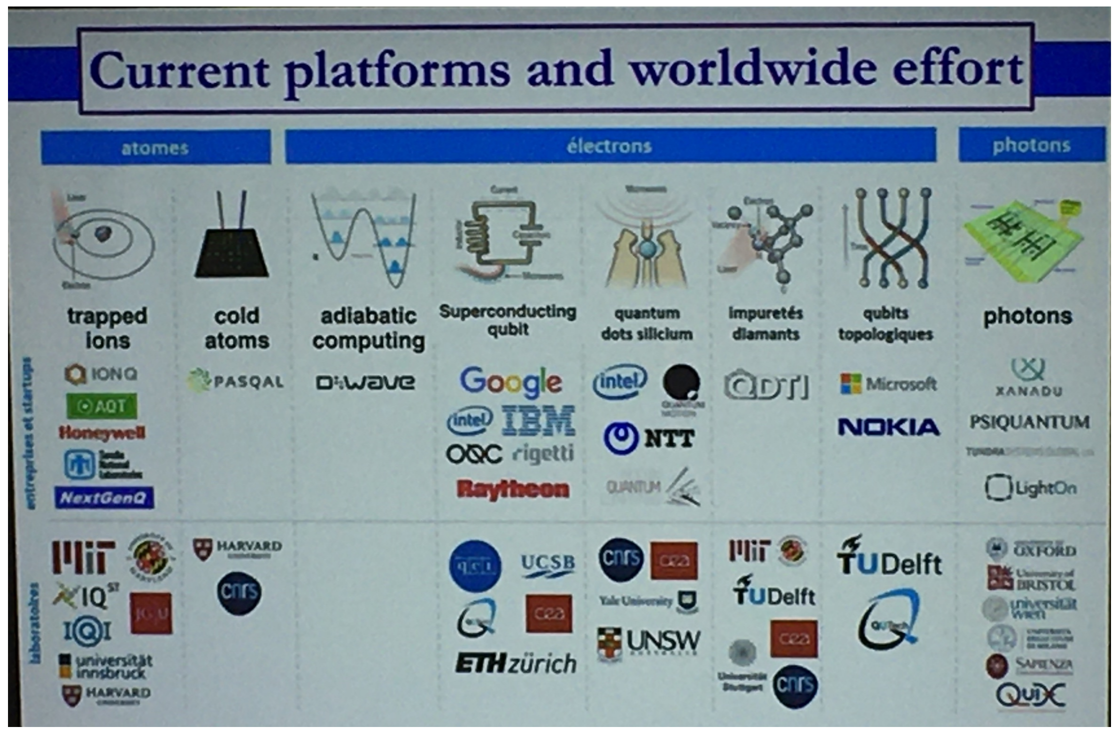
Qubits

- Only 2 answers to any question
- Only 1 bit of information

Qubits

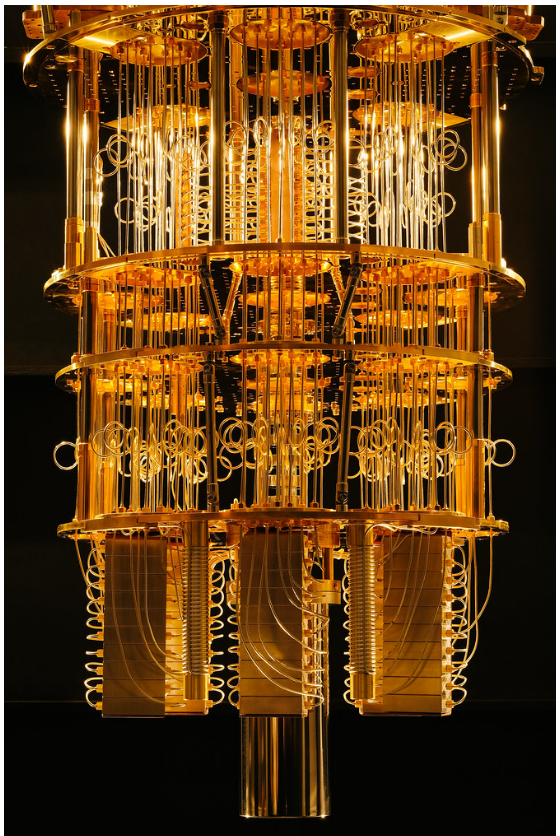
- Only 2 answers to any question
- Only 1 bit of information

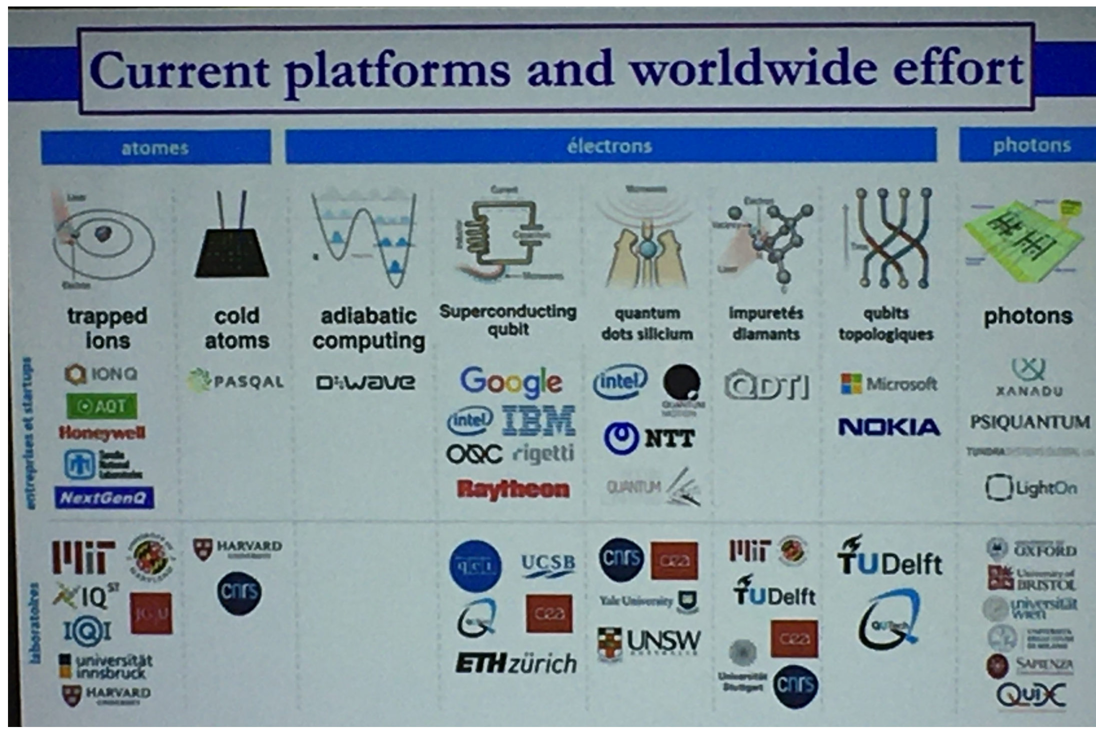
Quantum Computers



- Only 2 answers to any question
- Only 1 bit of information

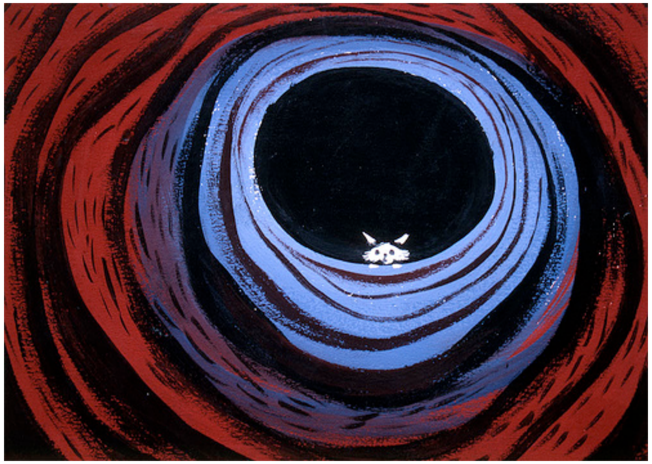
Quantum Computers





Plan

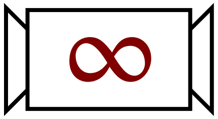
- What is quantum mechanics?
- The double slit experiment
- Electron Spin & qubits
- **Entanglement**



Mary Blair

Entanglement

Entanglement



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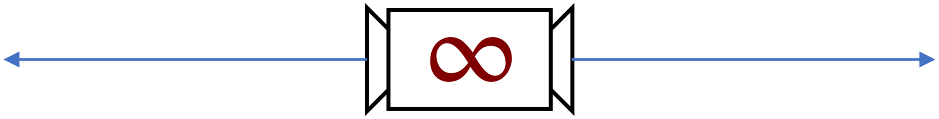
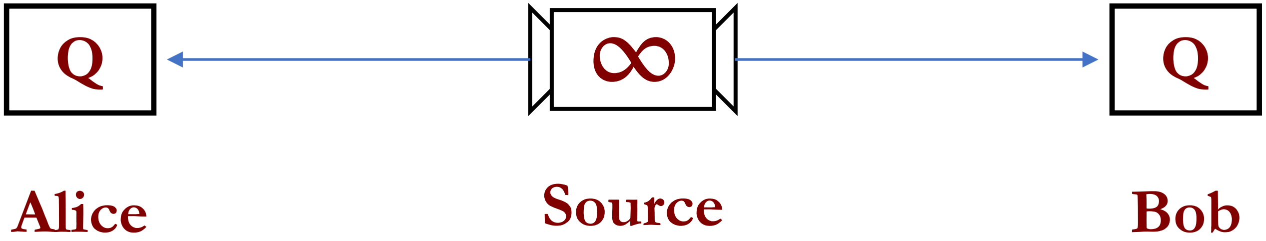
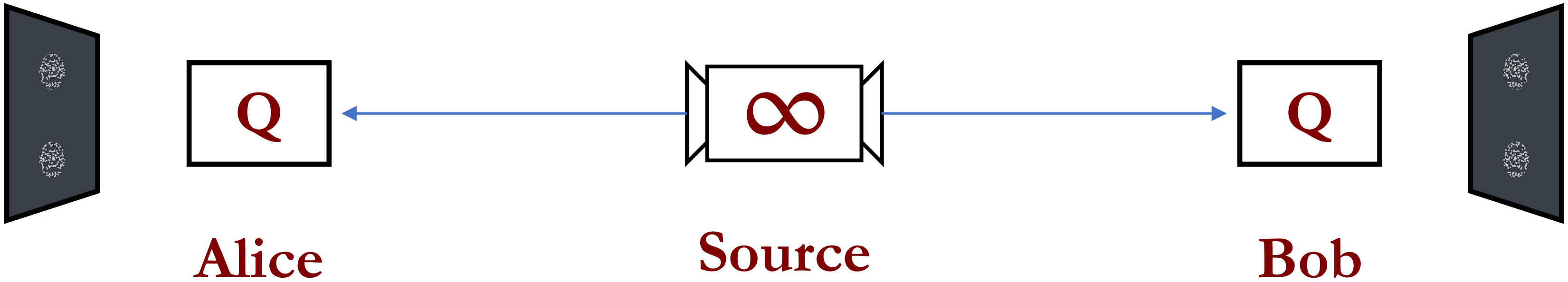


Source


Q
∞
Q
Alice
Source
Bob

Entanglement



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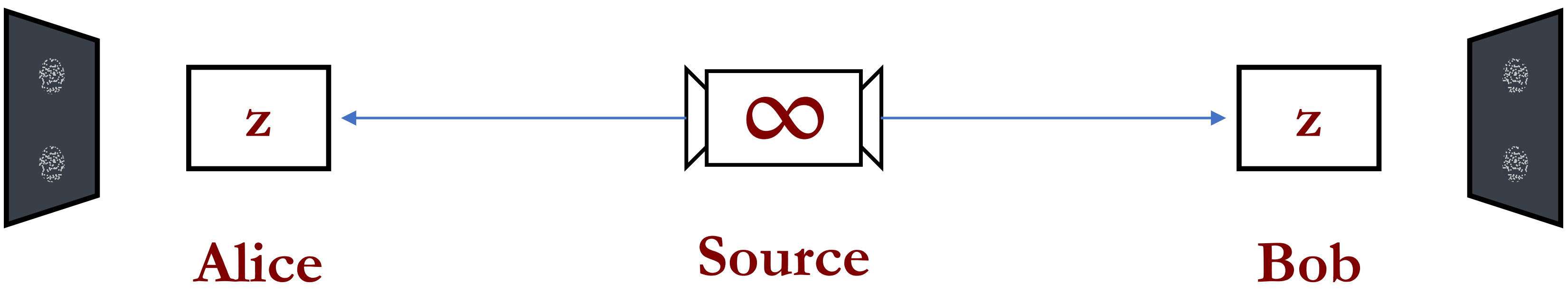

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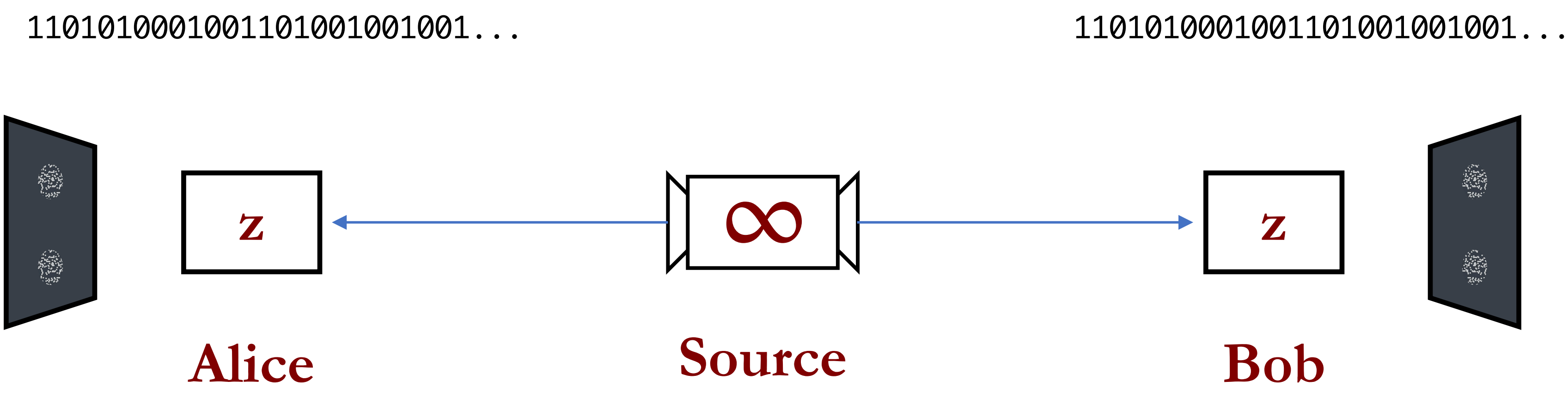

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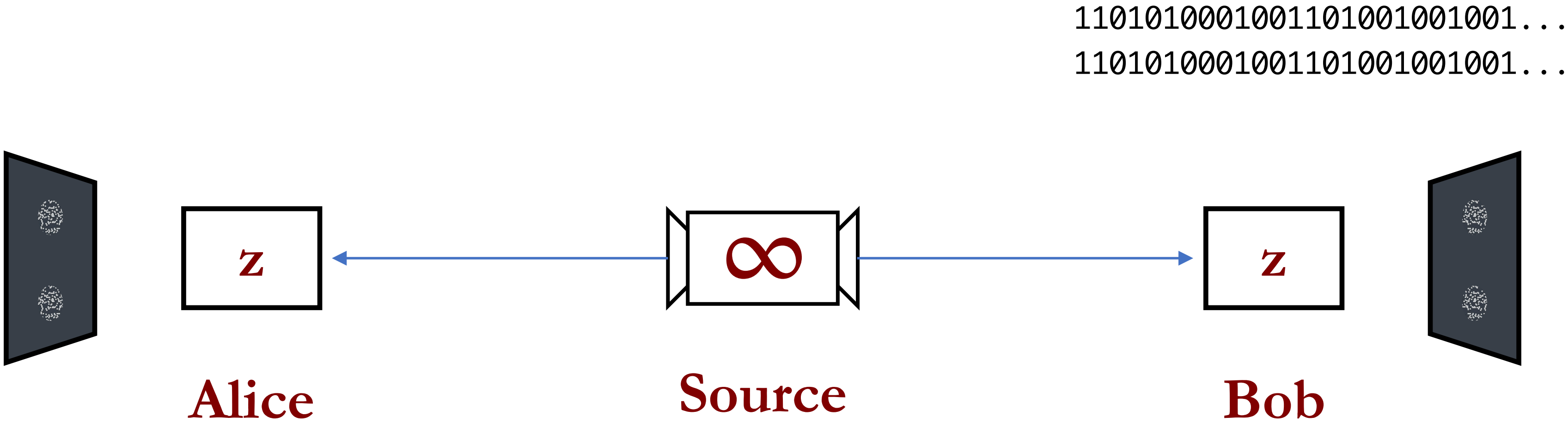
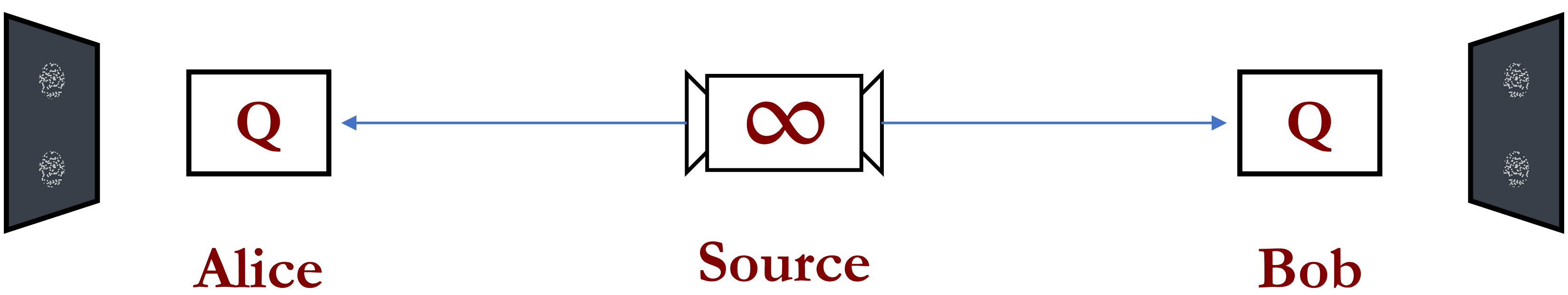


Entanglement

A \ B	z	x
z		
x		

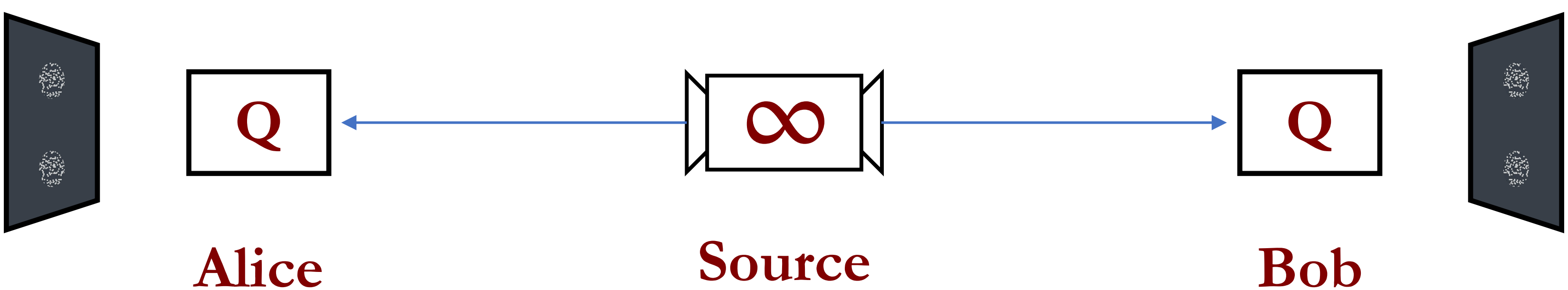
1101010001001101001001001...
1101010001001101001001001...



Entanglement

A \ B	z	x
z	=	
x		

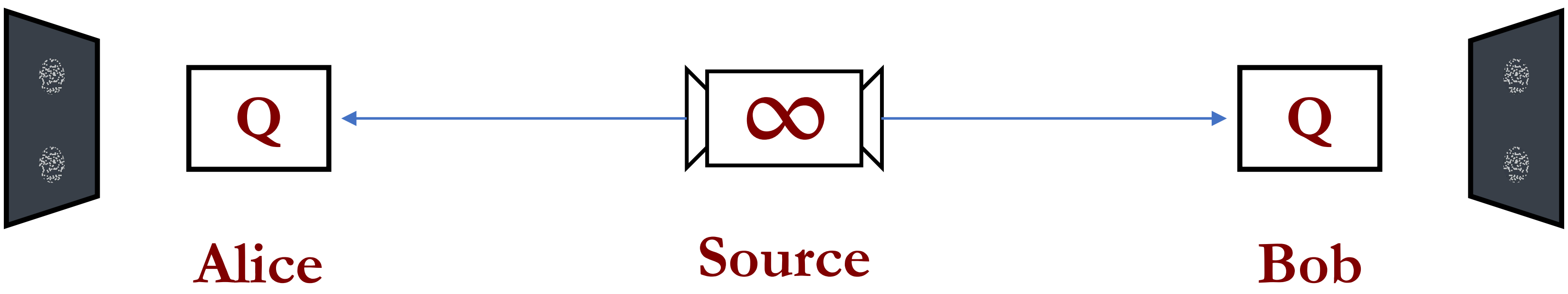
```
1101010001001101001001001...
1101010001001101001001001...
```



Entanglement

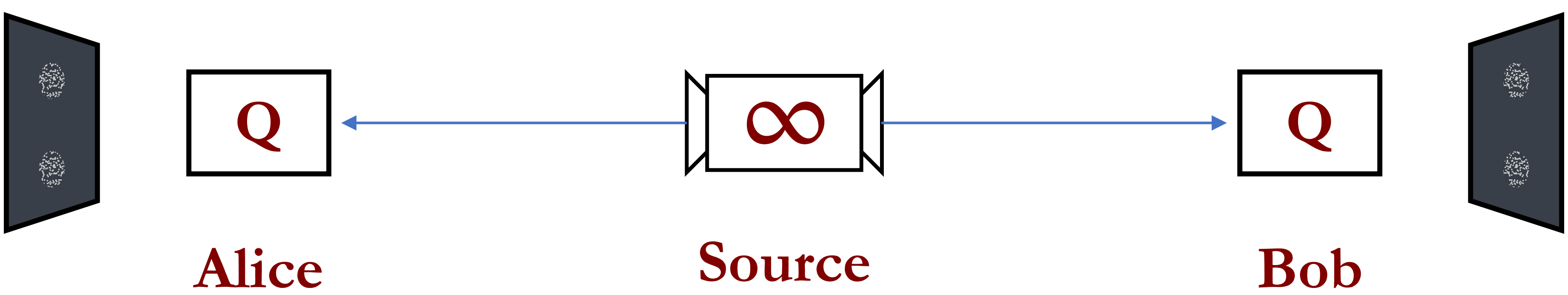
A \ B	z	x
z	=	
x		=

11010100010011010010010001...
11010100010011010010010001...



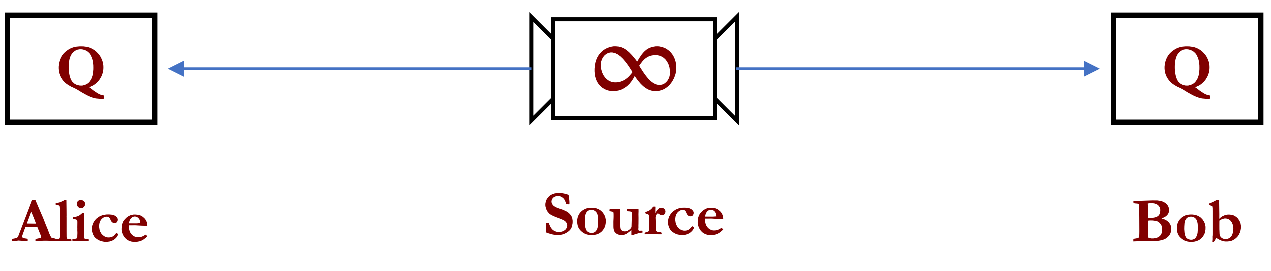
A \ B	z	x
z	=	R
x	R	=

1101010001001101001001001...
1101010001001101001001001...



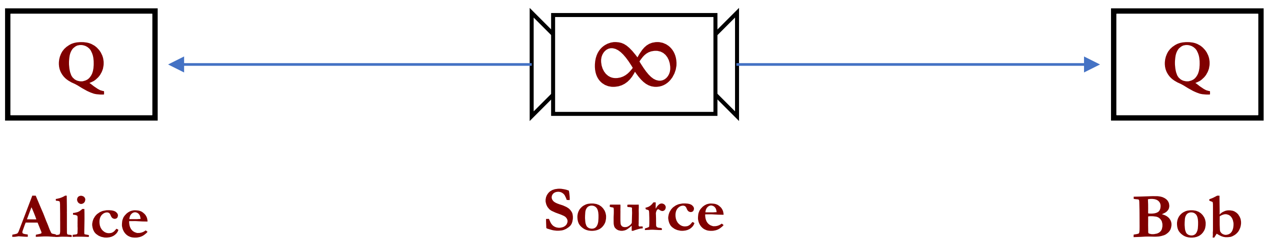
Entanglement

A \ B	z	x
z	=	R
x	R	=



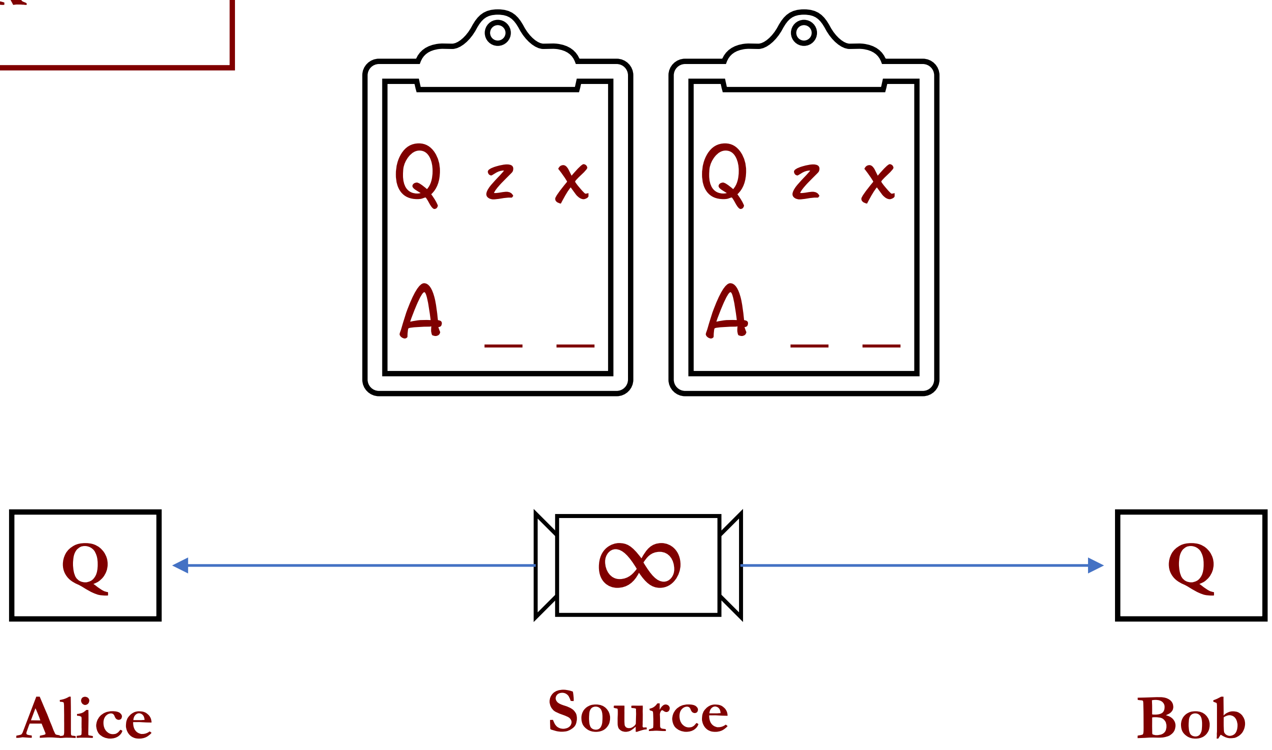
Entanglement

A \ B	z	x
z	=	R
x	R	=



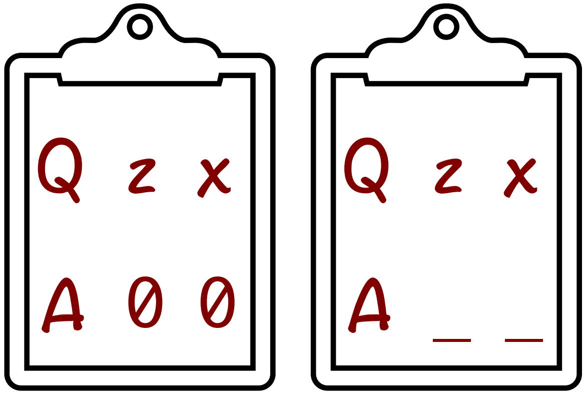
Entanglement

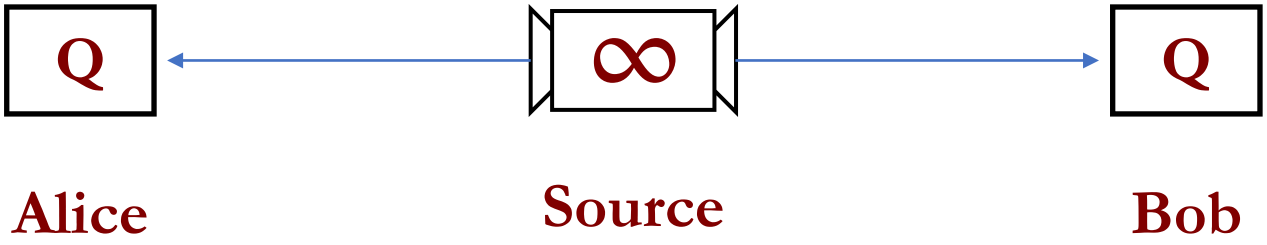
A \ B	z	x
z	=	R
x	R	=



Entanglement

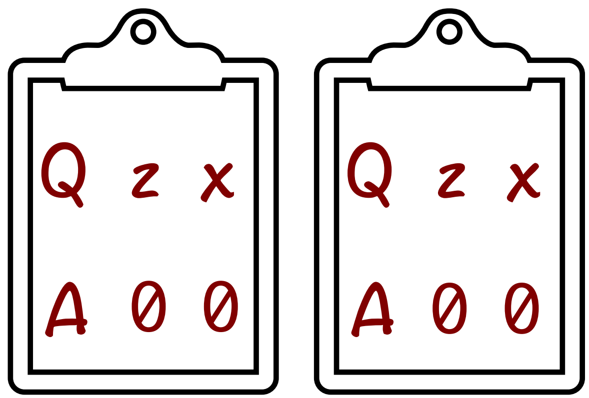
A \ B	z	x
z	=	R
x	R	=

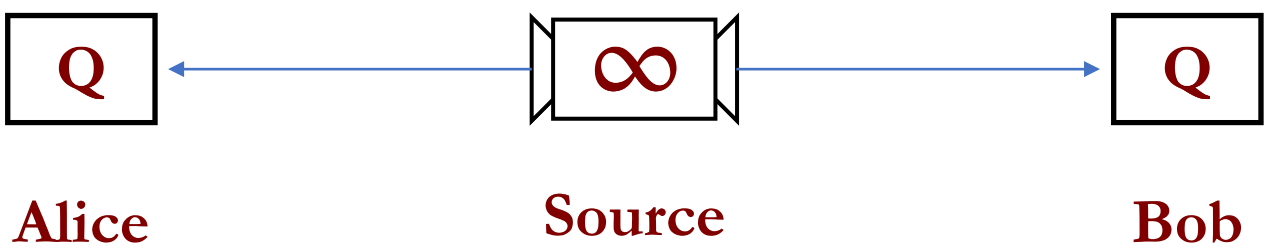




Entanglement

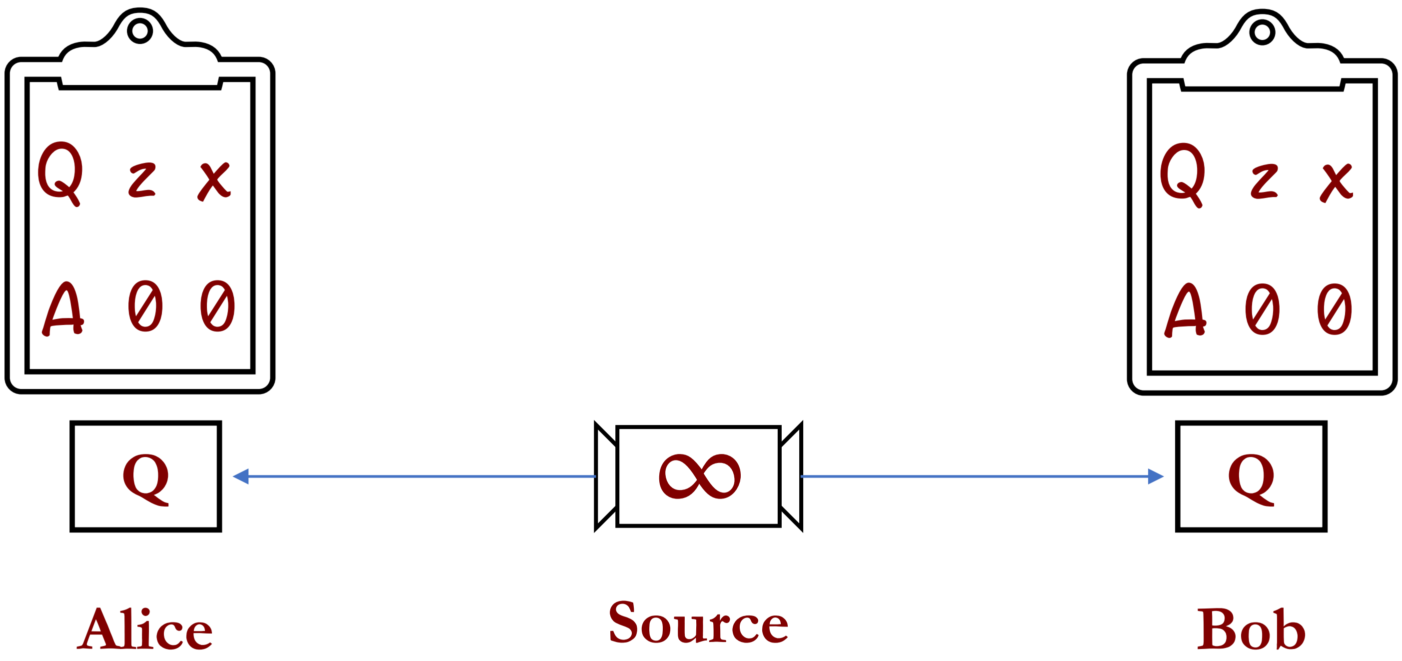
A \ B	z	x
z	=	R
x	R	=





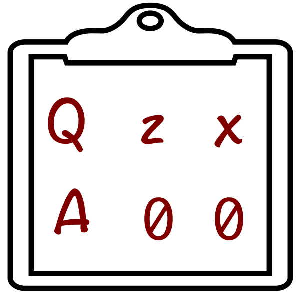
Entanglement

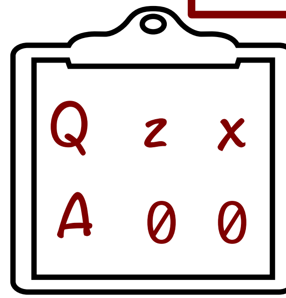
A \ B	z	x
z	=	R
x	R	=



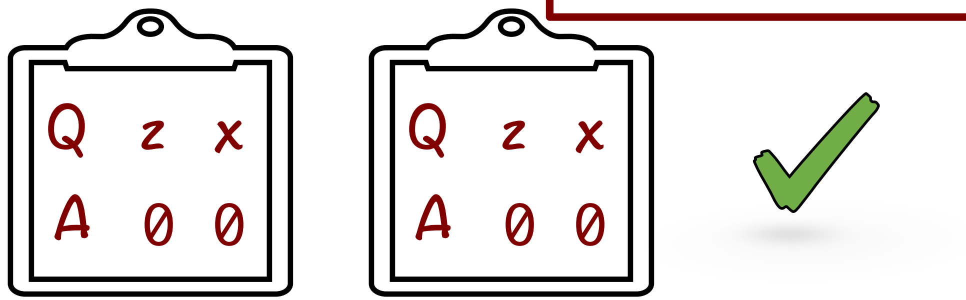
Entanglement

B / A	z	x
z	=	R
x	R	=



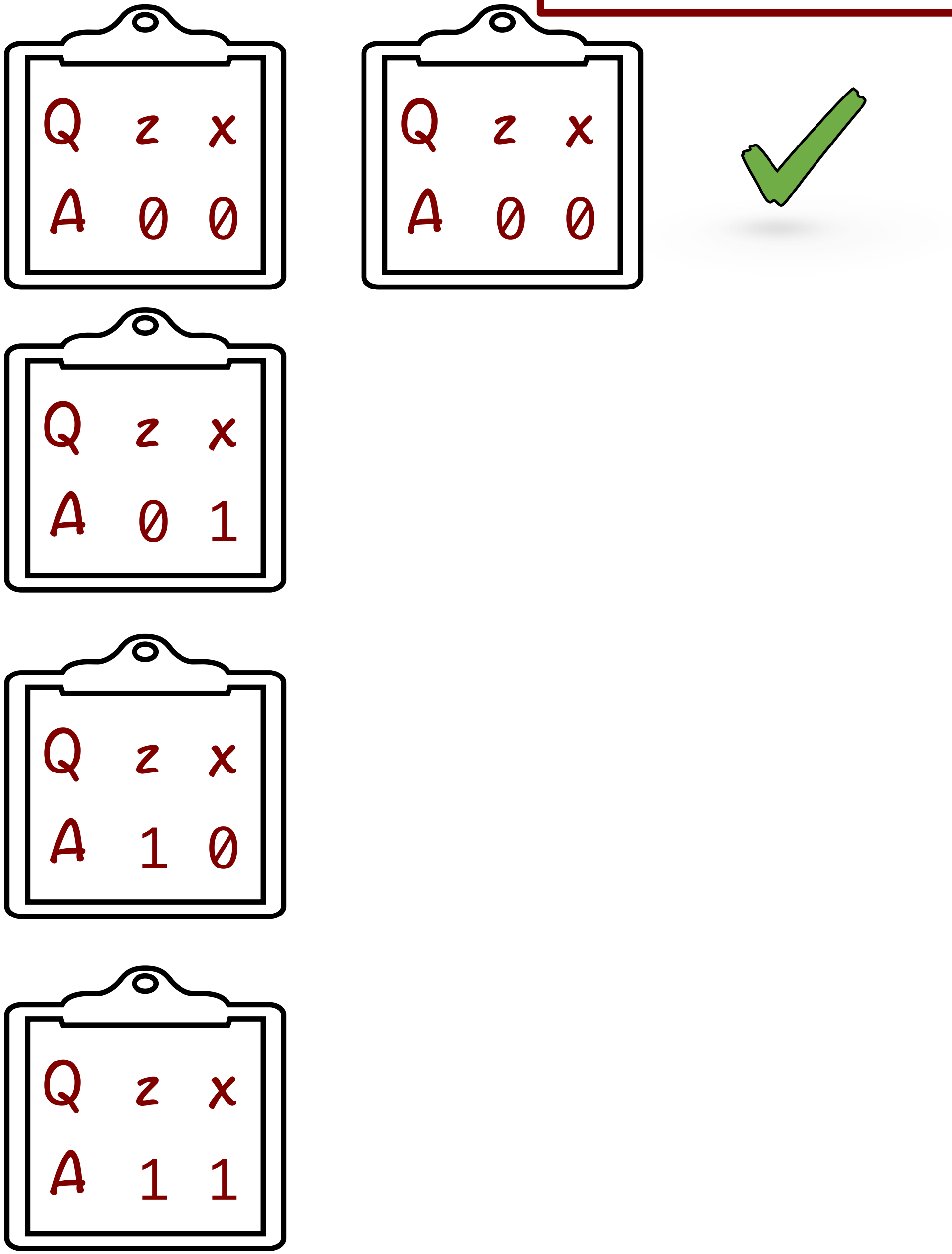


A \ B	z	x
z	=	R
x	R	=



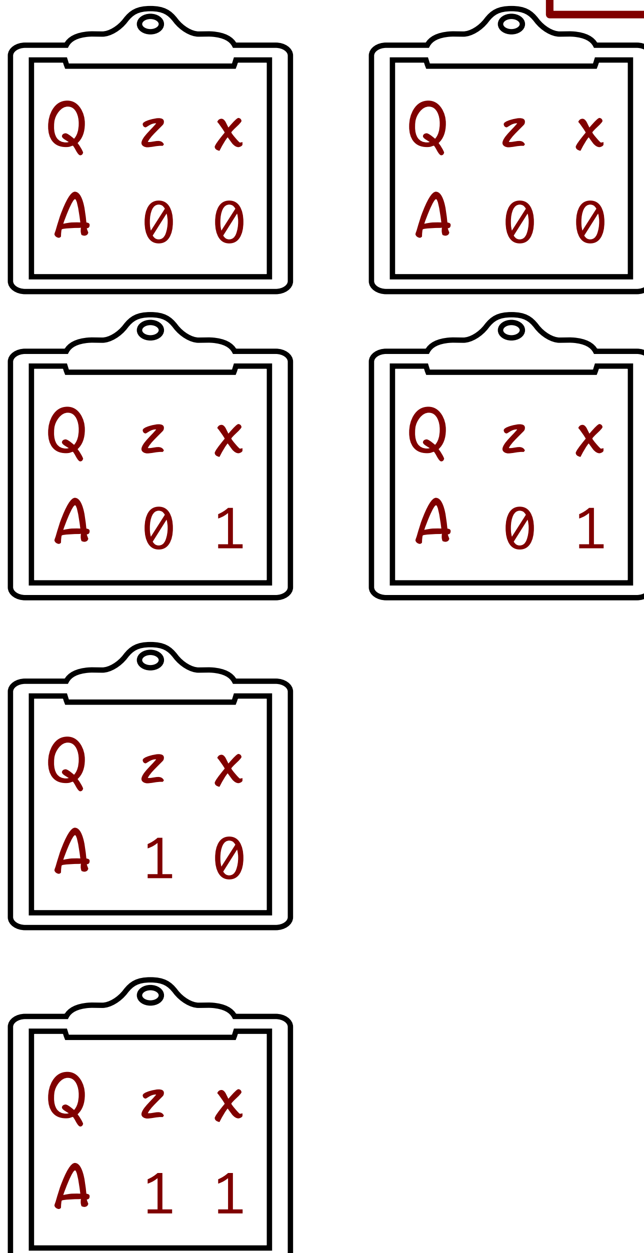
Entanglement

A \ B	z	x
z	=	R
x	R	=



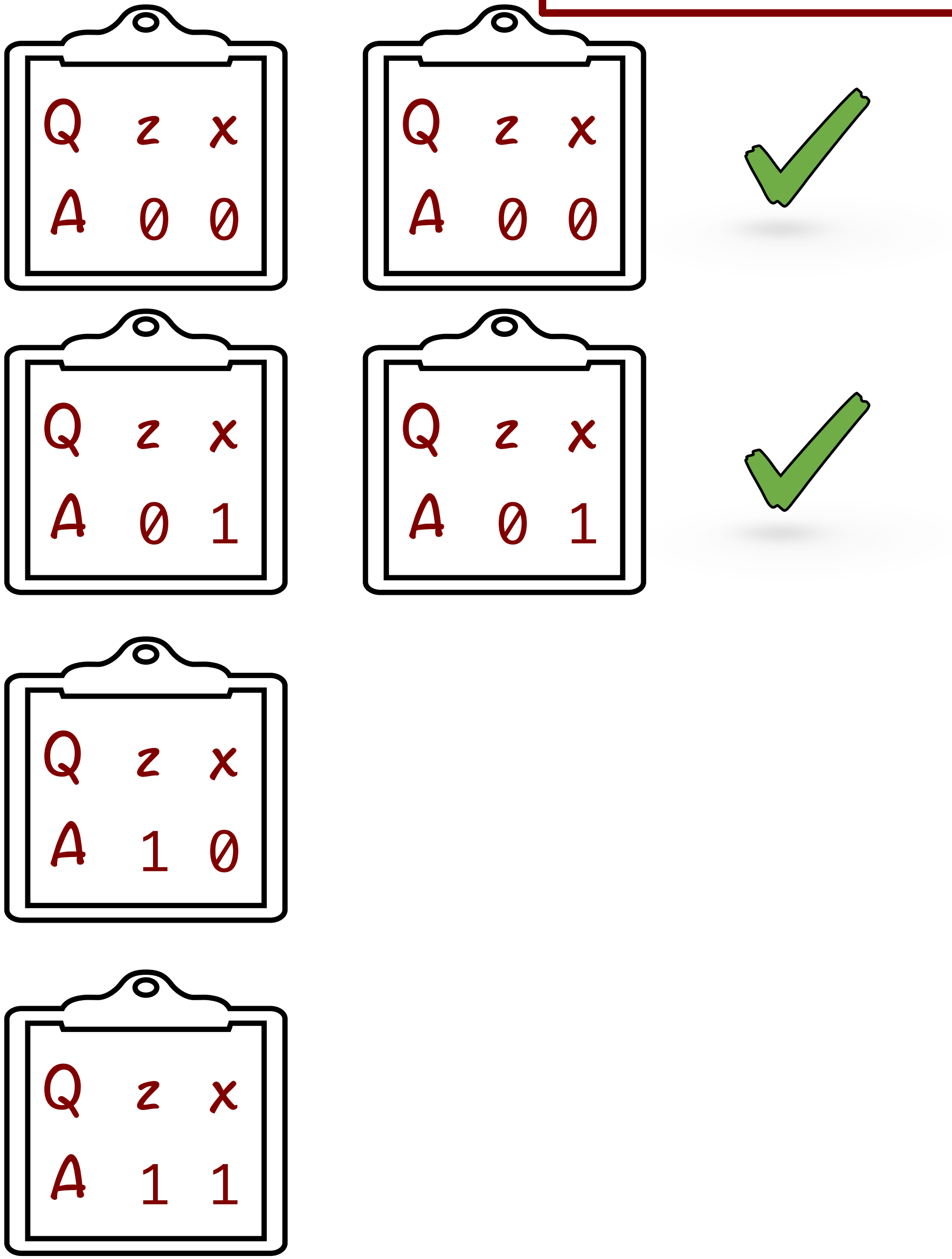
Entanglement

A \ B	z	x
z	=	R
x	R	=



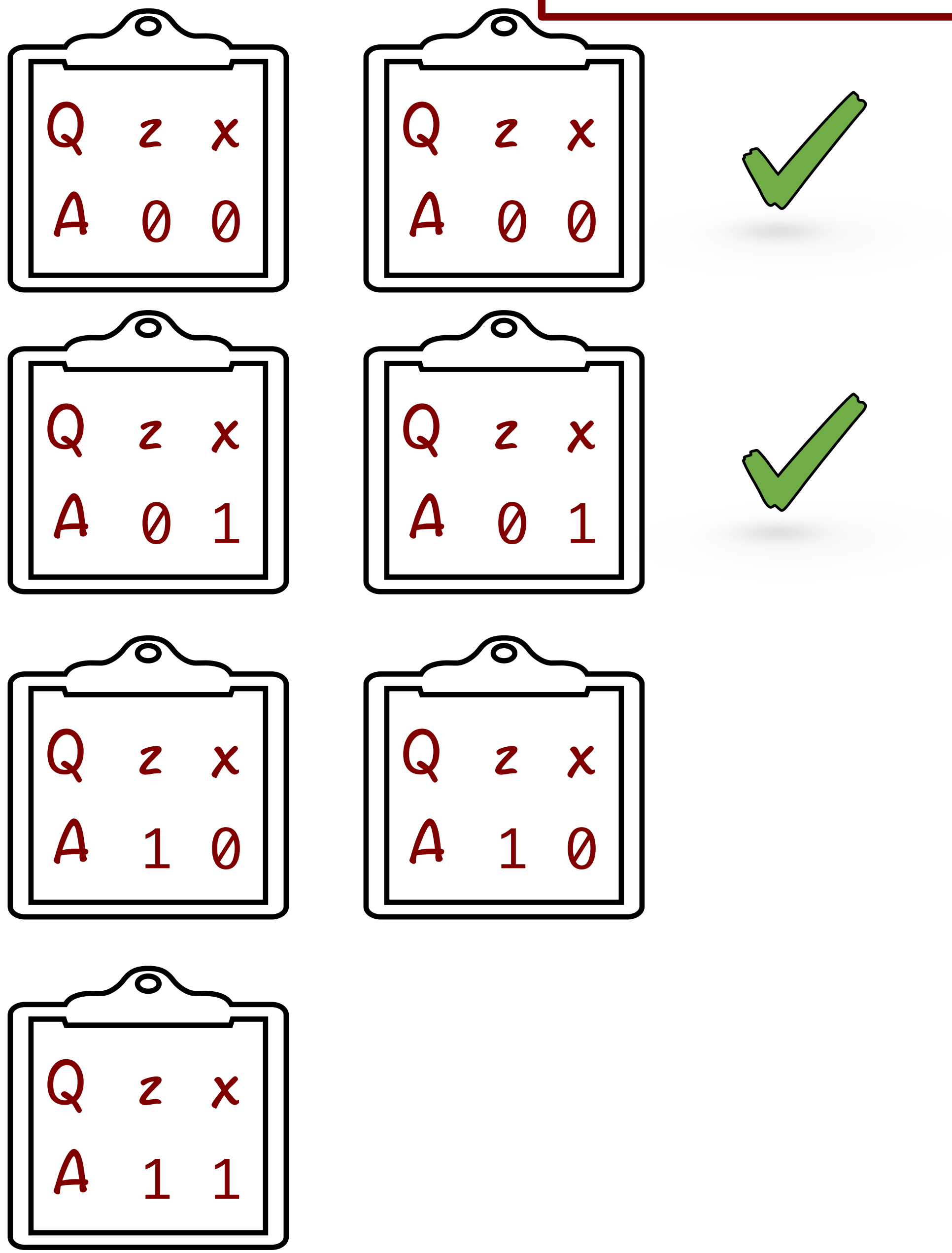
Entanglement

A \ B	z	x
z	=	R
x	R	=



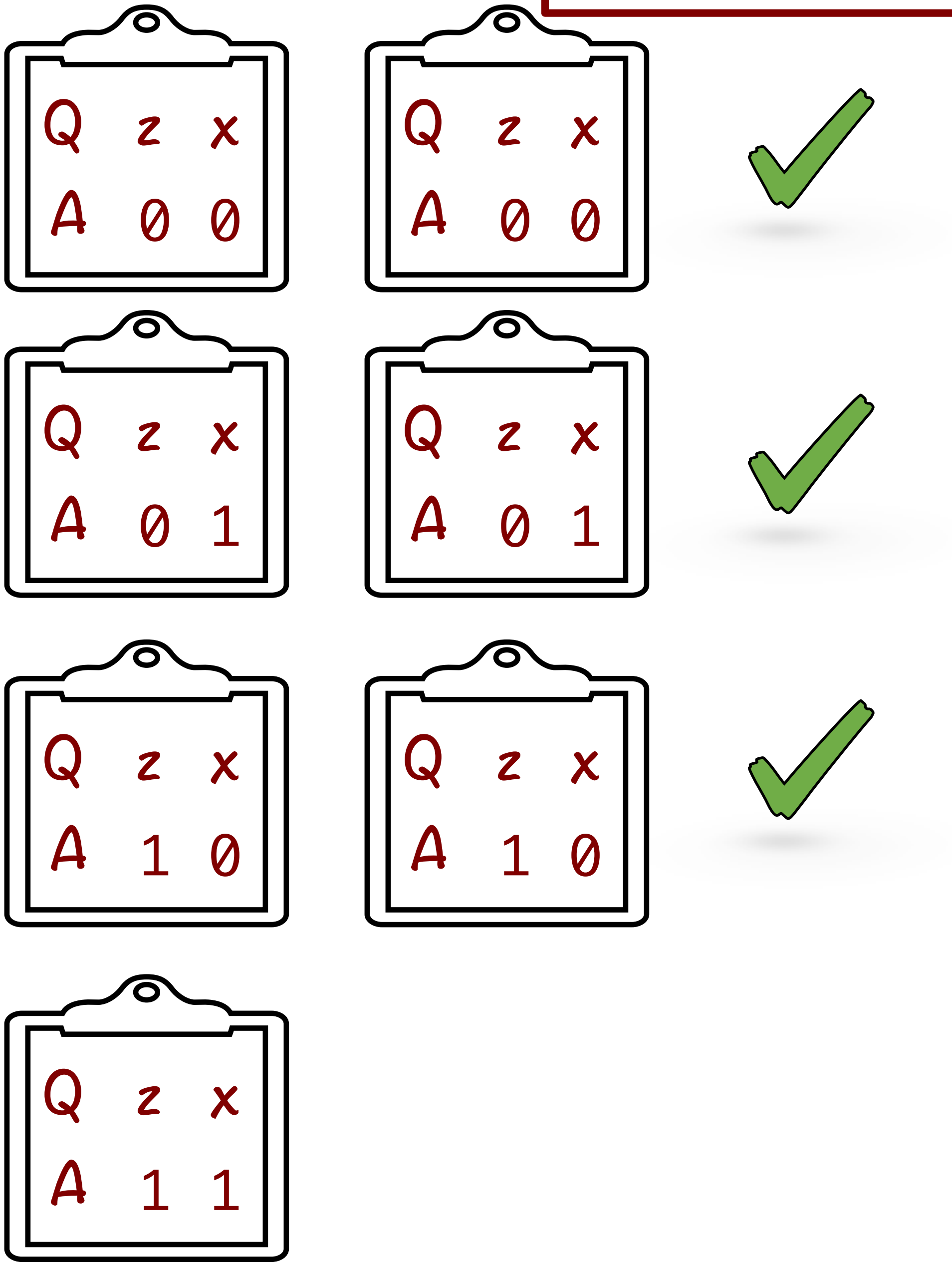
Entanglement

A \ B	z	x
z	=	R
x	R	=



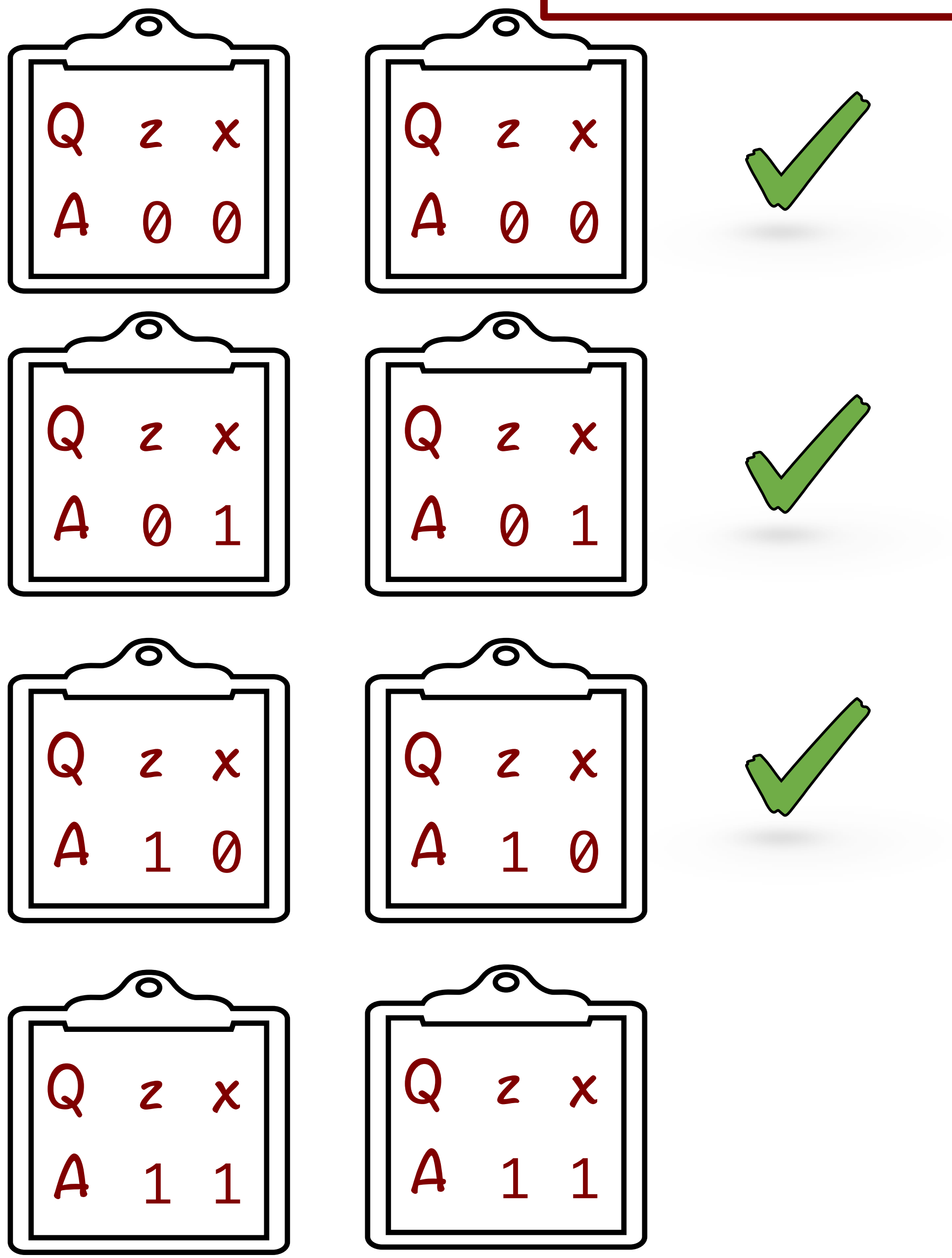
Entanglement

A \ B	z	x
z	=	R
x	R	=



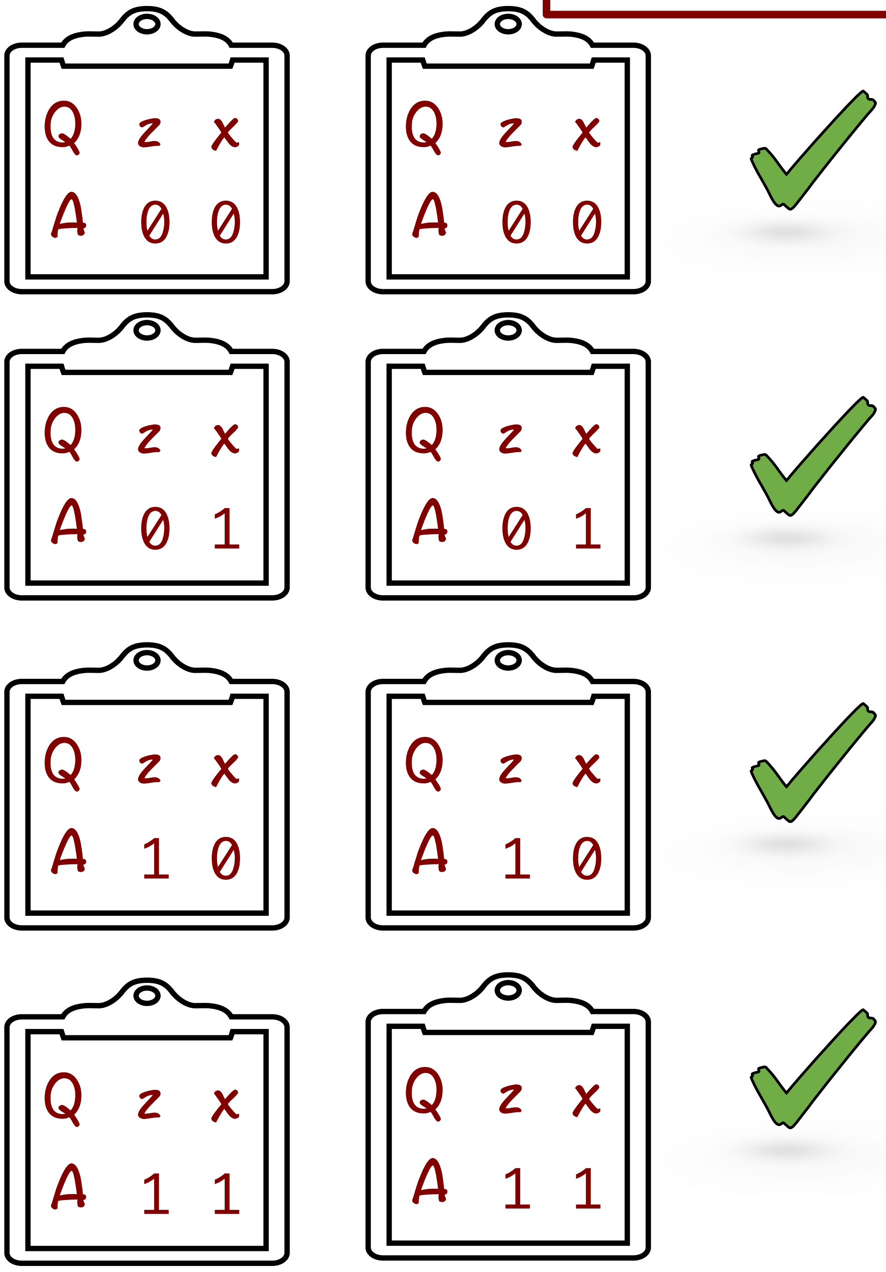
Entanglement

A \ B	z	x
z	=	R
x	R	=

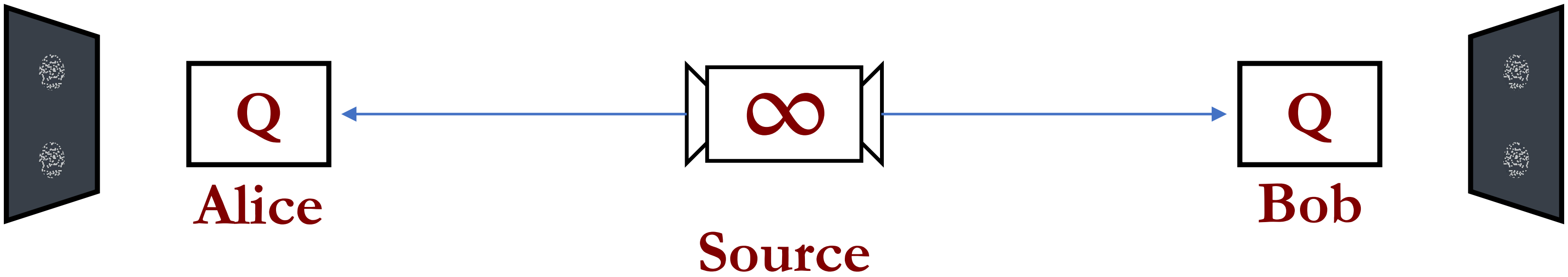


Entanglement

A \ B	z	x
z	=	R
x	R	=



Entanglement



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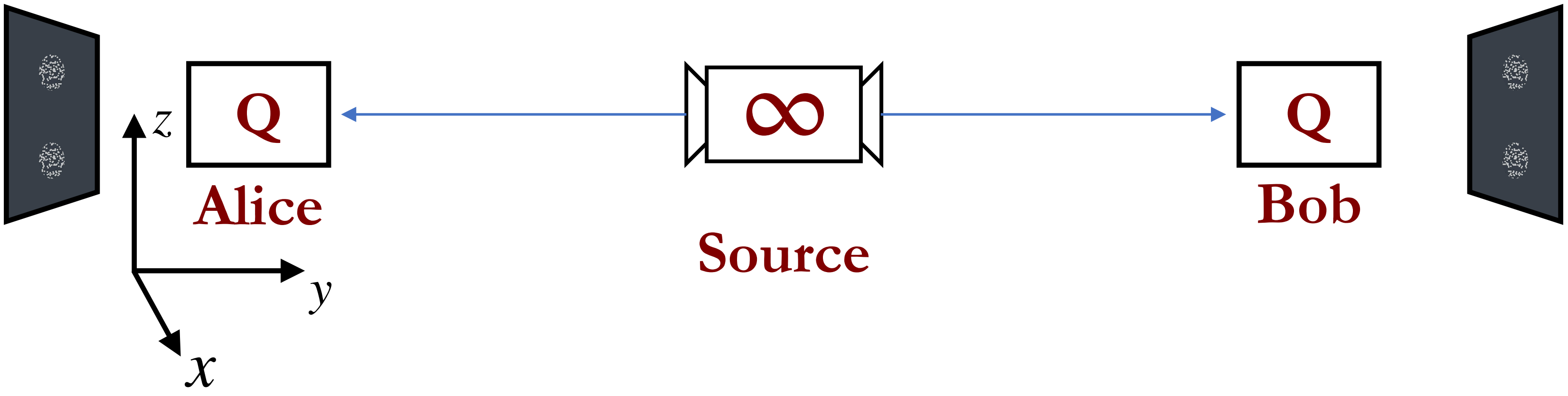
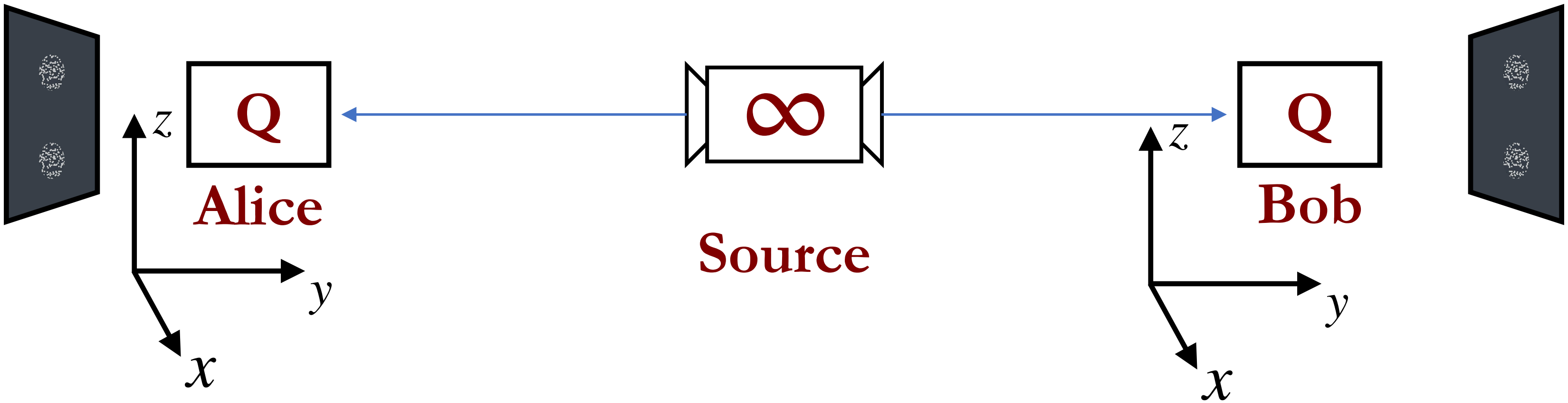
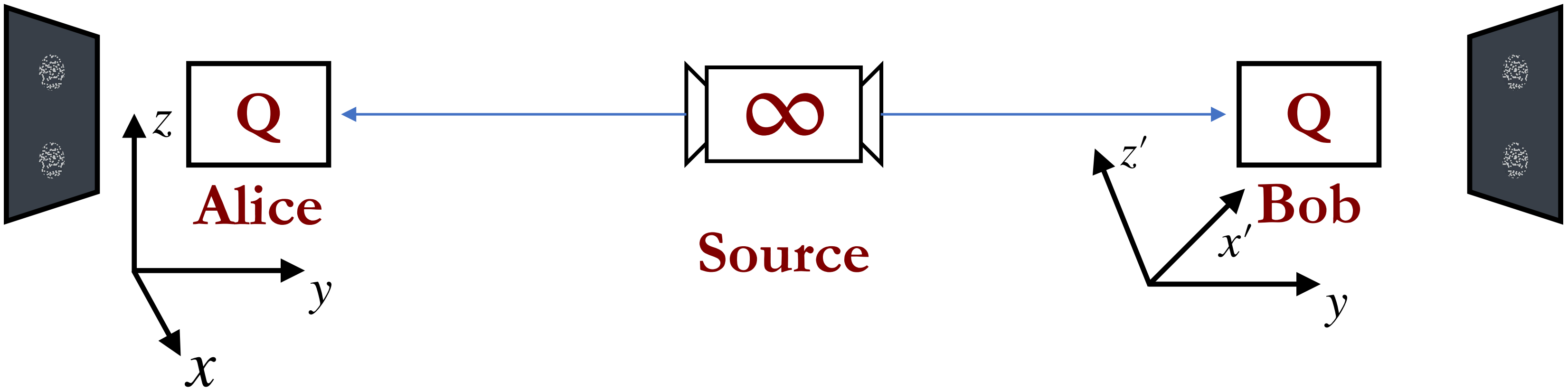
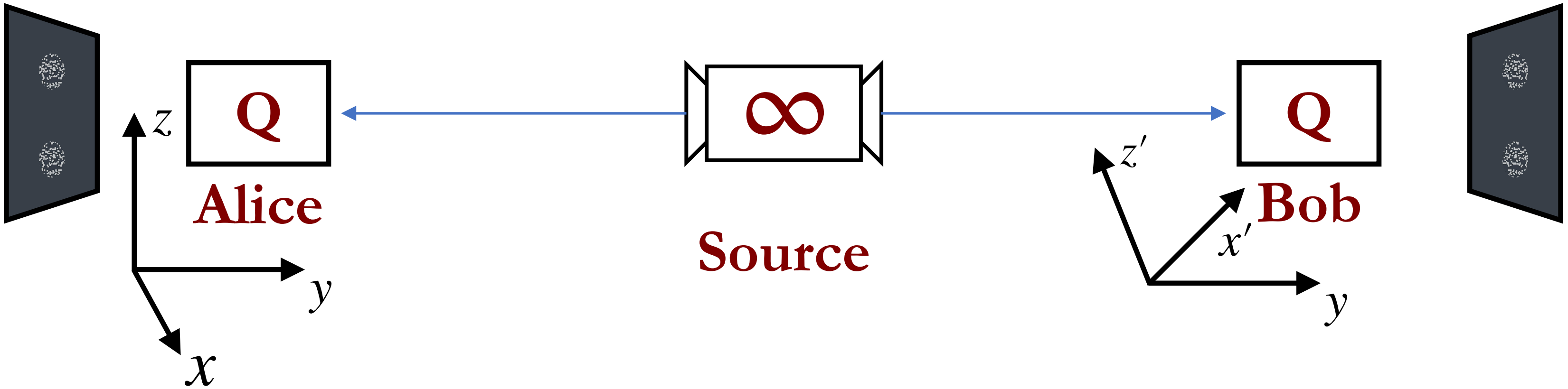


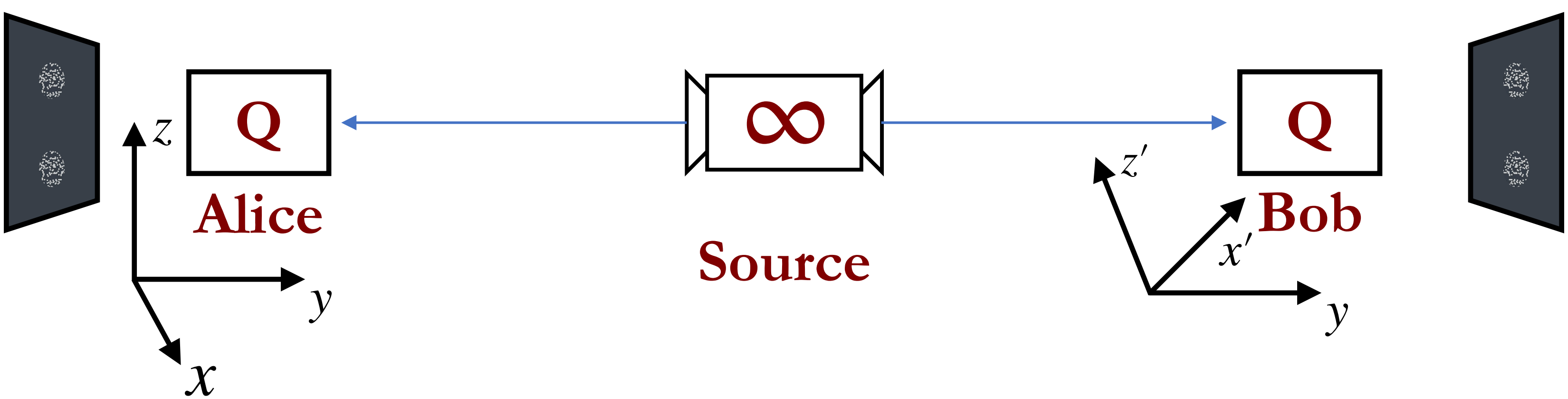

Q
Alice
z
y
x
Source
Q
Bob
z
y
x


Q
Alice
z
y
x
∞
Source
Q
Bob
z′
x′
y

B / A	z'	x'
z		
x		

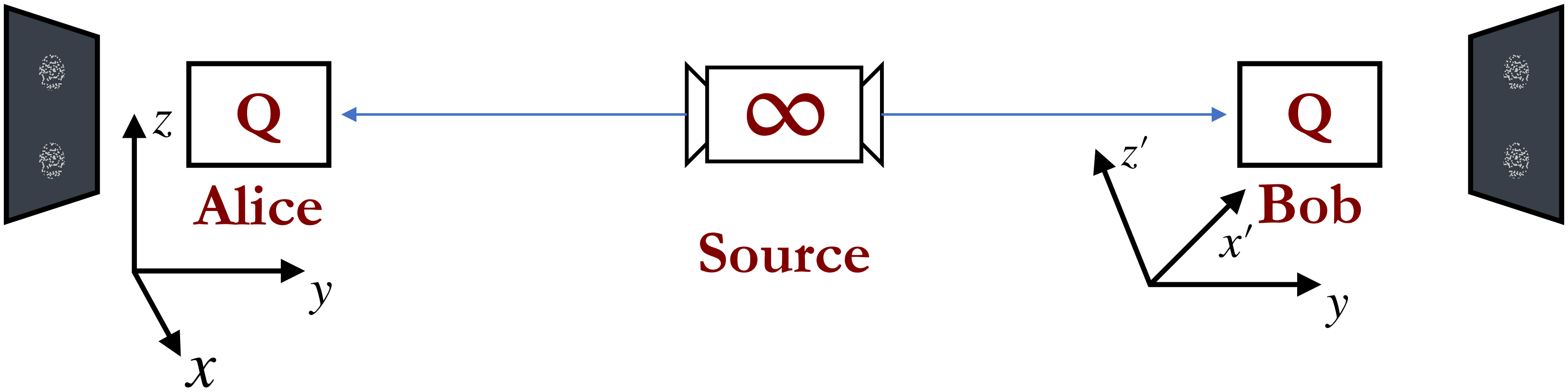


A \ B	z'	x'
z	=	
x		

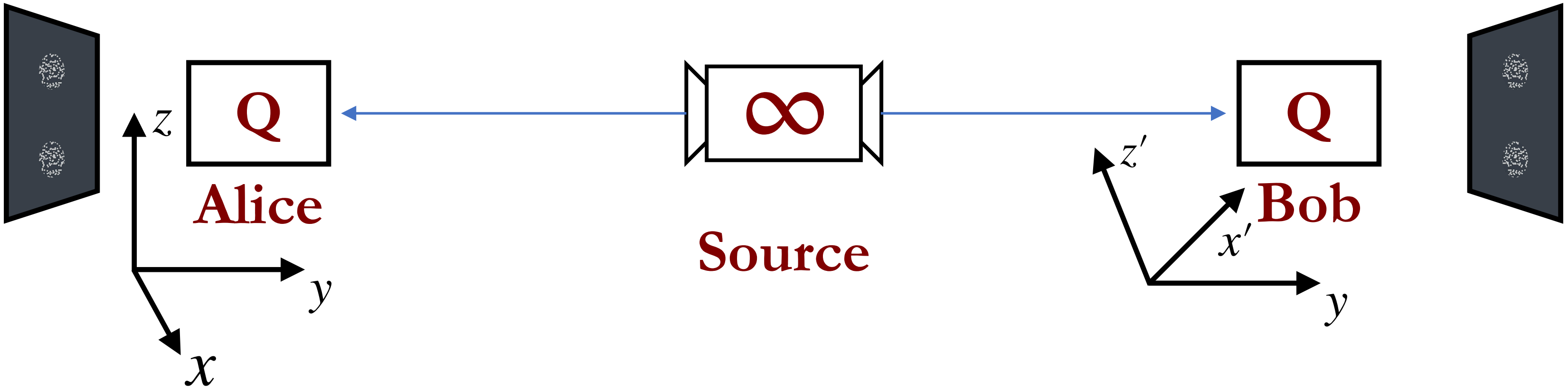


Entanglement

B / A	z'	x'
z	=	
x		≠

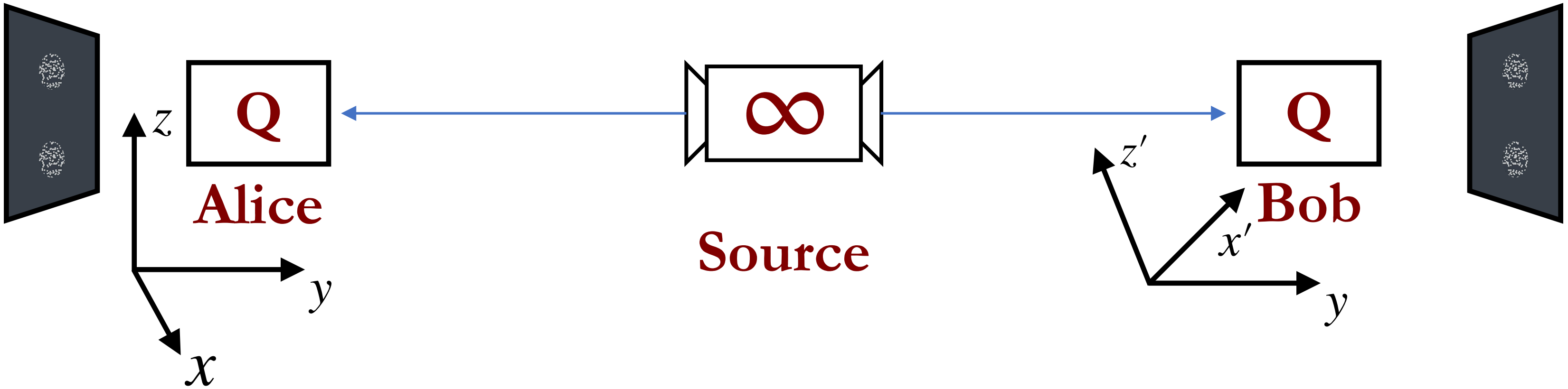


A \ B	z'	x'
z	=	=
x	=	≠

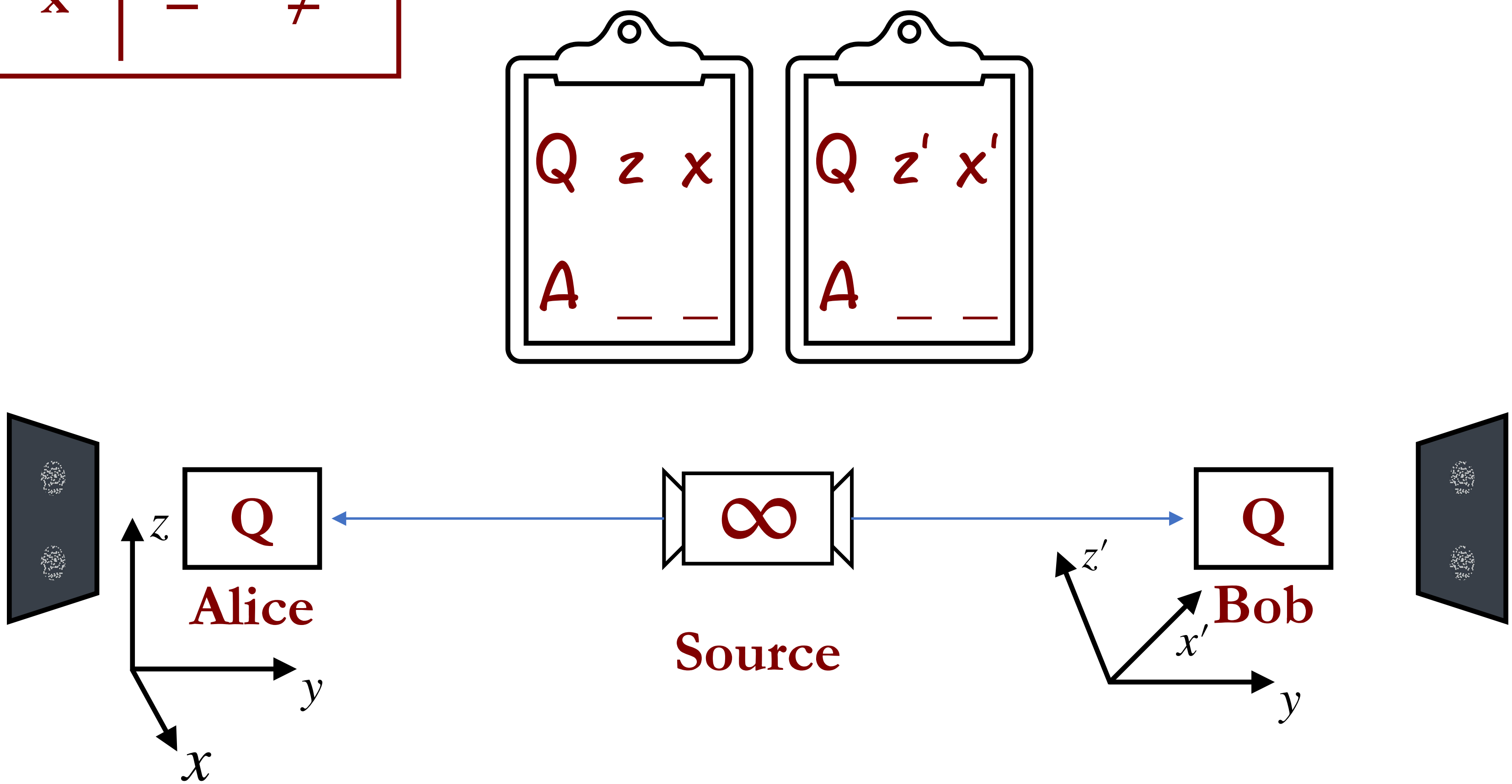


Entanglement

A \ B	z'	x'
z	=	=
x	=	≠

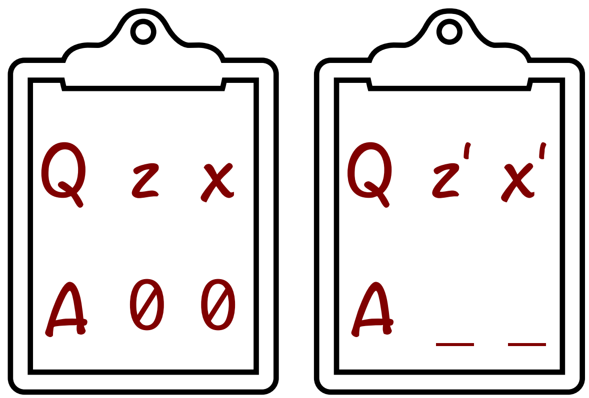


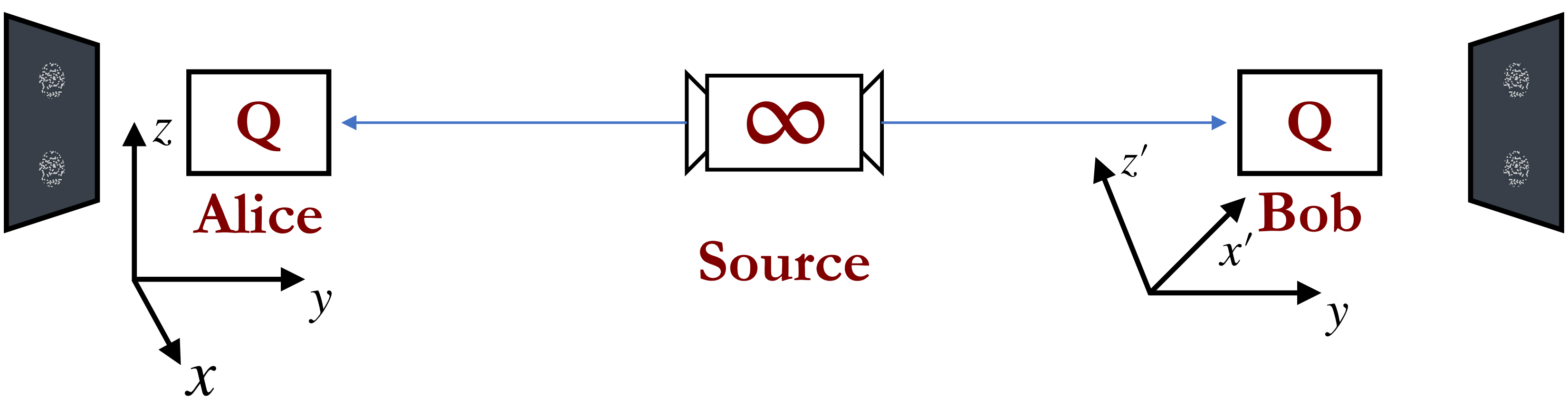
A \ B	z'	x'
z	=	=
x	=	≠



Entanglement

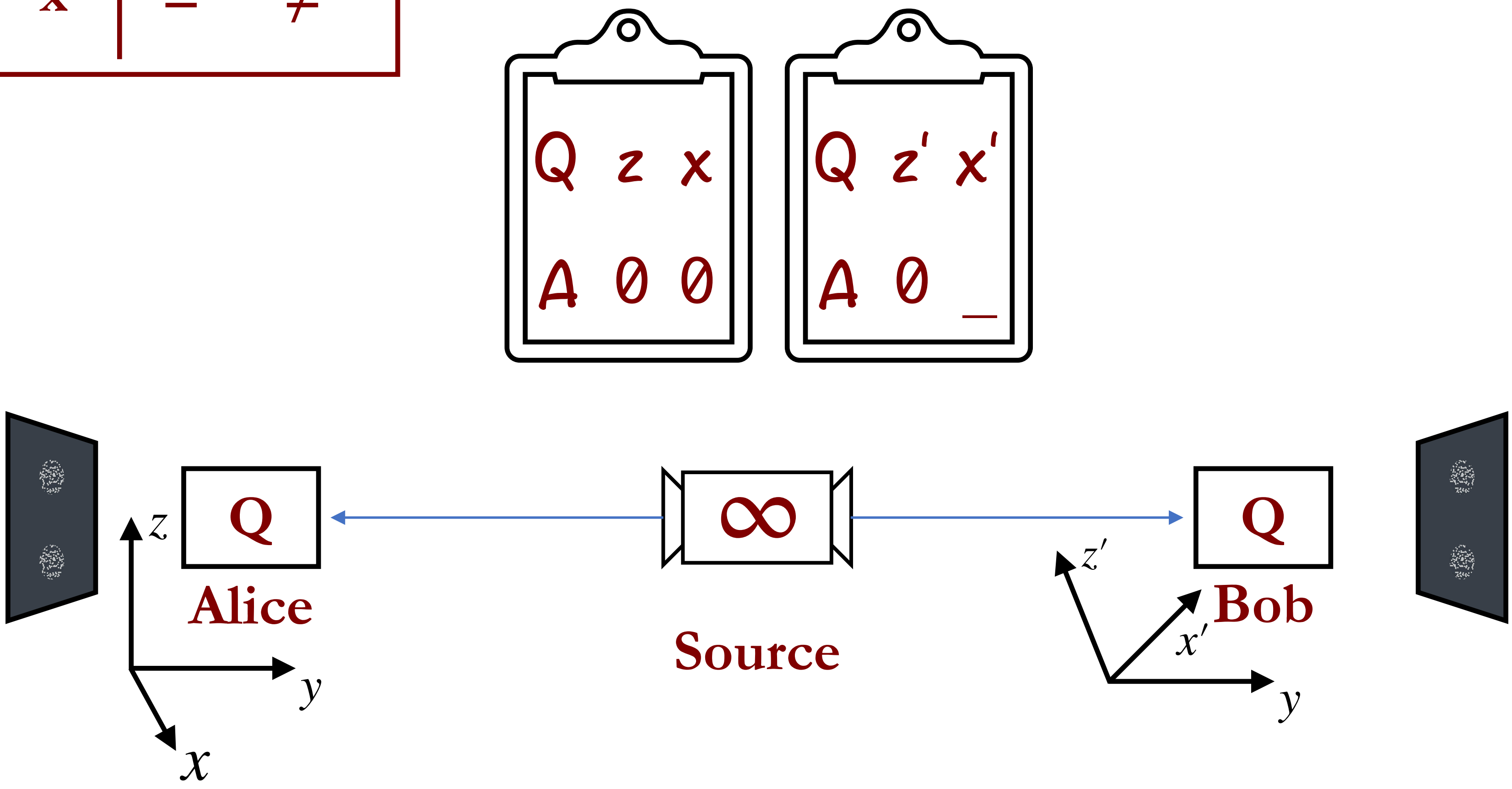
A \ B	z'	x'
z	=	=
x	=	≠





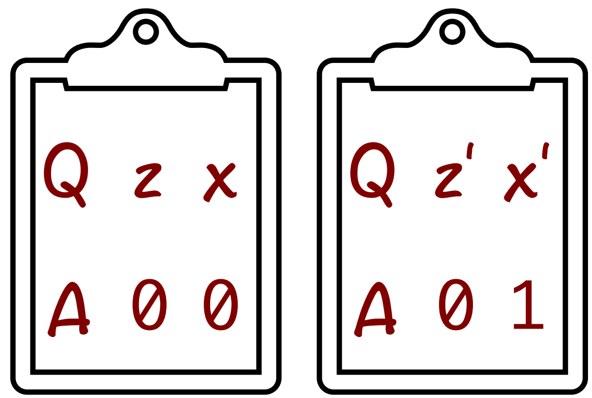
Entanglement

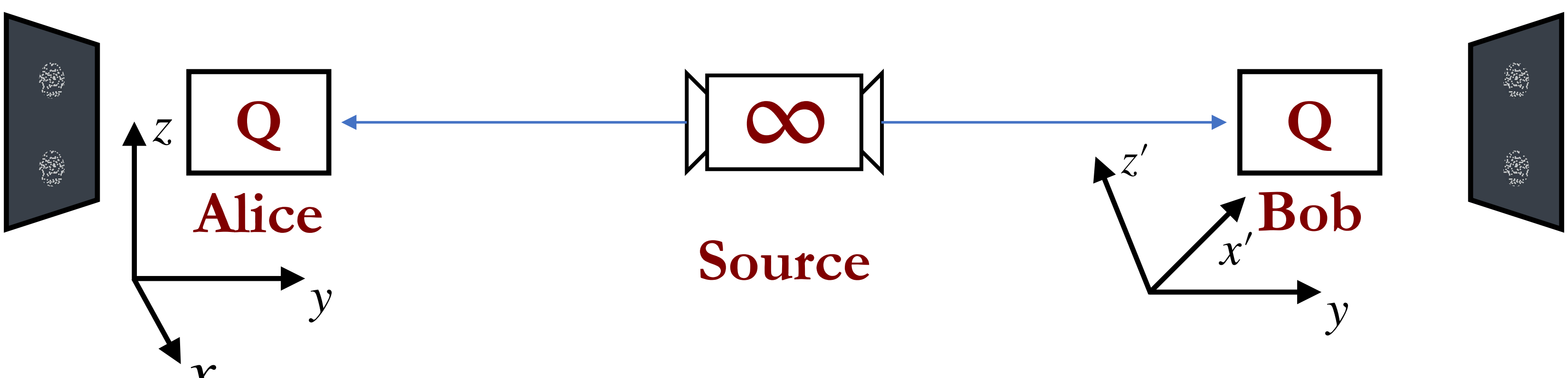
B / A	z'	x'
z	=	=
x	=	≠



Entanglement

A \ B	z'	x'
z	=	=
x	=	≠





Entanglement

A \ B	z'	x'
z	=	=
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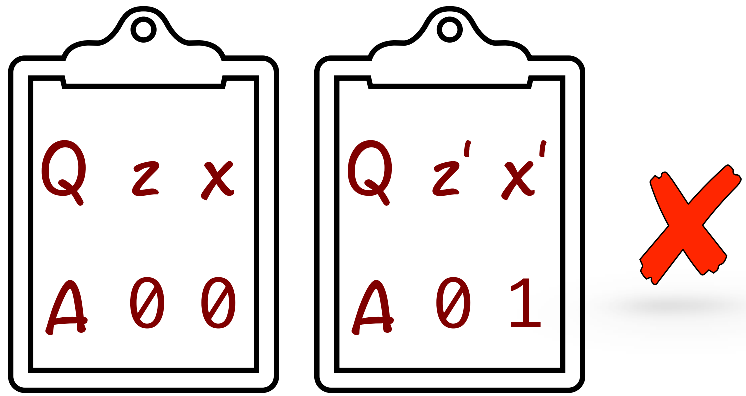
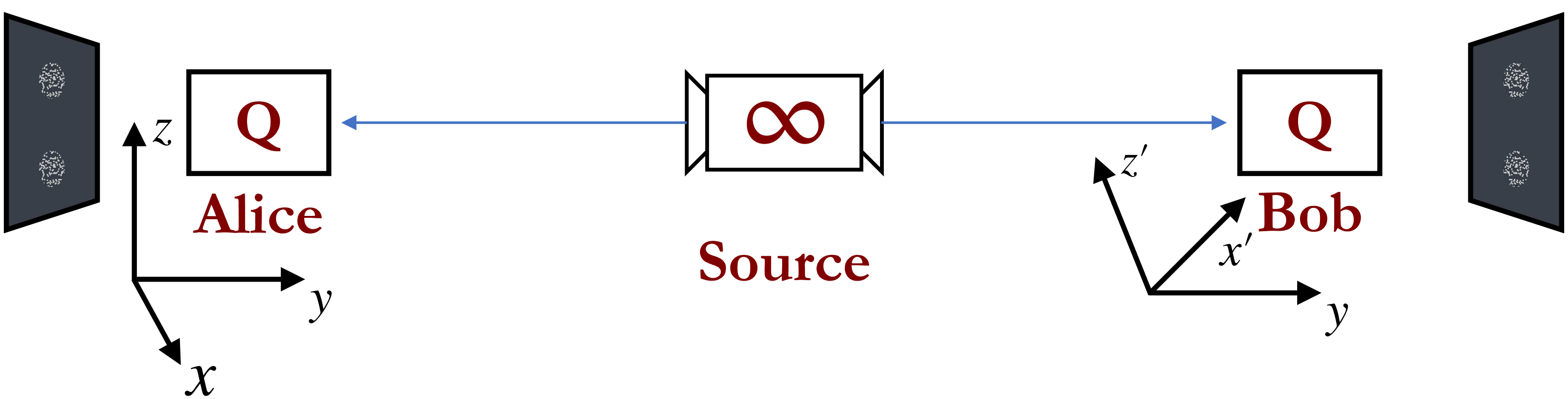
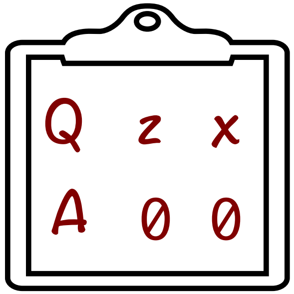
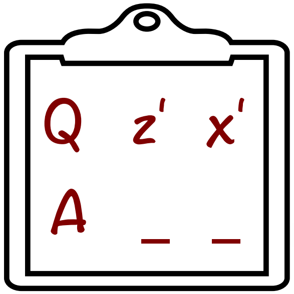




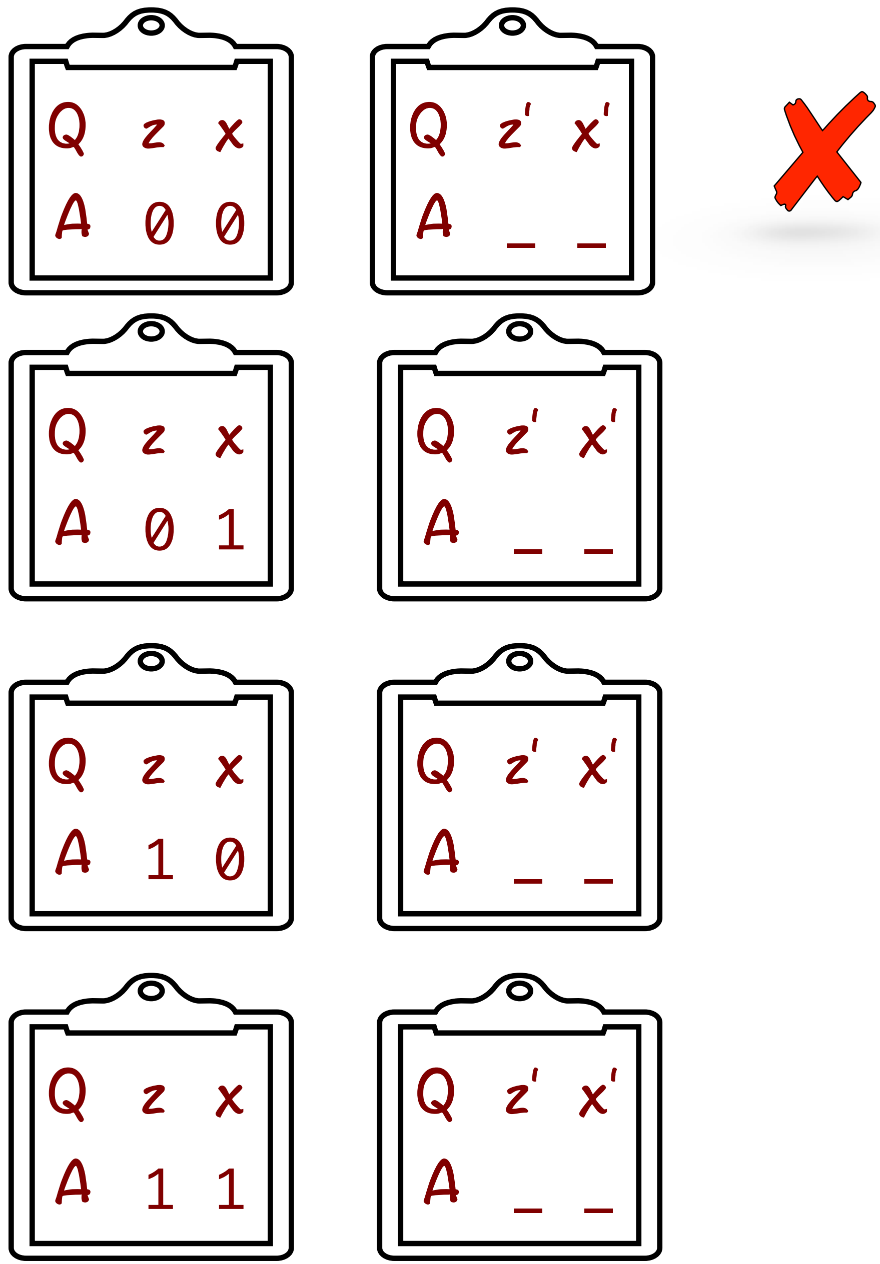
B / A	z'	x'
z	=	=
x	=	≠





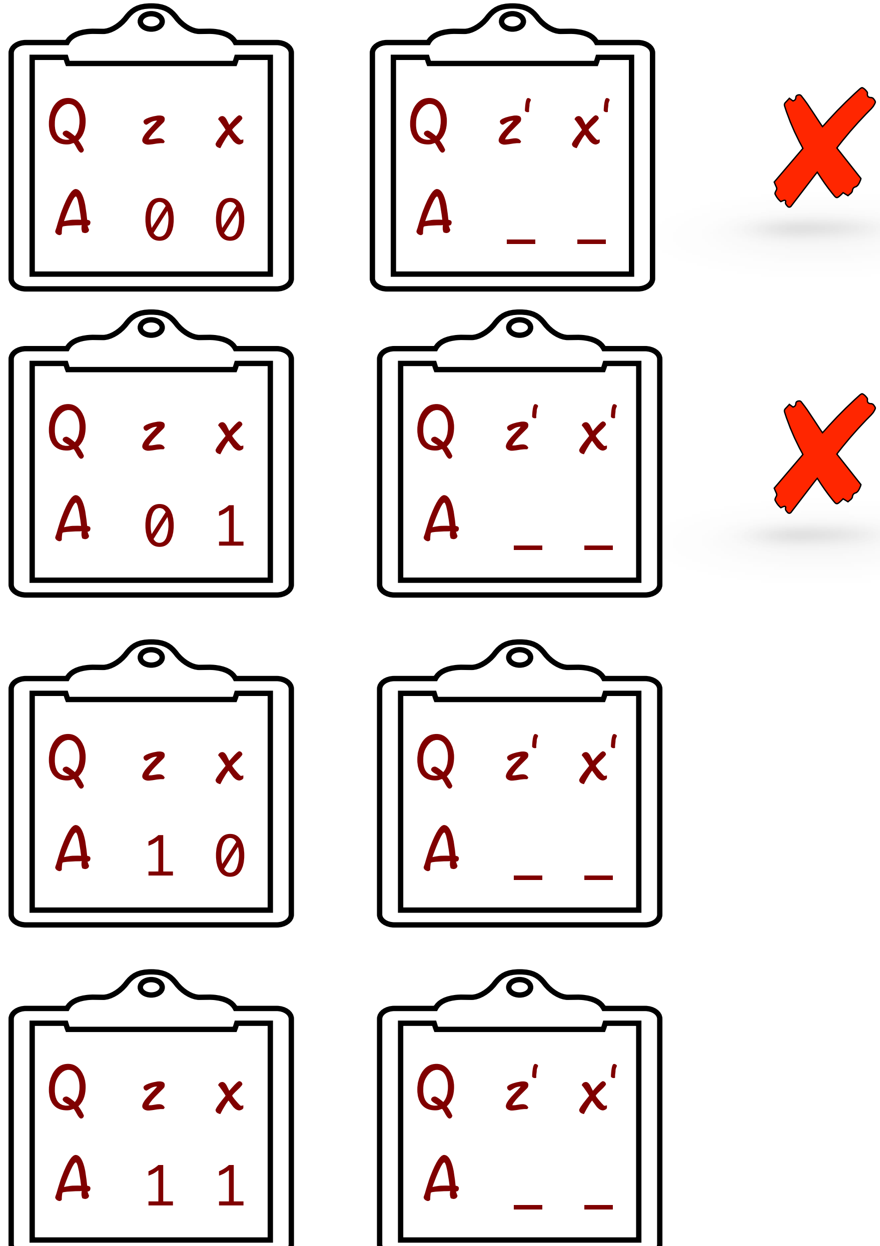
Entanglement

A \ B	z'	x'
z	=	=
x	=	≠



Entanglement

A \ B	z'	x'
z	=	=
x	=	≠



Entanglement

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z	=	=
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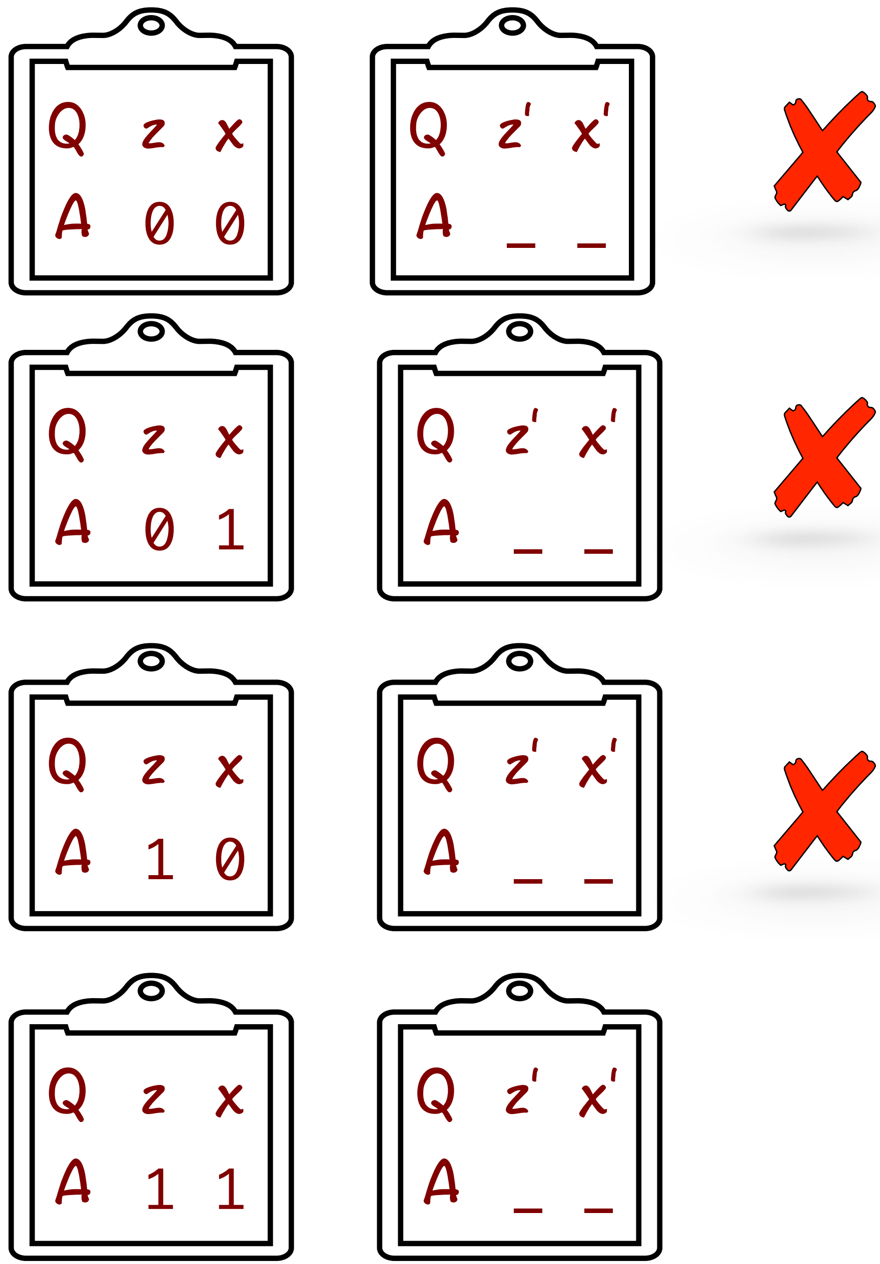

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z	=	=
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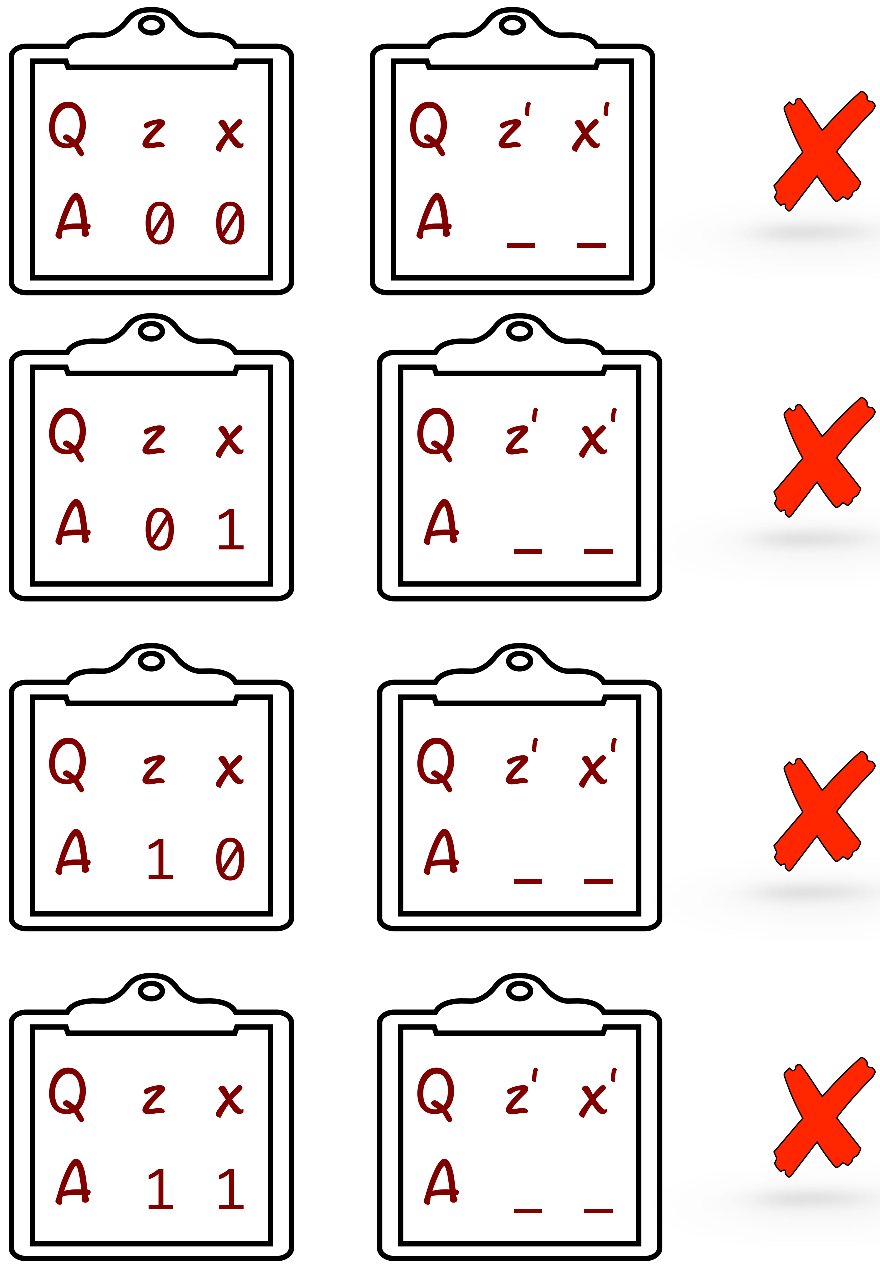
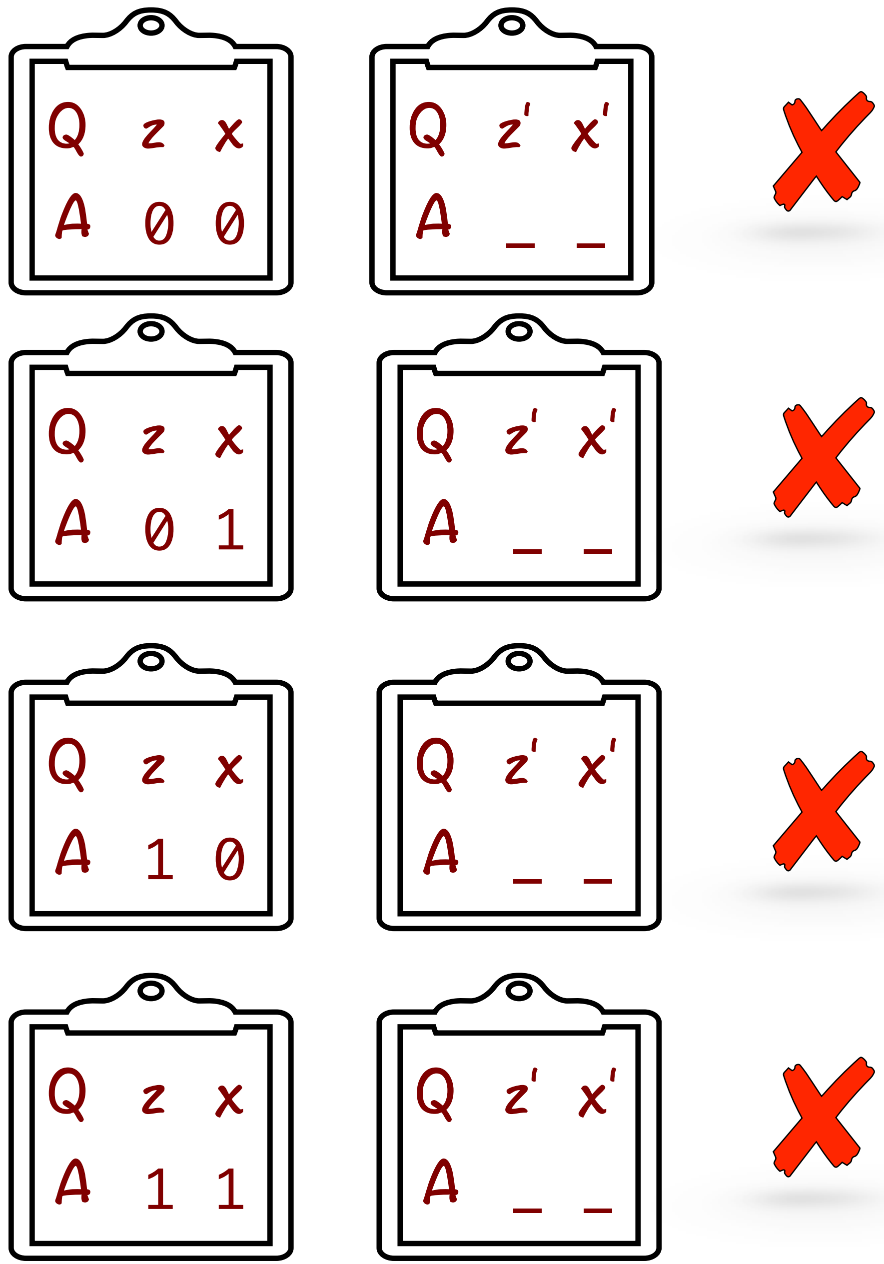


A \ B	z'	x'
z	=	=
x	=	≠

Can answer correctly only 75% of the time!



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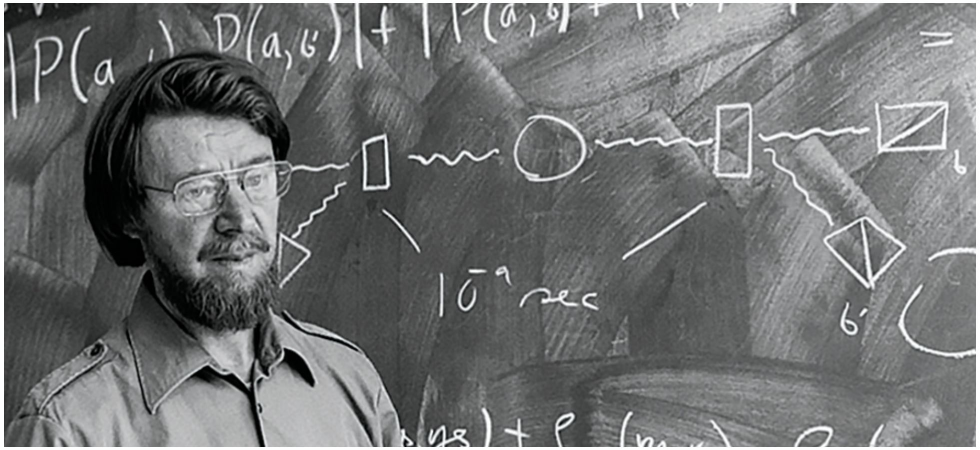
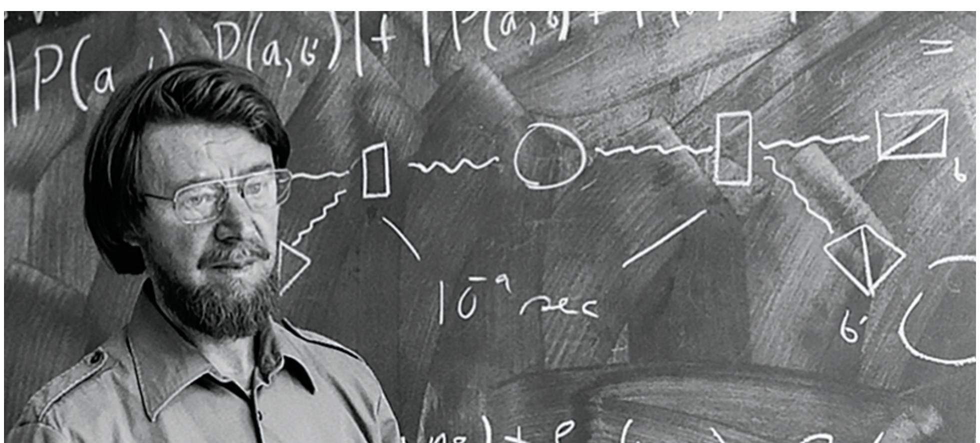


Entanglement

Experimental Realization of Einstein-Podolsky-Rosen-Bohm *Gedankenexperiment*: A New Violation of Bell's Inequalities

Alain Aspect, Philippe Grangier, and Gérard Roger
Phys. Rev. Lett. **49**, 91 – Published 12 July 1982



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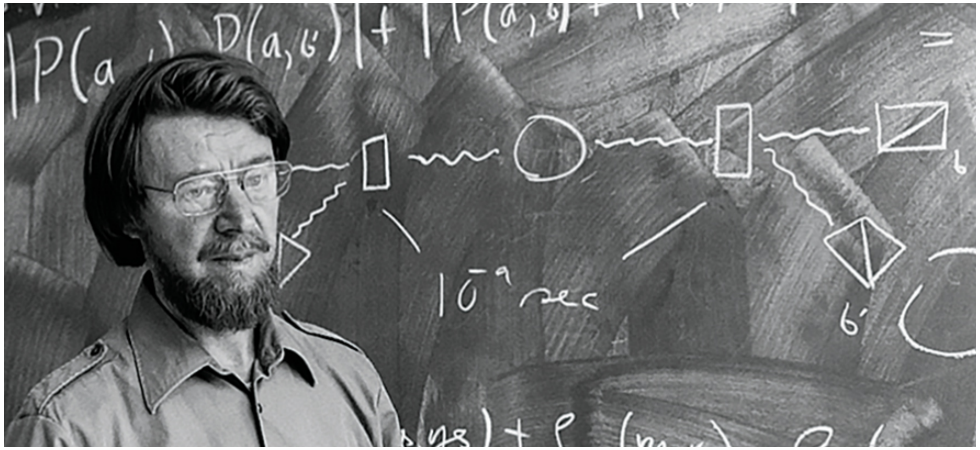

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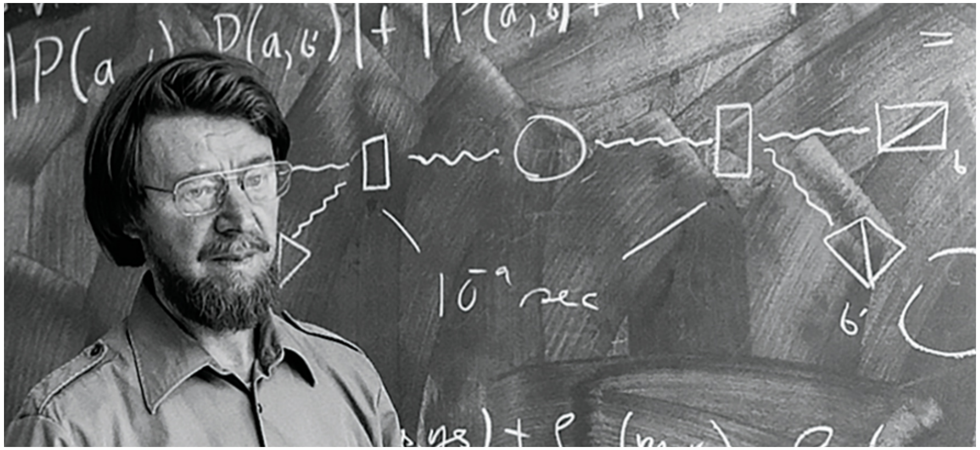

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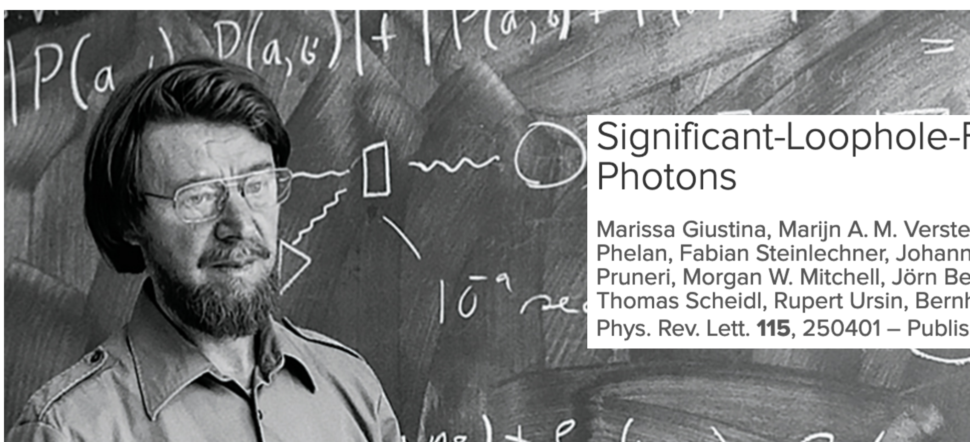

Significant-Loophole-Free Test of Bell's Theorem with Entangled Photons

Marissa Giustina, Marijn A. M. Versteegh, Sören Wengerowsky, Johannes Handsteiner, Armin Hochrainer, Kevin Phelan, Fabian Steinlechner, Johannes Kofler, Jan-Åke Larsson, Carlos Abellán, Waldimar Amaya, Valerio Pruneri, Morgan W. Mitchell, Jörn Beyer, Thomas Gerrits, Adriana E. Lita, Lynden K. Shalm, Sae Woo Nam, Thomas Scheidl, Rupert Ursin, Bernhard Wittmann, and Anton Zeilinger
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Nature answers correctly 82% of the time!

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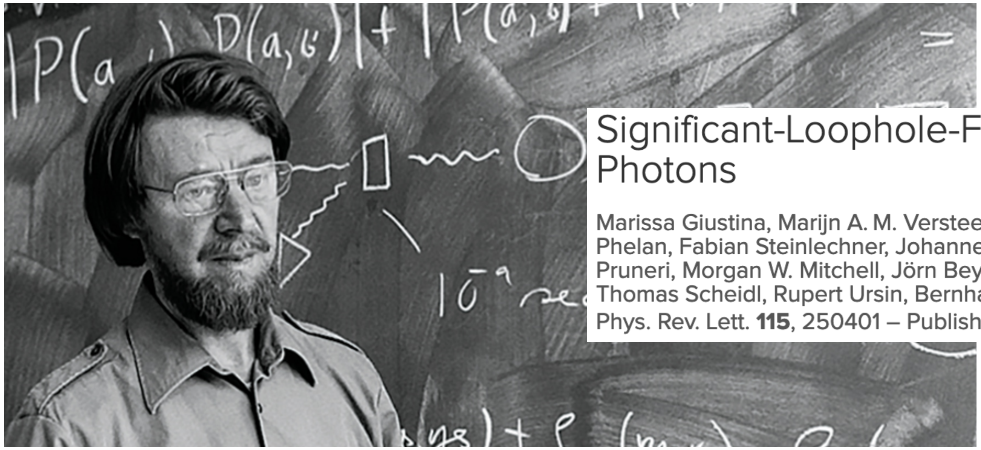

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Interpretations

Interpretations

Interpretation	Year published	Author(s)	Deterministic?	Ontic wave-function?	Unique history?	Hidden variables?	Collapsing wave-functions?	Observer role?	Local dynamics?	Counter-factually definite?	Extant universal wave-function?
Ensemble interpretation	1926	Max Born	Agnostic	No	Yes	Agnostic	No	No	No	No	No
Copenhagen interpretation	1927	Niels Bohr, Werner Heisenberg	No	No[a]	Yes	No	Yes[b]	Causal	Yes	No	No
de Broglie–Bohm theory	1927–1952	Louis de Broglie, David Bohm	Yes	Yes[c]	Yes[d]	Yes	Phenomen-ological	No	No	Yes	Yes
Quantum logic	1936	Garrett Birkhoff	Agnostic	Agnostic	Yes[e]	No	No	Interpre-tational[f]	Agnostic	No	No
Time-symmetric theories	1955	Satosi Watanabe	Yes	No	Yes	Yes	No	No	No[55]	No	Yes
Many-worlds interpretation	1957	Hugh Everett	Yes	Yes	No	No	No	No	Yes	Ill-posed	Yes
Consciousness causes collapse	1961–1993	John von Neumann, Eugene Wigner, Henry Stapp	No	Yes	Yes	No	Yes	Causal	No	No	Yes
Stochastic interpretation	1966	Edward Nelson	No	No	Yes	Yes[g]	No	No	No	Yes[g]	No
Many-minds interpretation	1970	H. Dieter Zeh	Yes	Yes	No	No	No	Interpre-tational[h]	Yes	Ill-posed	Yes
Consistent histories	1984	Robert B. Griffiths	No	No	No	No	No[i]	No	Yes	No	Yes
Transactional interpretation	1986	John G. Cramer	No	Yes	Yes	No	Yes[j]	No	No[k]	Yes	No
Objective collapse theories	1986–1989	Ghirardi–Rimini–Weber, Penrose interpretation	No	Yes	Yes	No	Yes	No	No	No	No
Relational interpretation	1994	Carlo Rovelli	No[56]	No	Agnostic[l]	No	Yes[m]	Intrinsic[n]	Yes[57]	No	No
QBism	2010	Christopher Fuchs, Ruediger Schack	No	No[o]	Agnostic[p]	No	Yes[q]	Intrinsic[r]	Yes	No	No

https://en.wikipedia.org/wiki/Interpretations_of_quantum_mechanics#Comparisons

What could be an explanation for entanglement?

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- Reality is relational

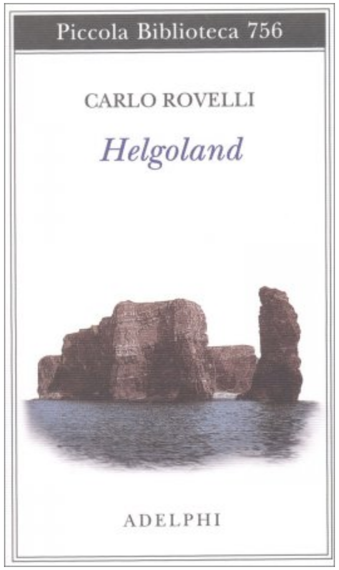
What could be an explanation for entanglement?

- Alice and Bob somehow rarely ask the "wrong" question
- Faster-than-light signalling (= signalling back in time)
- ???
- Parallel worlds
- Reality is relational
- Need a new concept of "explanation"

Thank You!

Hope you are confused

Read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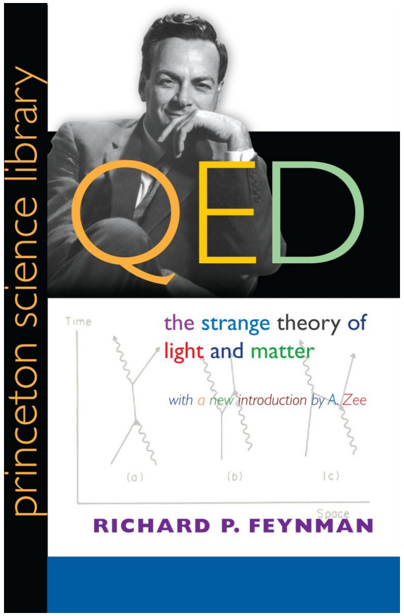
CARLO ROVELLI
Helgoland
ADELPHI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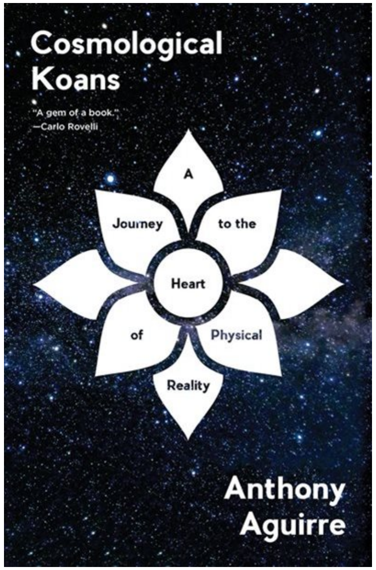
with a new introduction by A. Zee
RICHARD P. FEYNMAN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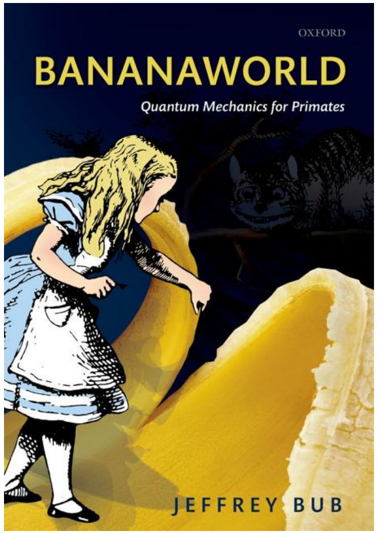
—Carlo Rovelli
A Journey to the Heart of Physical Reality
Anthony Aguirre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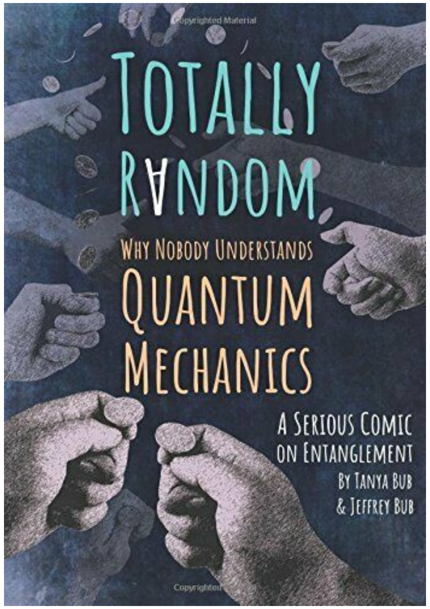
BANANAWORLD
Quantum Mechanics for Primates
JEFFREY BUB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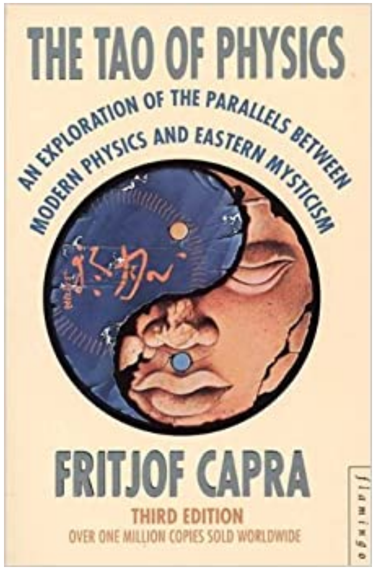
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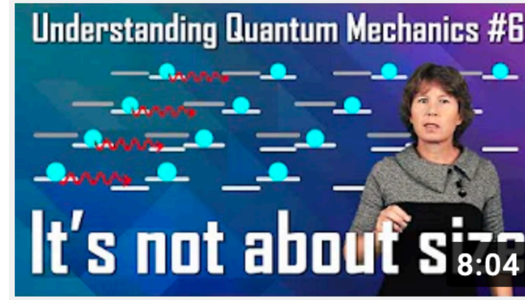

Understanding Quantum Mechanics #6: It's not just a...

Sabine Hossenfelder

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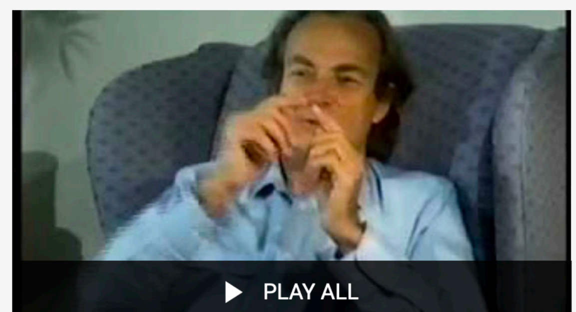
The Character of Physical Law - Richard Feynman (1964)



Feynman 'Fun to Imagine'