Seminario

Introducción a los fundamentos de la computación cuántica I: Principios físicos

Isaac Alejandro Pimentel Morales

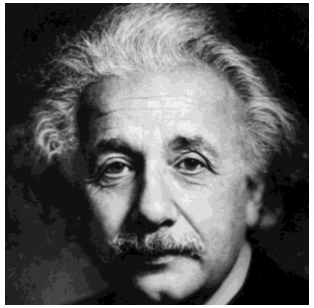
Diego Pérez Reyes

QUANTUM LAB

Historia

M. Faraday
Rayos Catódicos
1838

H. Hertz
Efecto fotoeléctrico
1887

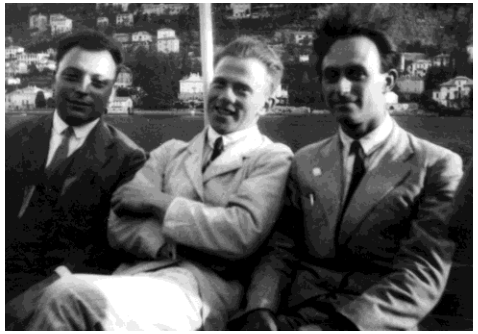


A. Einstein
Teoría del efecto fotoeléctrico
1905

G. Kirchhoff
Radiación de cuerpo negro
1877

L. Boltzmann
Estados de energía discretos
1877

Max Plank
Hipótesis Cuántica
1900



Max Born
W. Heisenberg
W. Pauli
"Quantum Mechanik"
1924

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Journal of Statistical Physics, Vol. 22, No. 5, 1980

The Computer as a Physical System: A Microscopic Quantum Mechanical Hamiltonian Model of Computers as Represented by Turing Machines

Paul Benioff[1,2]

Received June 11, 1979; revised August 9, 1979

In this paper a microscopic quantum mechanical model of computers as represented by Turing machines is constructed. It is shown that for each number N and Turing machine Q there exists a Hamiltonian $H_N{}^Q$ and a class of appropriate initial states such that if $\Psi_Q{}^N(0)$ is such an initial state, then $\Psi_Q{}^N(t) = \exp(-iH_N{}^Q t)\,\Psi_Q{}^N(0)$ correctly describes at times $t_3, t_6, \ldots, t_{3N}$ model states that correspond to the completion of the first, second,..., Nth computation step of Q. The model parameters can be adjusted so that for an arbitrary time interval Δ around $t_3, t_6, \ldots, t_{3N}$, the "machine" part of $\Psi_Q{}^N(t)$ is stationary.

KEY WORDS: Computer as a physical system; microscopic Hamiltonian models of computers; Schrödinger equation description of Turing machines; Coleman model approximation; closed conservative system; quantum spin lattices.

International Journal of Theoretical Physics, Vol. 21, Nos. 6/7, 1982

Simulating Physics with Computers

Richard P. Feynman

Department of Physics, California Institute of Technology, Pasadena, California 91107

Received May 7, 1981

1. INTRODUCTION

On the program it says this is a keynote speech—and I don't know what a keynote speech is. I do not intend in any way to suggest what should be in this meeting as a keynote of the subjects or anything like that. I have my own things to say and to talk about and there's no implication that anybody needs to talk about the same thing or anything like it. So what I want to talk about is what Mike Dertouzos suggested that nobody would talk about. I want to talk about the problem of simulating physics with computers and I mean that in a specific way which I am going to explain. The reason for doing this is something that I learned about from Ed Fredkin, and my entire interest in the subject has been inspired by him. It has to do with learning something about the possibilities of computers, and also something about possibilities in physics. If we suppose that we know all the physical laws perfectly, of course we don't have to pay any attention to computers. It's interesting anyway to entertain oneself with the idea that we've got something to learn about physical laws; and if I take a relaxed view here (after all I'm here and not at home) I'll admit that we don't understand everything.

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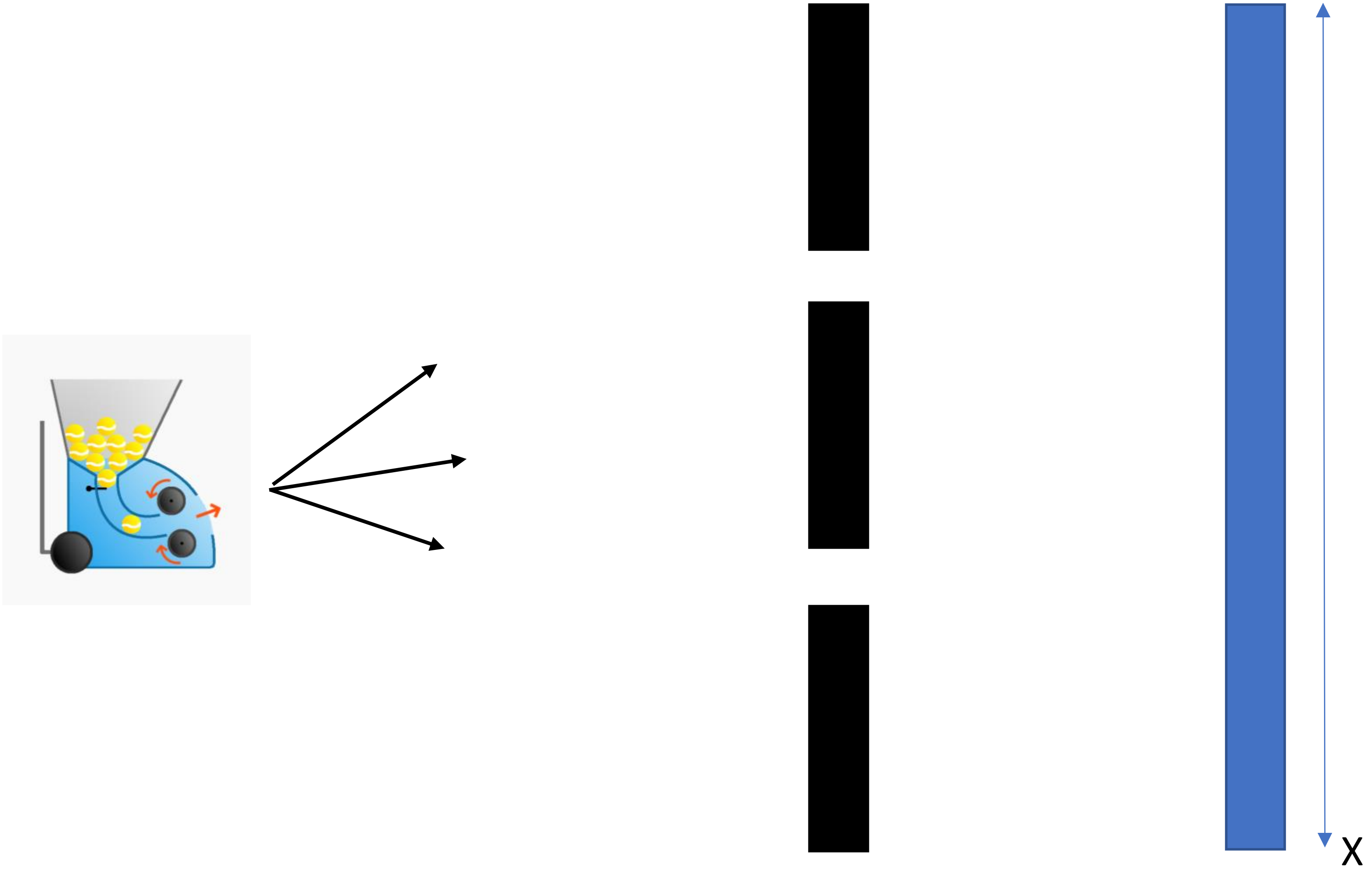

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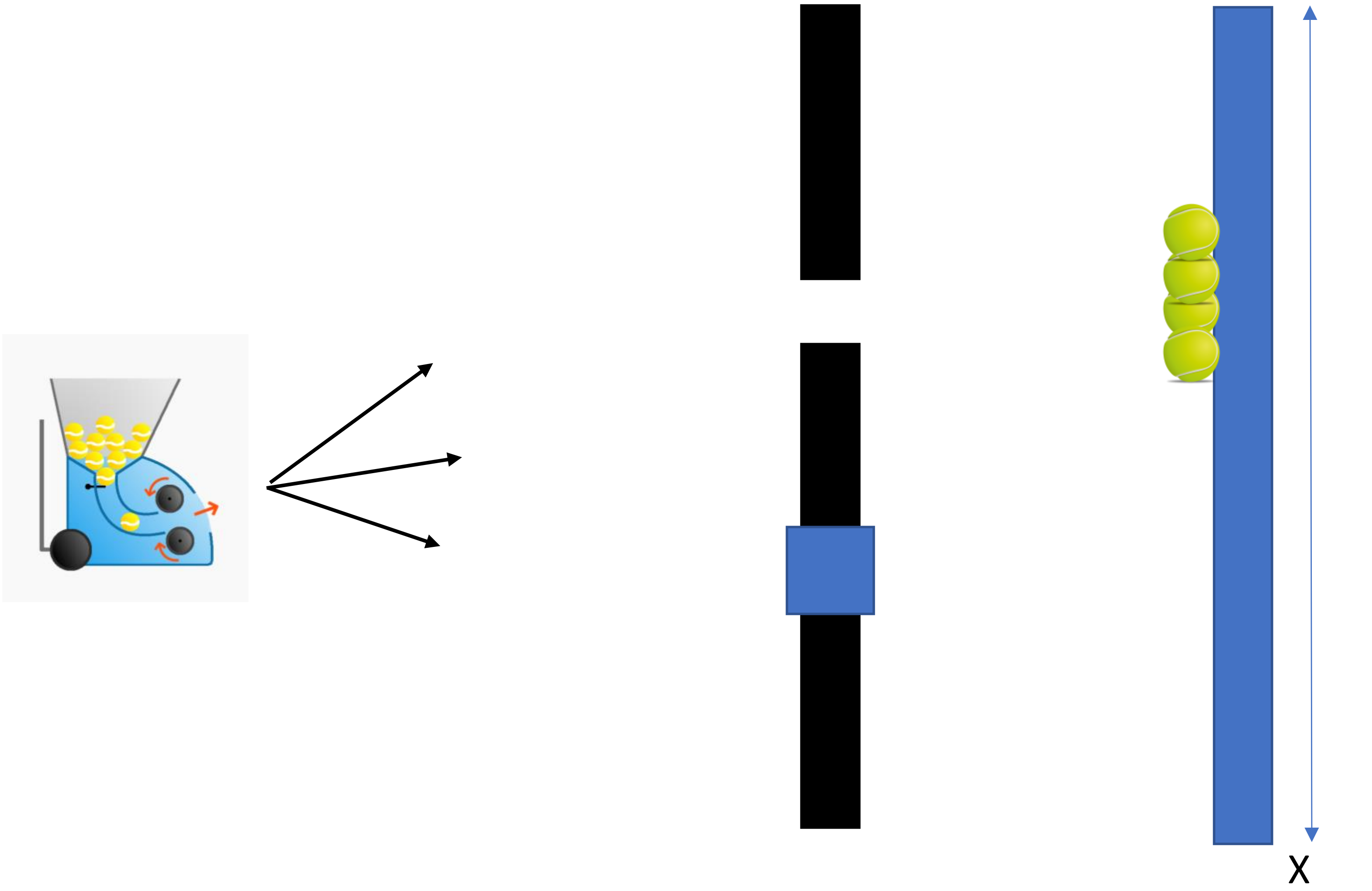

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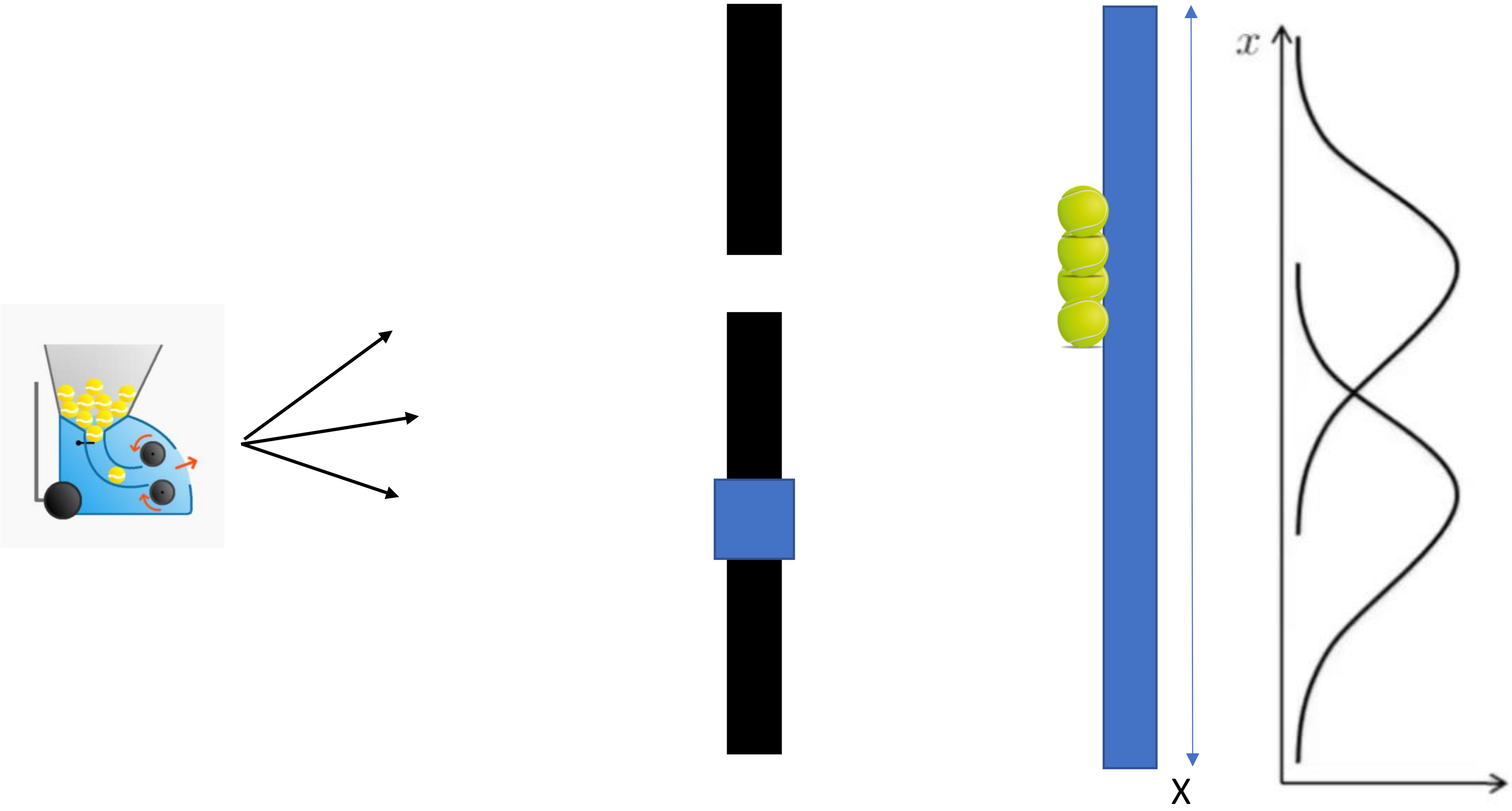

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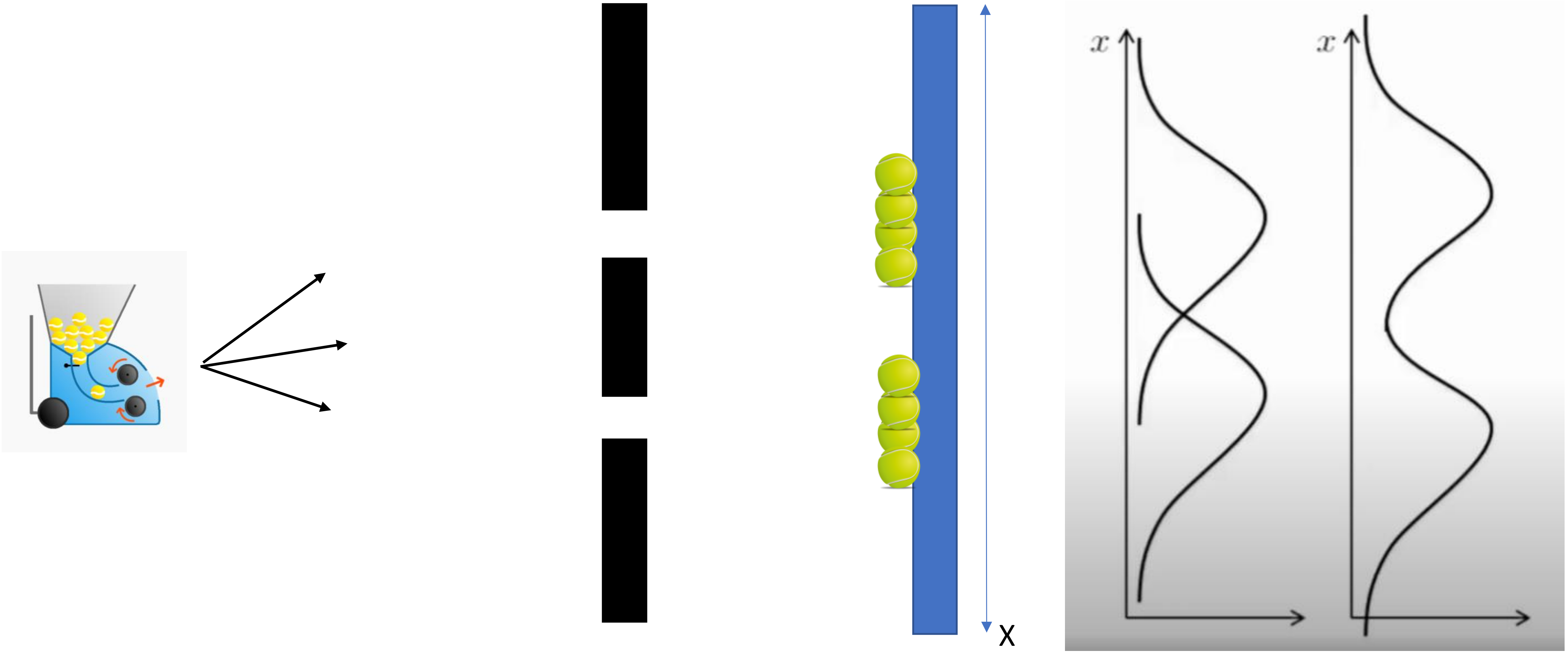

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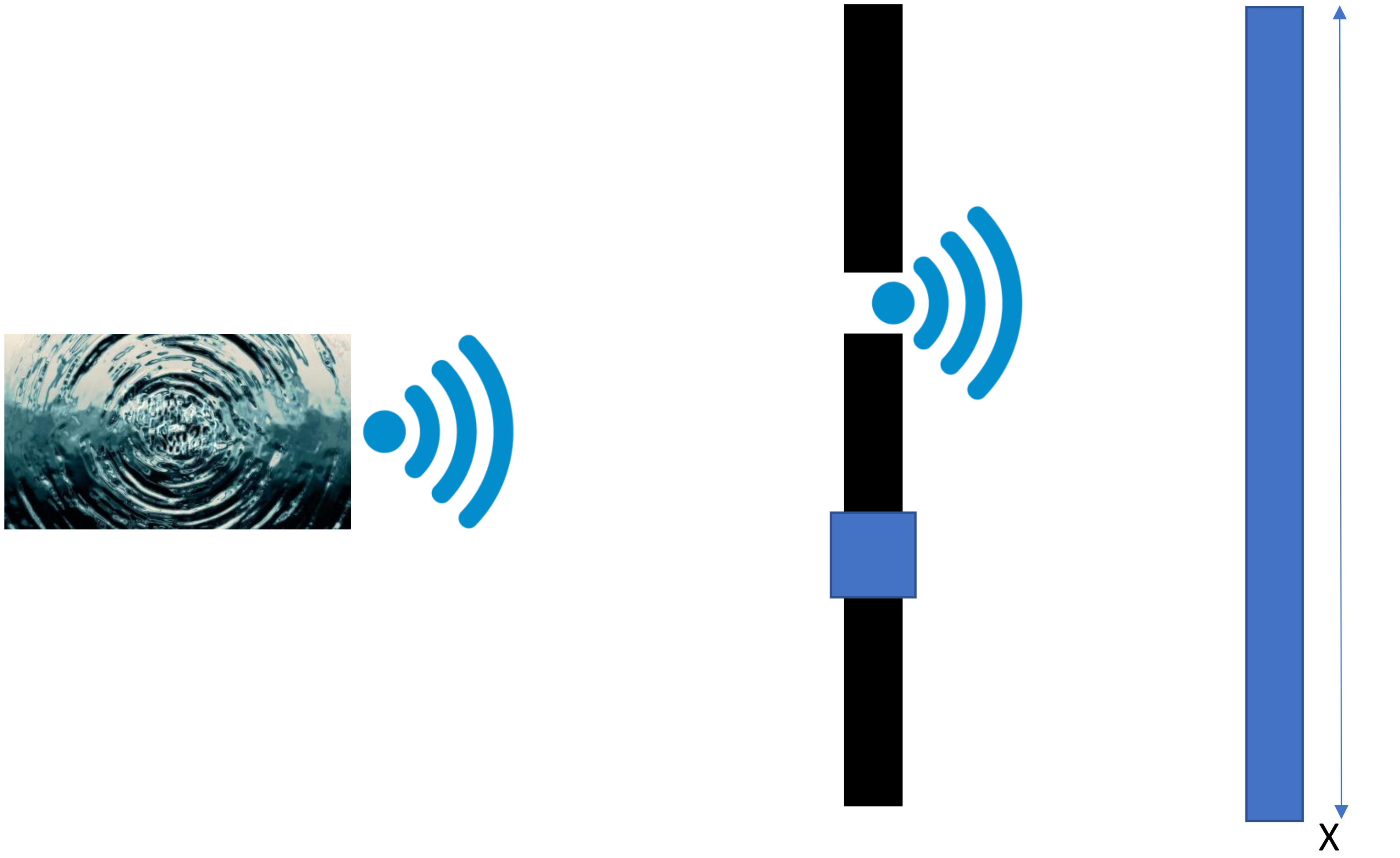
Experimento de la doble rendija



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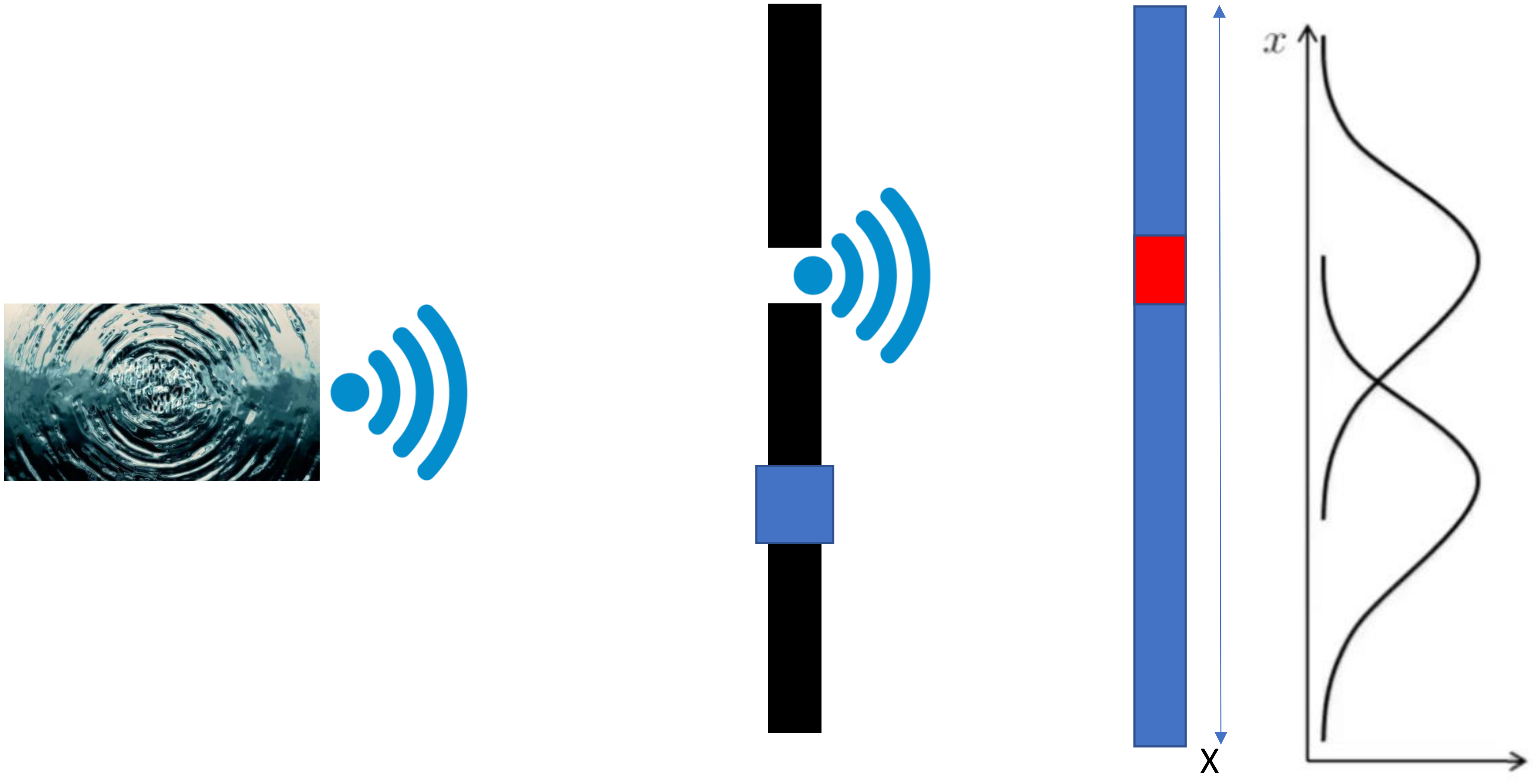

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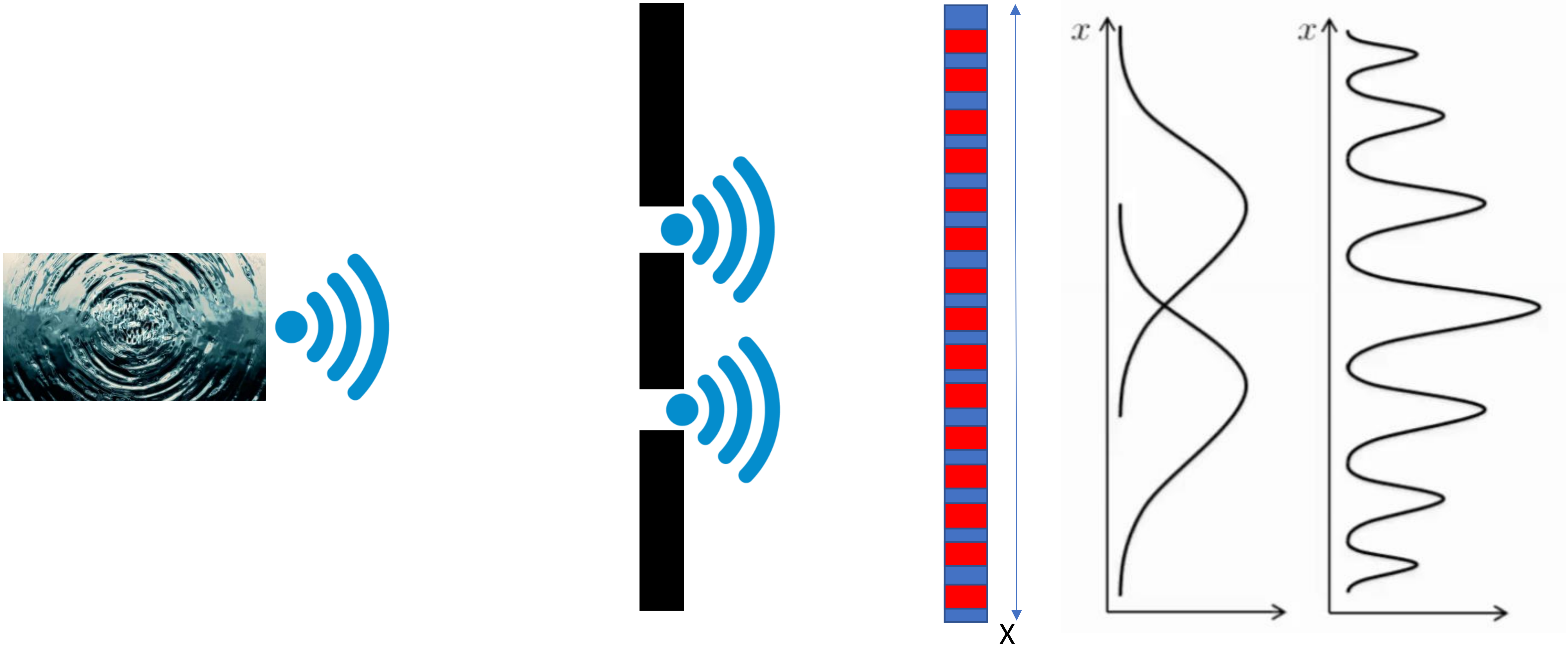

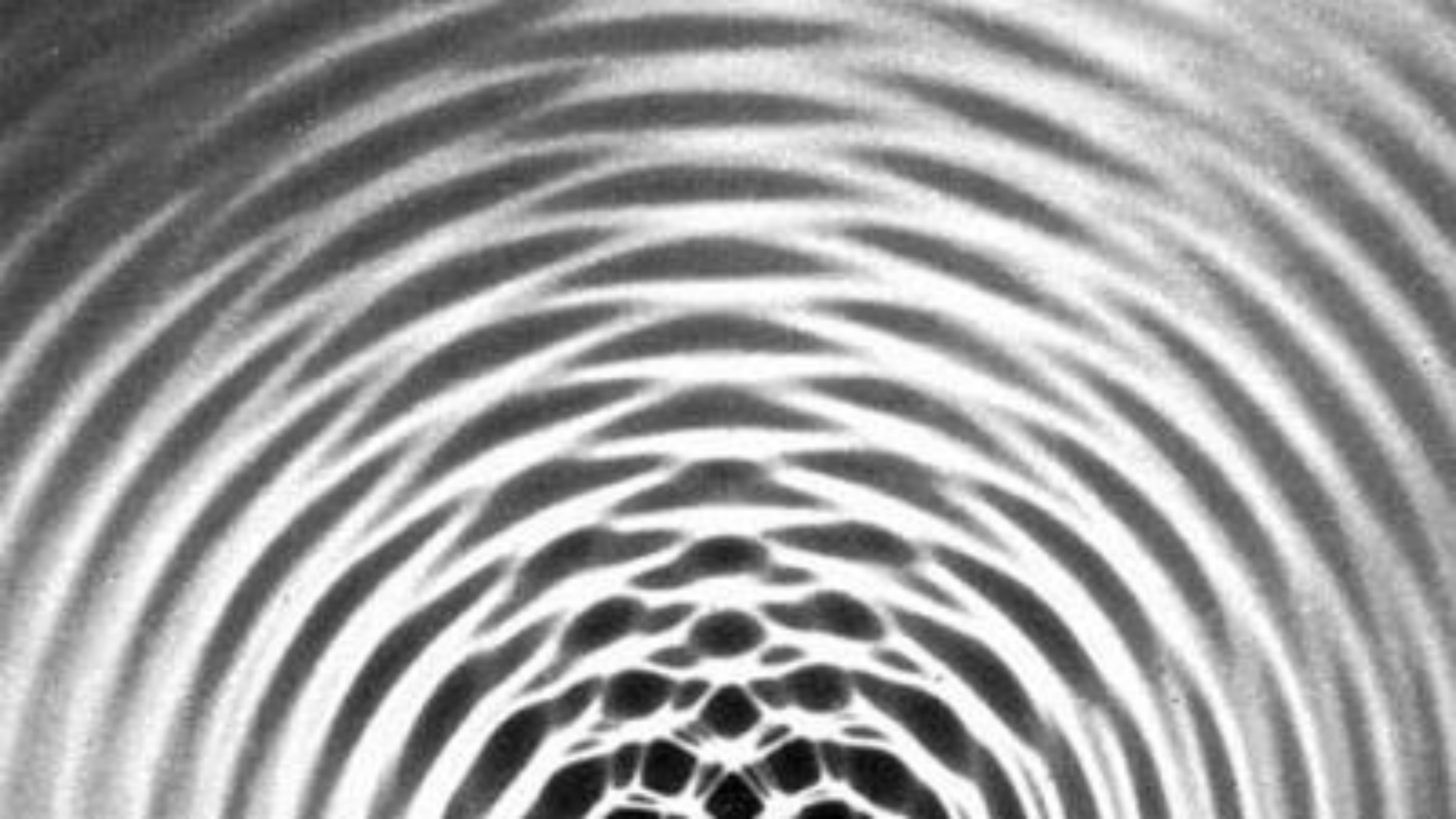

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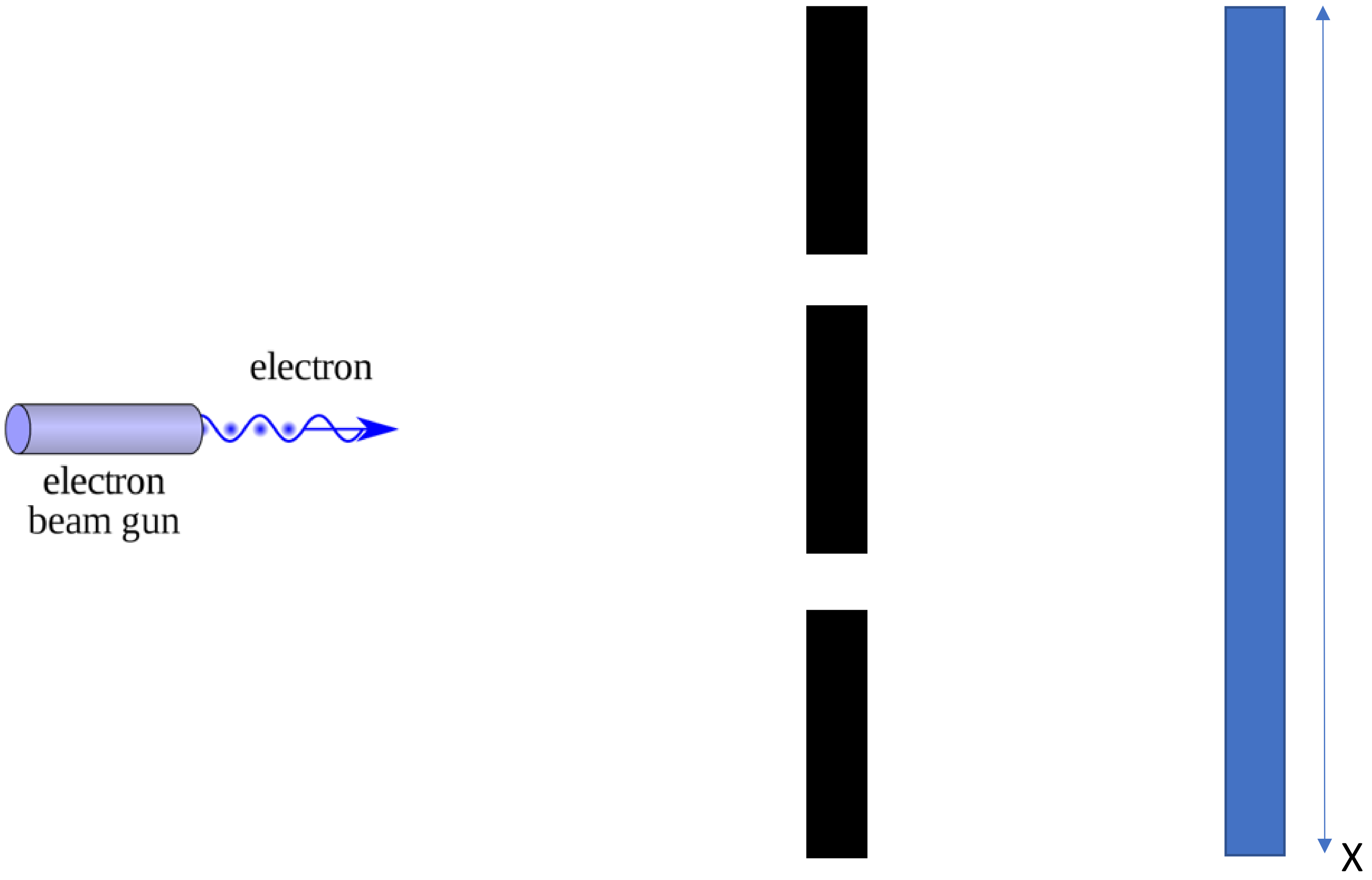

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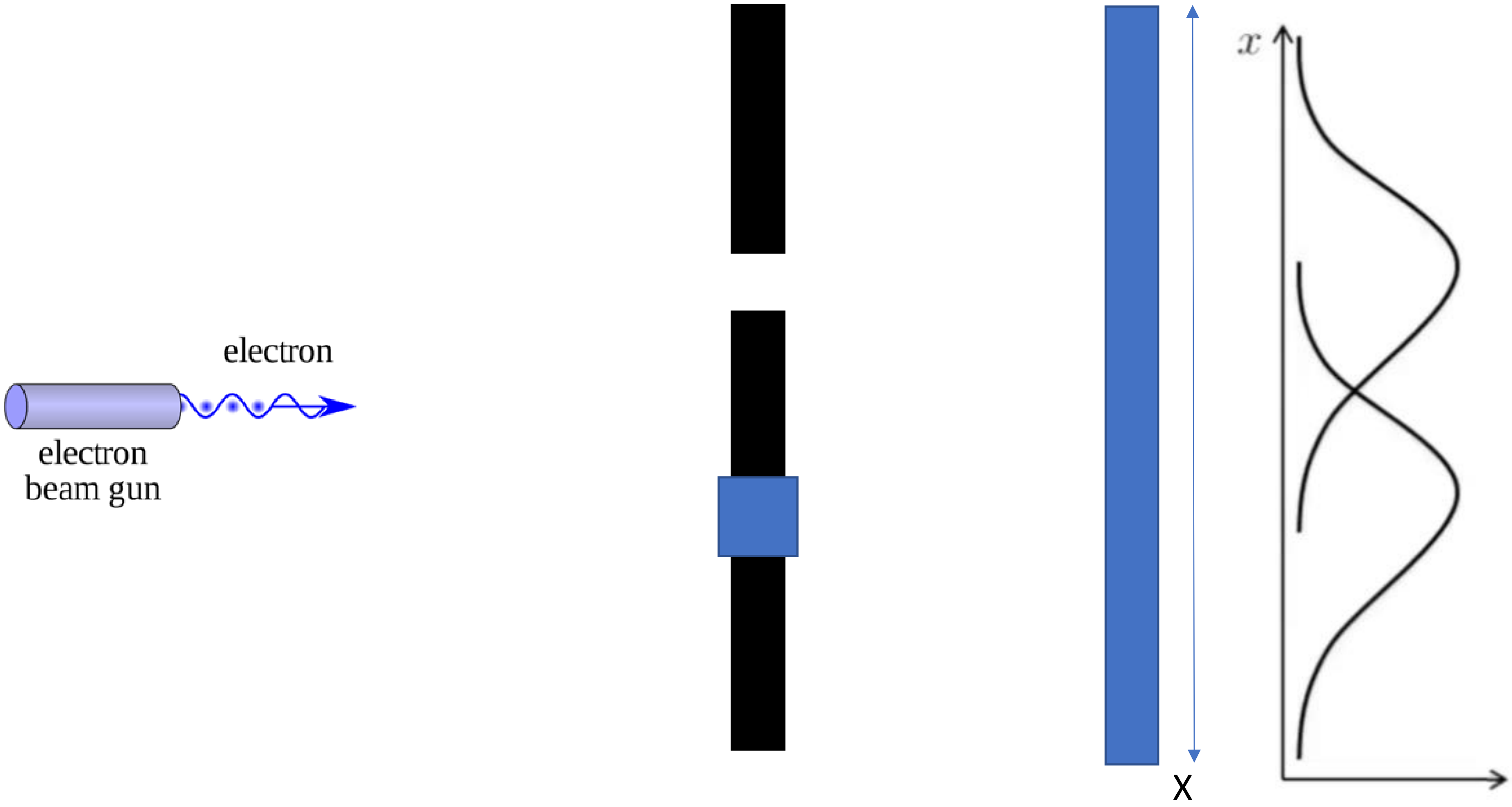

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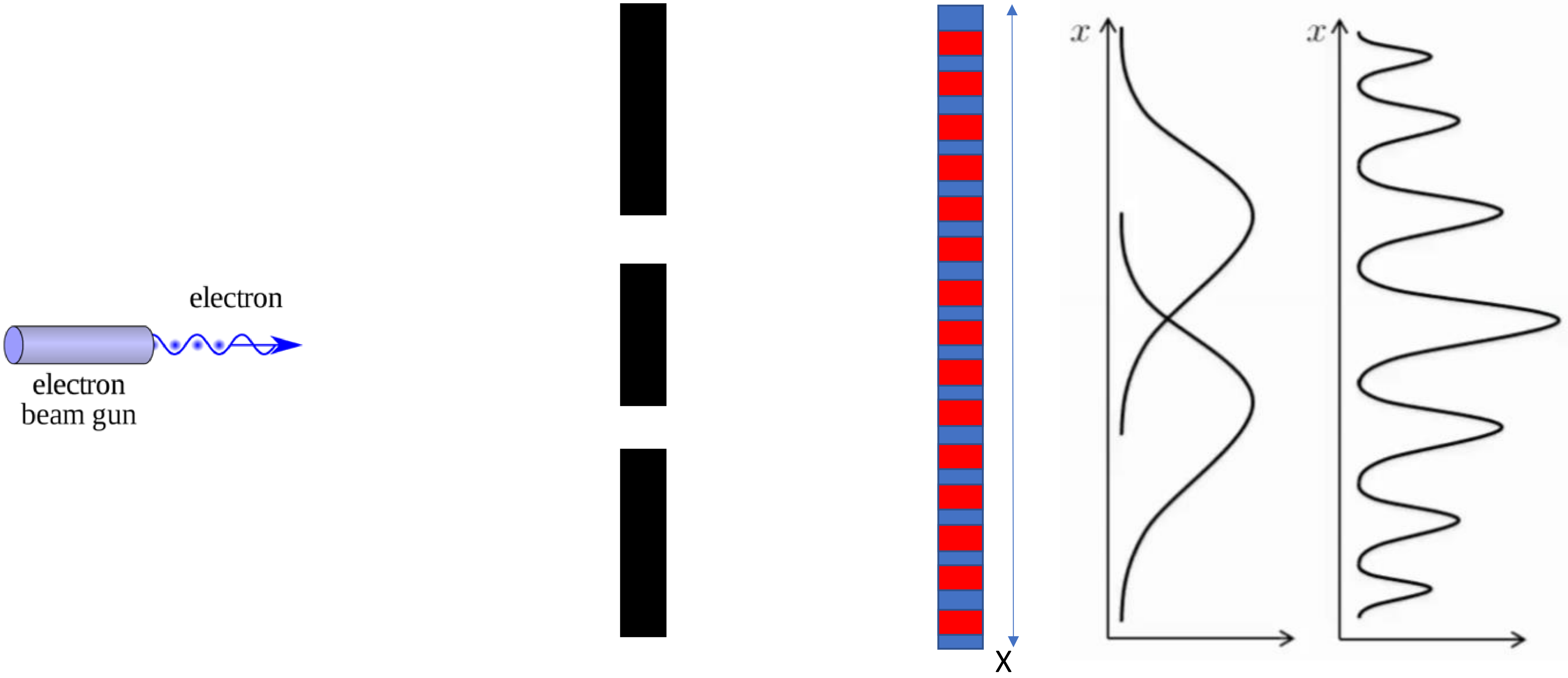

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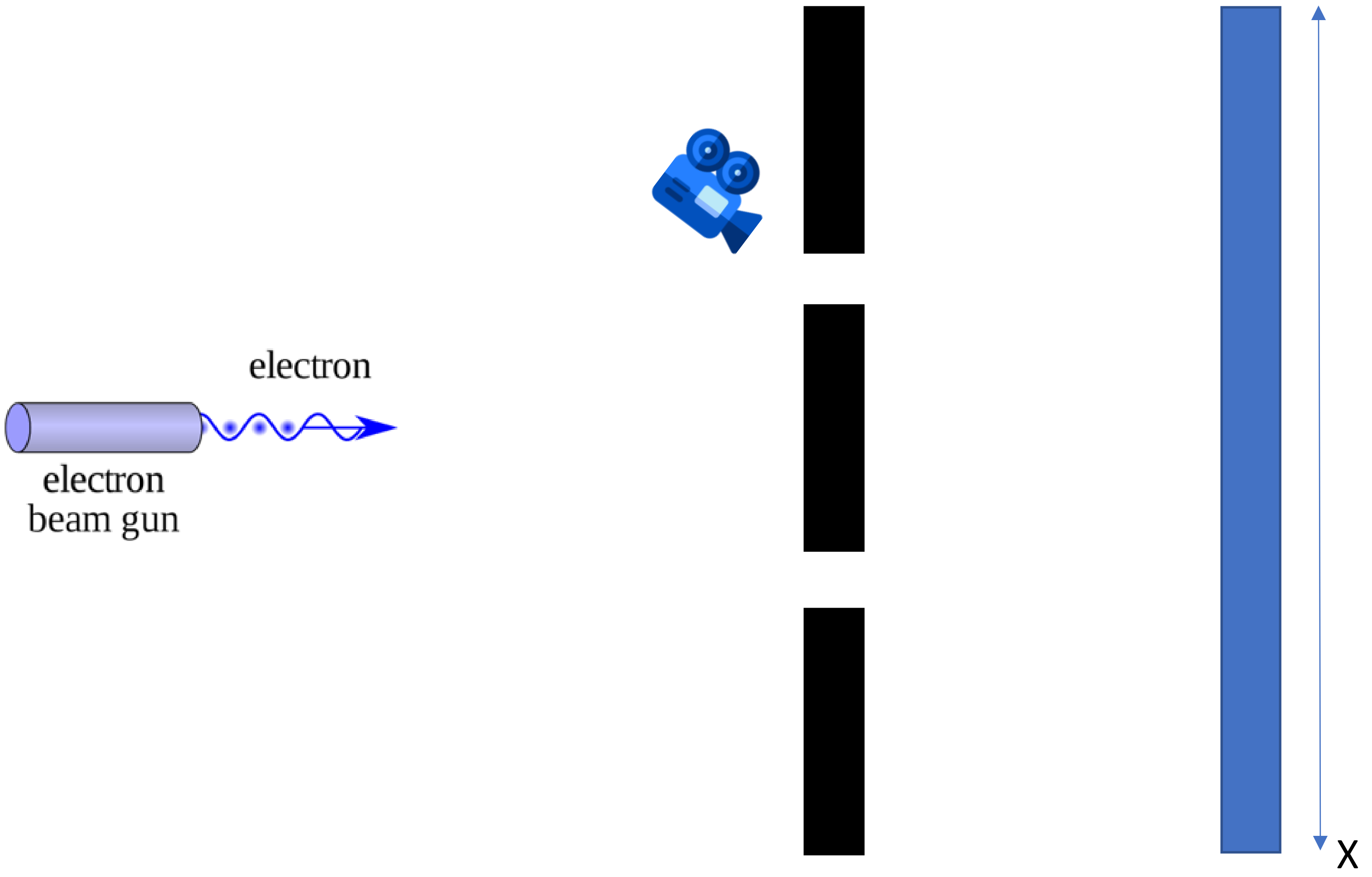
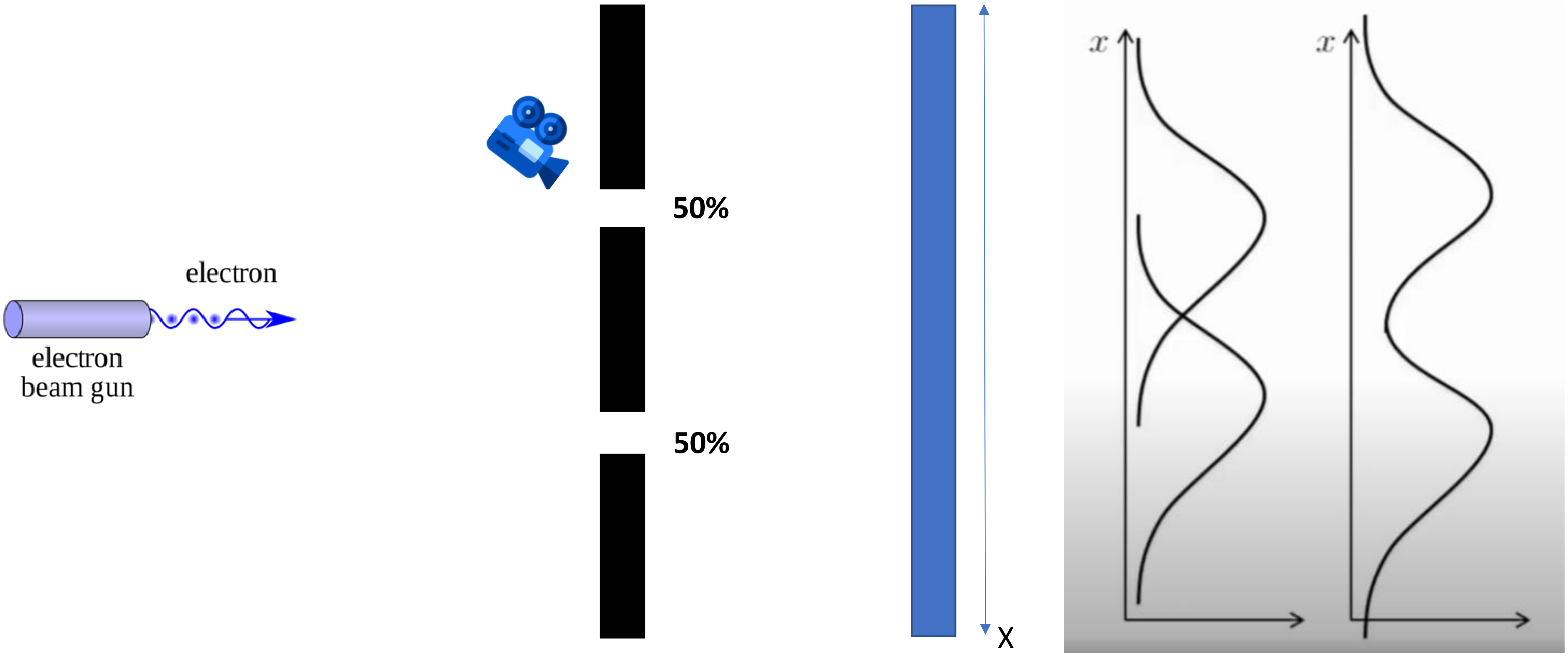


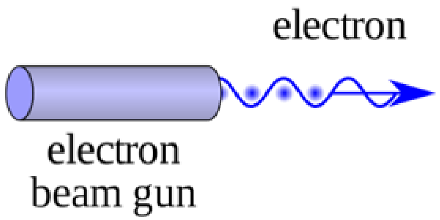
Experimento de la doble rendija

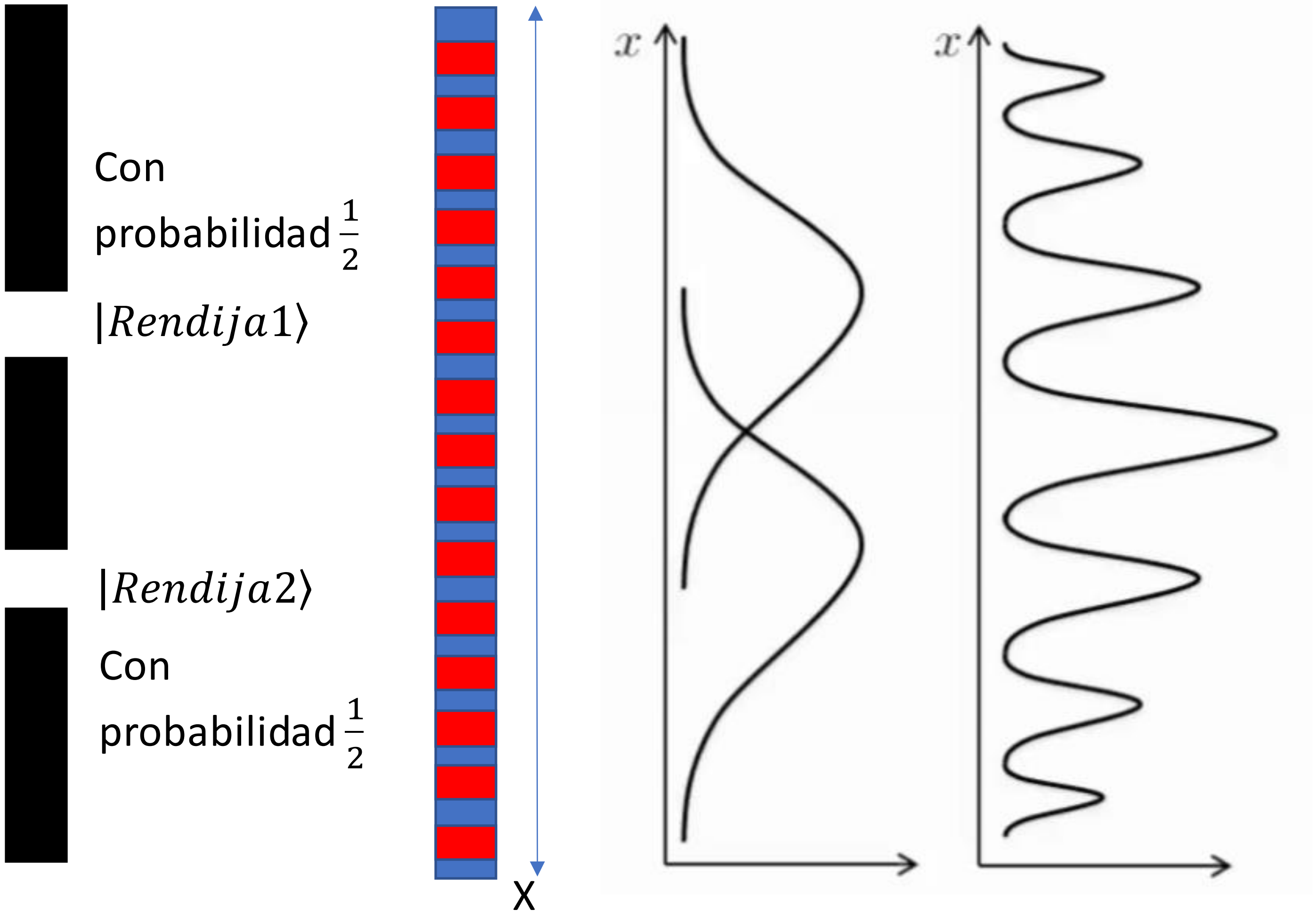


Principio de incertidumbre de Heisenberg

- Es imposible diseñar un aparato que detecte por cual rendija pasó cada electrón sin destruir el patrón de interferencia

!En ambos estados al mismo tiempo!





$$\frac{1}{\sqrt{2}}|Rendija1\rangle + \frac{1}{\sqrt{2}}|Rendija2\rangle$$

Amplitudes de probabilidad

Posibles estados

$$\frac{1}{\sqrt{2}}|Rendija1\rangle + \frac{1}{\sqrt{2}}|Rendija2\rangle$$

$$\left|\frac{1}{\sqrt{2}}\right|^2 = \frac{1}{2}$$

Principios básicos de la Mecánica Cuántica

- Un sistema adquiere un estado definitivo solo cuando se le mide.
- Antes de la medición, un sistema cuántico se encuentra en un estado indeterminado. A esto se le conoce como **superposición.**
- Dos sistemas cuánticos pueden generar **interferencia** entre ellos.
- En general, un sistema cuántico con n estados se escribe.

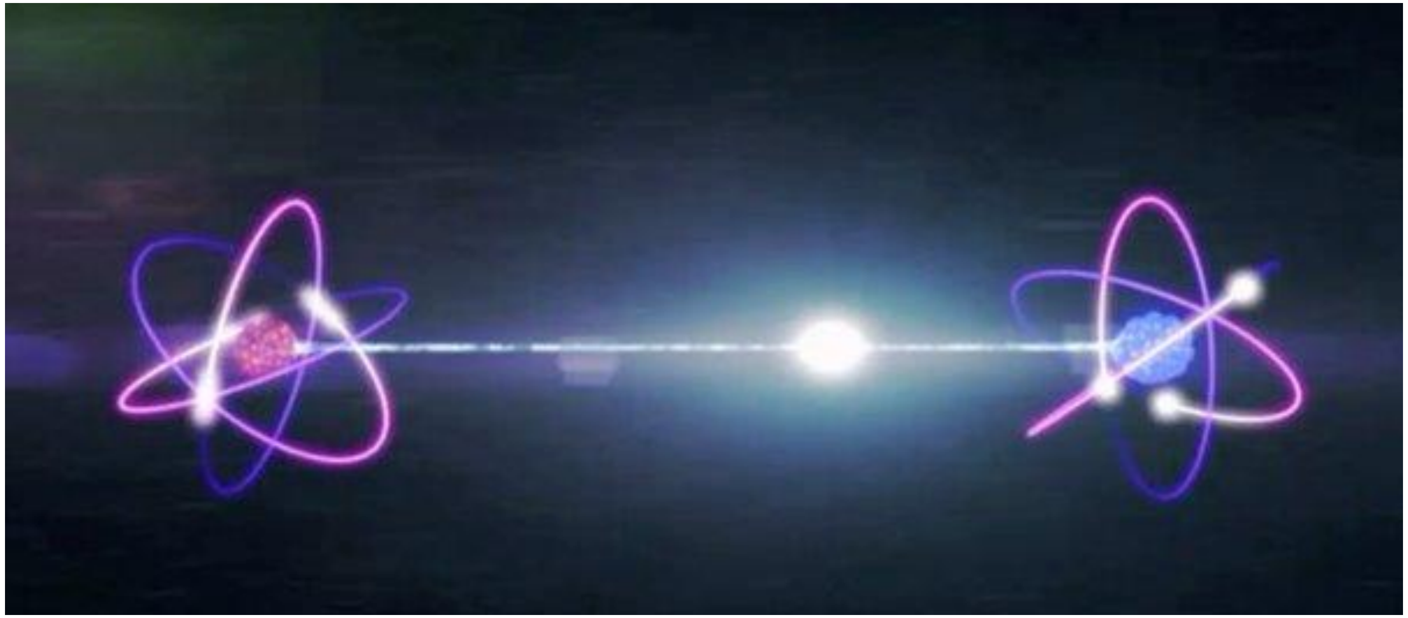
$$|\Psi\rangle = \sum_{i=1}^{n} \alpha_i |Edo.i\rangle$$

Donde,

$$\sum_{i=1}^{n} |\alpha_i|^2 = 1, \alpha_i \in \mathbb{C}$$

Entrelazamiento Cuántico

- Cuando consideramos la superposición de estados de dos partículas obtenemos el fenómeno conocido como entrelazamiento cuántico



Supongamos que tenemos el sistema cuántico con dos partículas:

$$\left|u_1\right\rangle \otimes \left|v_1\right\rangle + \left|u_2\right\rangle \otimes \left|v_2\right\rangle$$

Supongamos que tenemos el sistema cuántico con dos partículas:

$$|u_1\rangle \otimes |v_1\rangle + |u_2\rangle \otimes |v_2\rangle$$

Estados de la partícula u

Estados de la partícula v

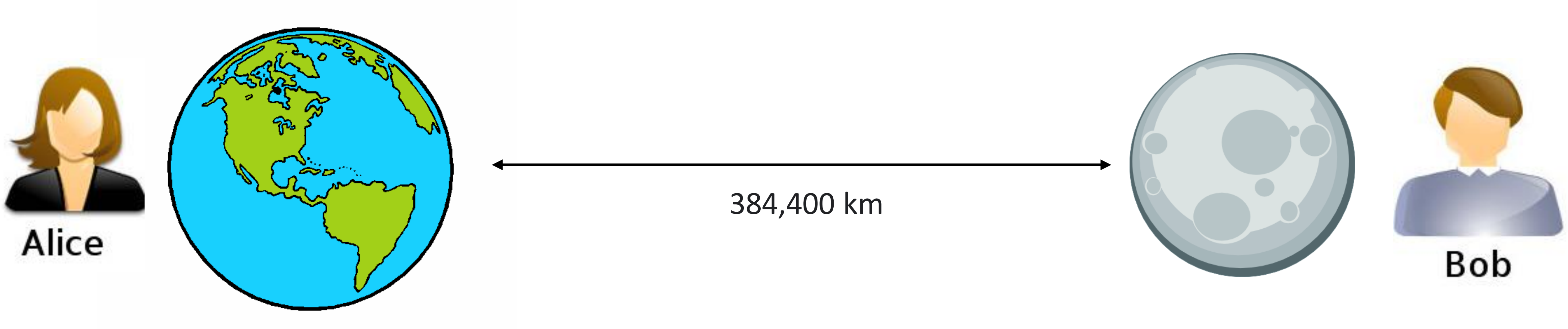
Supongamos que tenemos el sistema cuántico con dos partículas:

$$|u_1\rangle \otimes |v_1\rangle + |u_2\rangle \otimes |v_2\rangle$$

Producto Tensorial

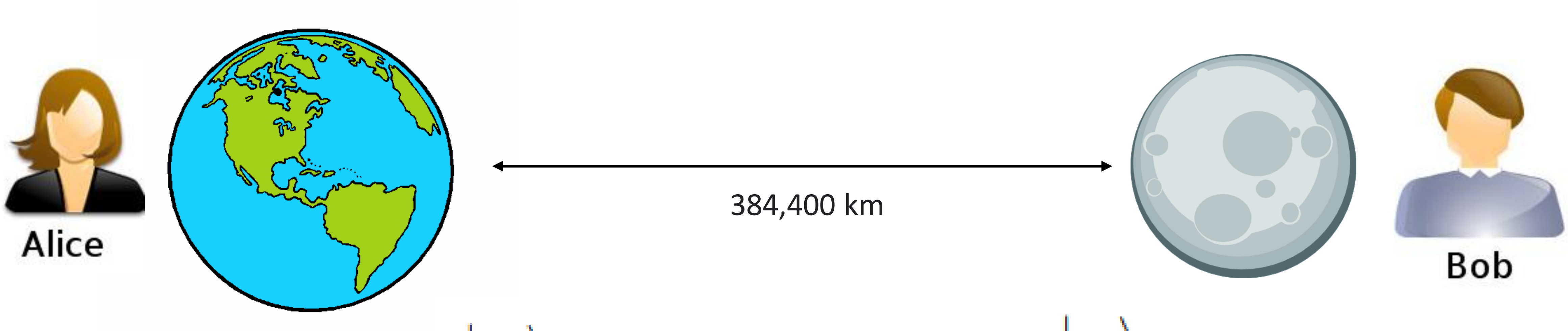
Supongamos que tenemos el sistema cuántico con dos partículas:

$$|u_1\rangle \otimes |v_1\rangle + |u_2\rangle \otimes |v_2\rangle$$



Supongamos que tenemos el sistema cuántico con dos partículas:

$$|u_1\rangle \otimes |v_1\rangle + |u_2\rangle \otimes |v_2\rangle$$



$$|u_1\rangle \longleftrightarrow |v_1\rangle$$

$$|v_2\rangle \longleftrightarrow |u_2\rangle$$

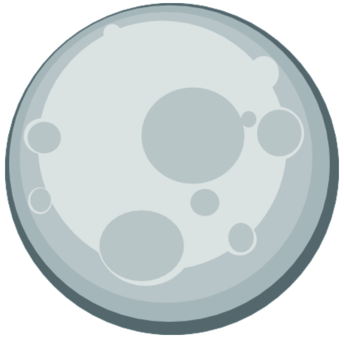
Supongamos que tenemos el sistema cuántico con dos partículas:

$$|u_1\rangle \otimes |v_1\rangle + |u_2\rangle \otimes |v_2\rangle$$

No localidad

$$\longleftrightarrow$$

384,400 km



$$|u_1\rangle \longleftrightarrow |v_1\rangle$$

$$|v_2\rangle \longleftrightarrow |u_2\rangle$$

Qué es la computación cuántica

- La computación cuántica es el uso de las propiedades de los sistemas cuánticos para realizar computación.

Qué es la computación cuántica

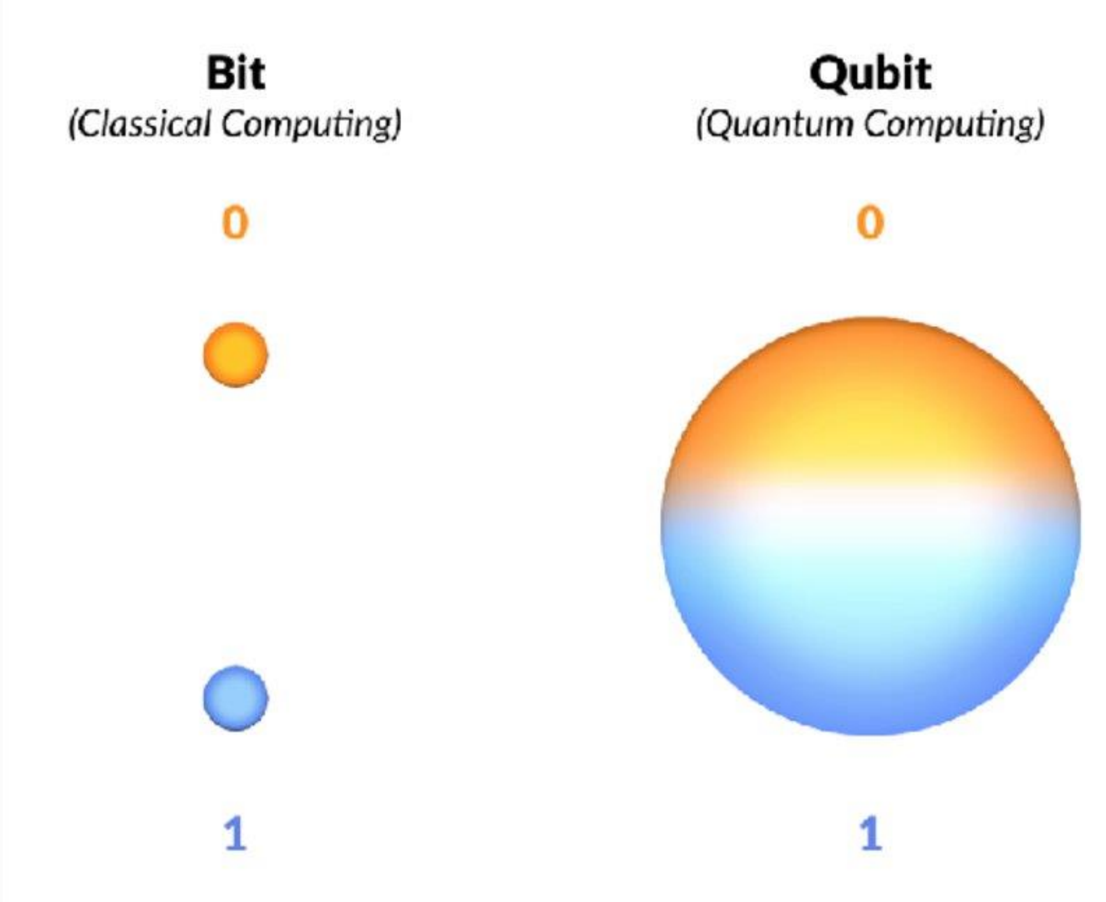
- La computación cuántica es el uso de las propiedades de los sistemas cuánticos para realizar computación.
- La computación cuántica es el estudio de las tareas de procesamiento de información que se pueden lograr utilizando sistemas mecánicos cuánticos.

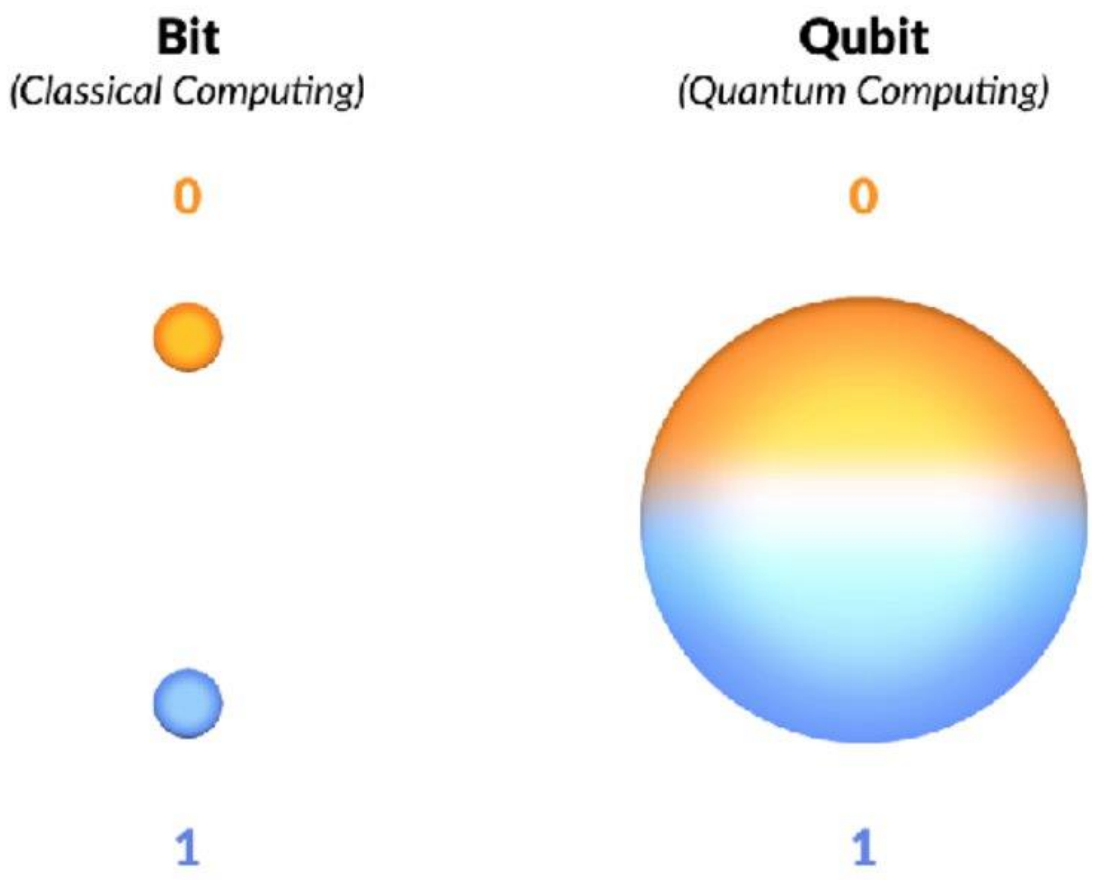
Qubits

Mínima unidad de información en la computación cuántica

Qubits

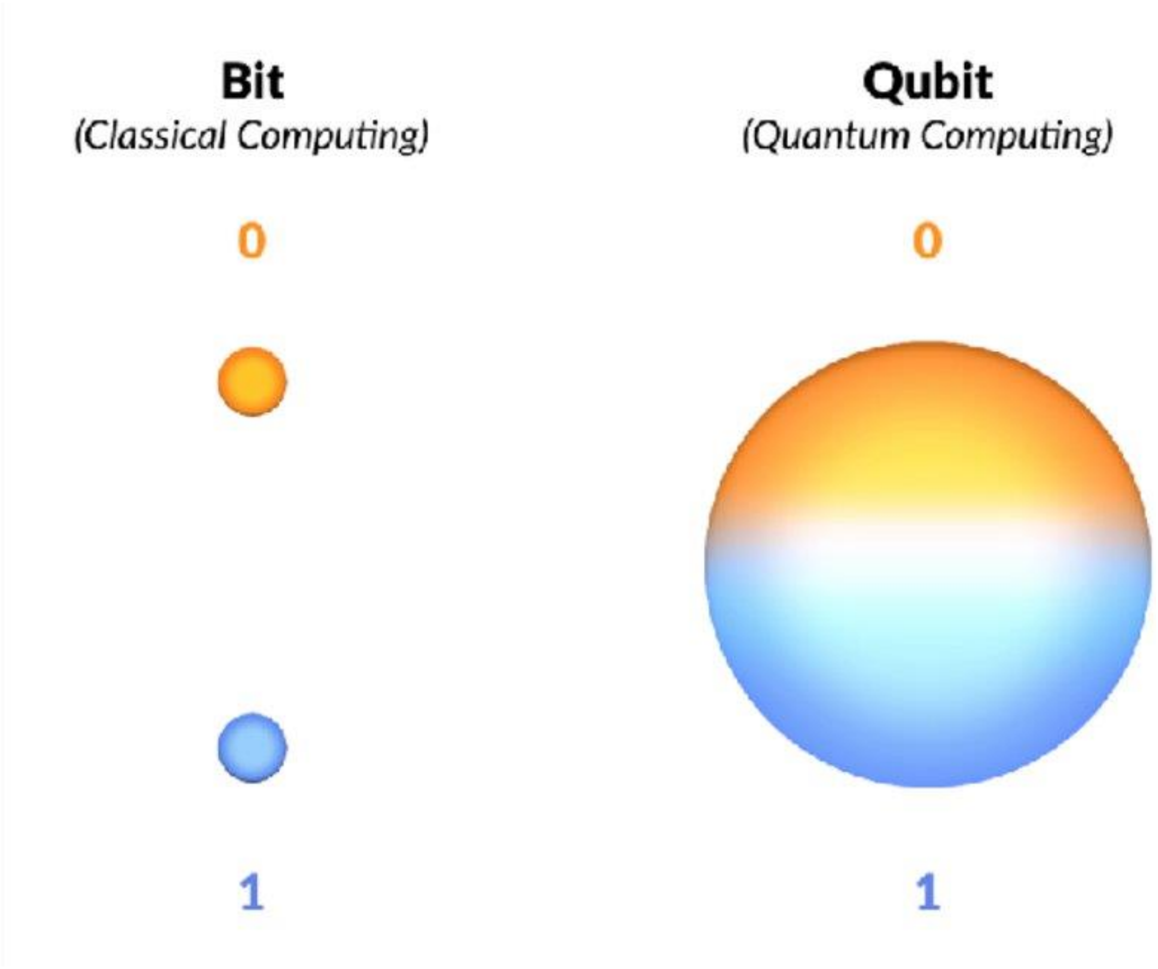
Mínima unidad de información en la computación cuántica



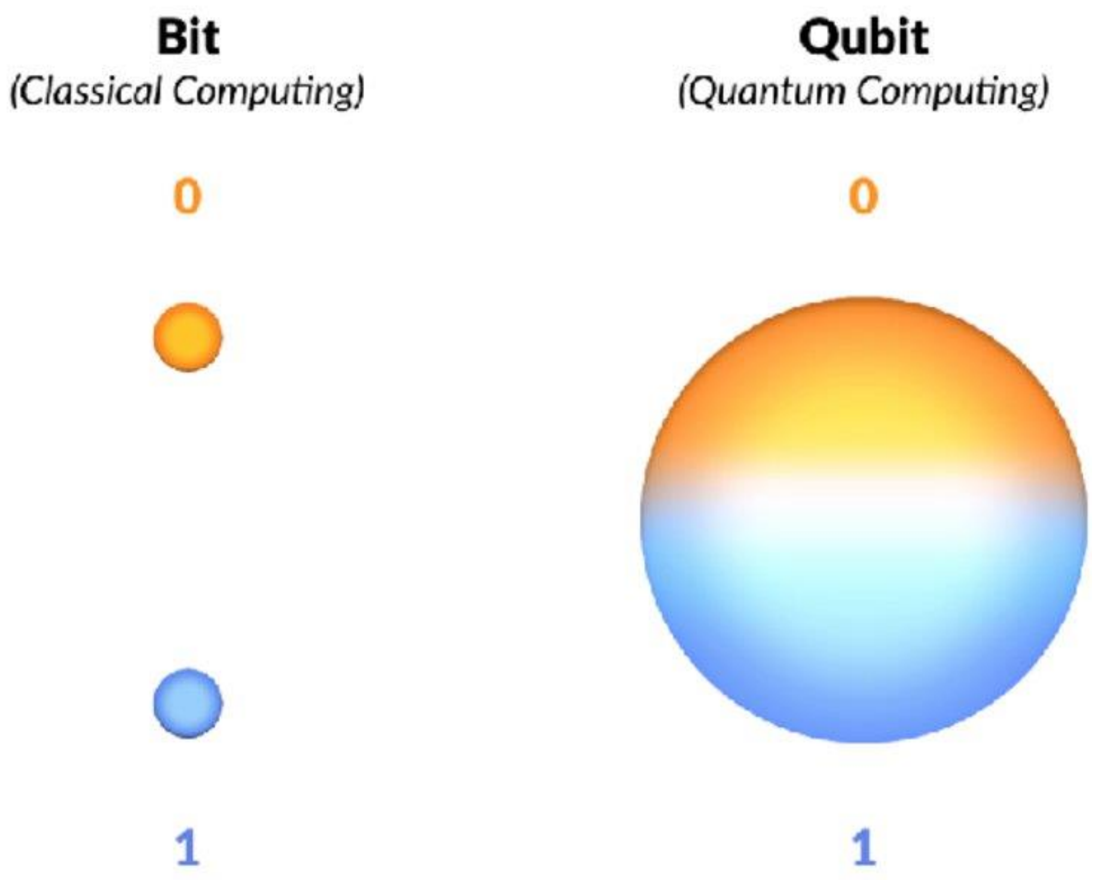


$$|\Psi\rangle = \alpha_1|Edo.1\rangle + \alpha_2|Edo.2\rangle$$

$$= \alpha_1|0\rangle + \alpha_2|1\rangle$$



$$|\Psi\rangle = \alpha_1|Edo.1\rangle + \alpha_2|Edo.2\rangle$$



$$|\Psi\rangle = \alpha_1|Edo.1\rangle + \alpha_2|Edo.2\rangle$$
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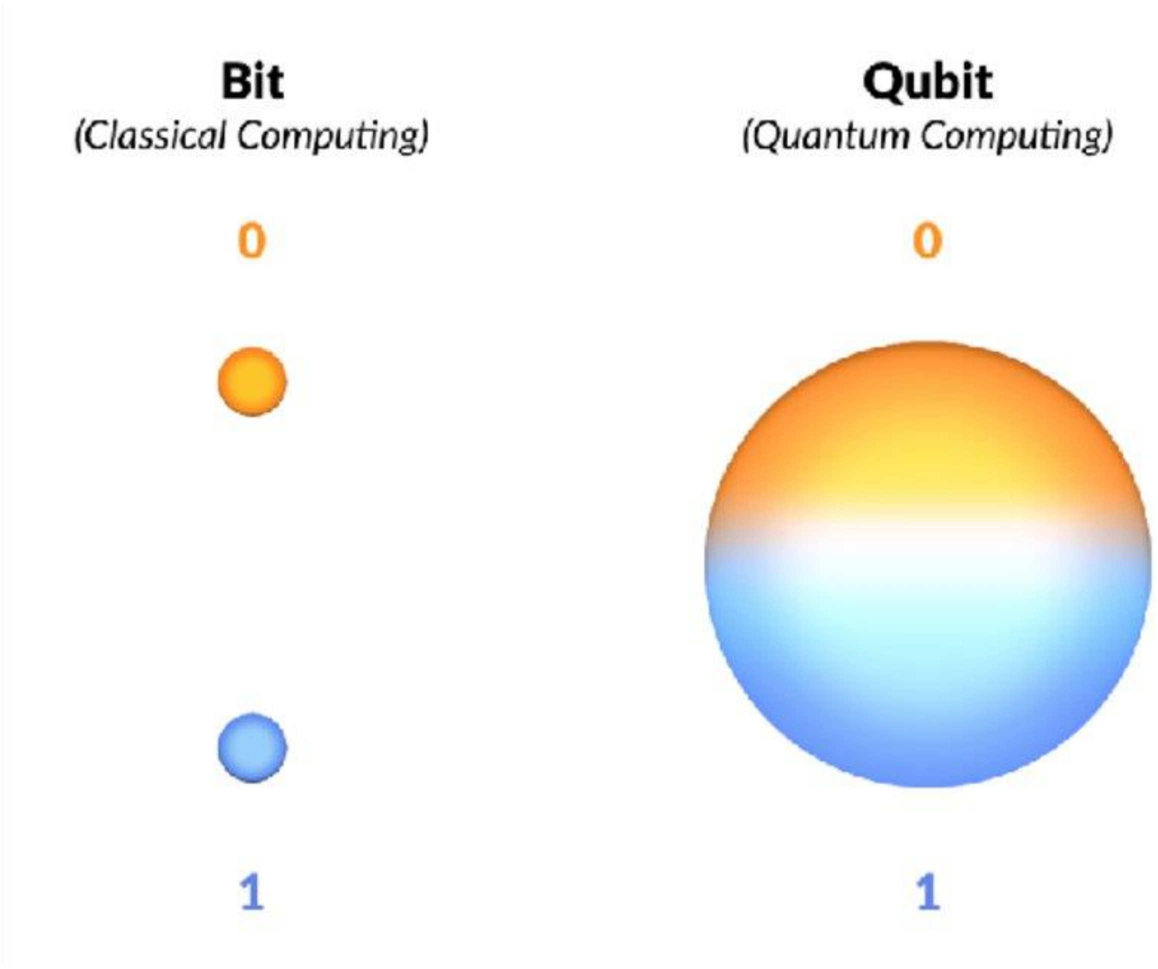


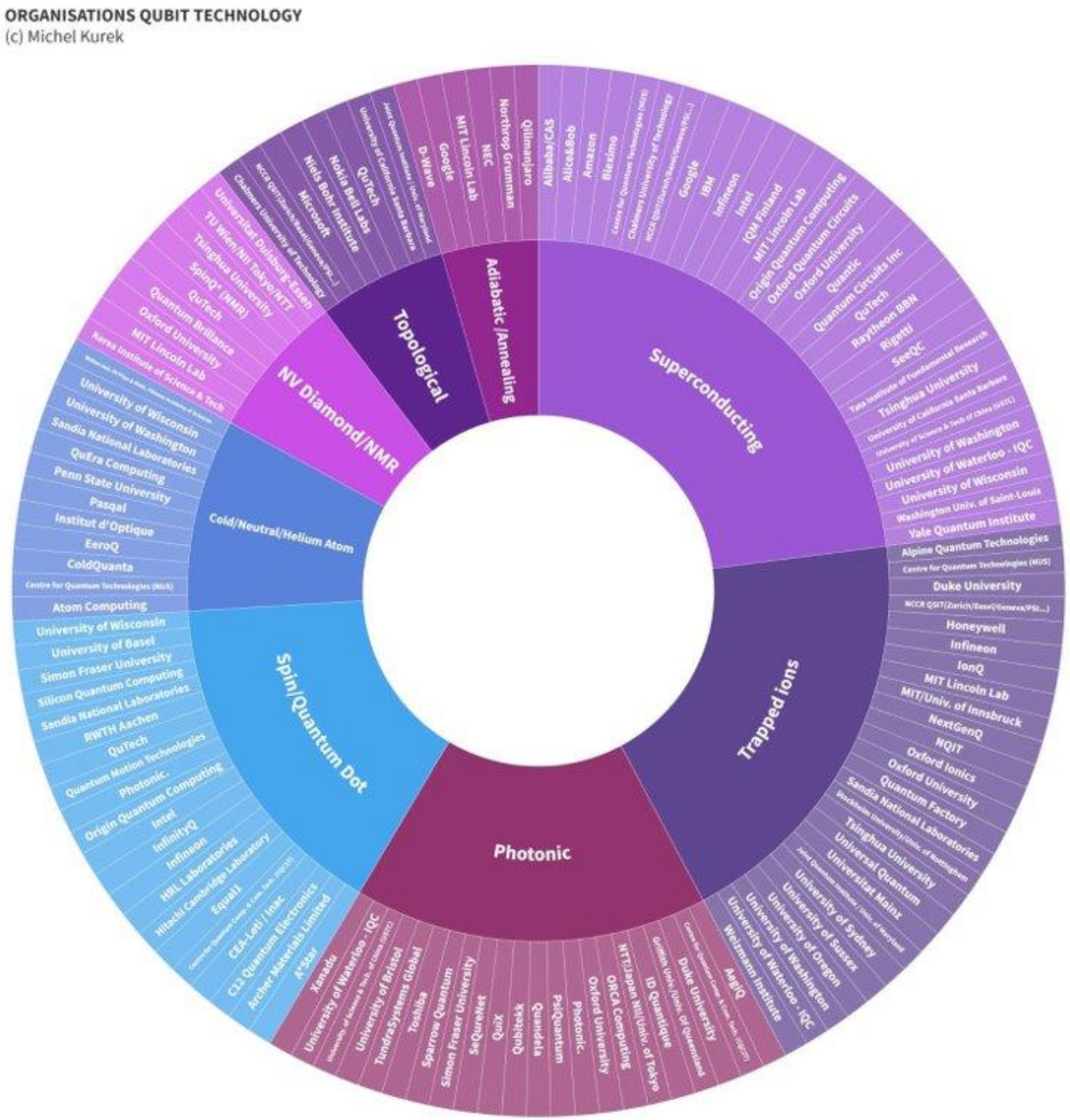
$$|\Psi\rangle = \alpha_1|Edo.1\rangle + \alpha_2|Edo.2\rangle$$

$$= \alpha_1|0\rangle + \alpha_2|1\rangle$$

Entrelazando Qubits

$$|\Psi\rangle = \alpha_1|001\rangle + \alpha_2|010\rangle$$

Implementación de computadoras cuánticas



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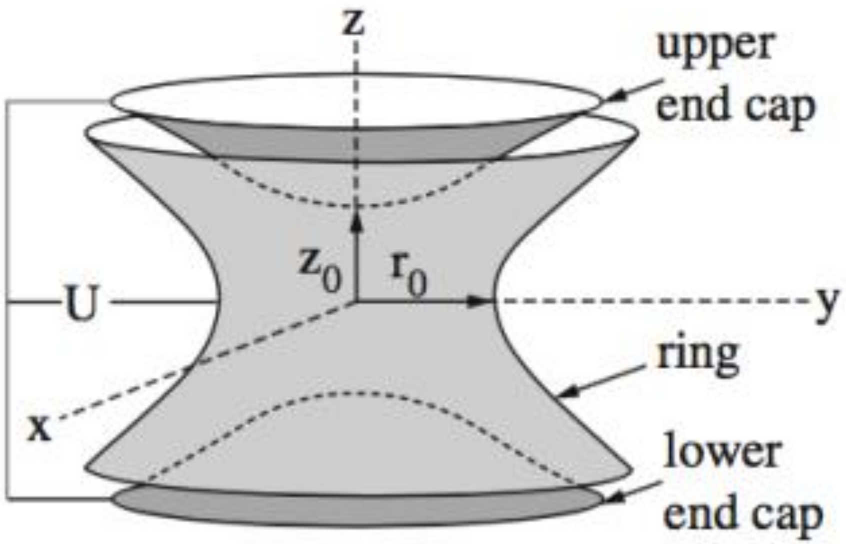
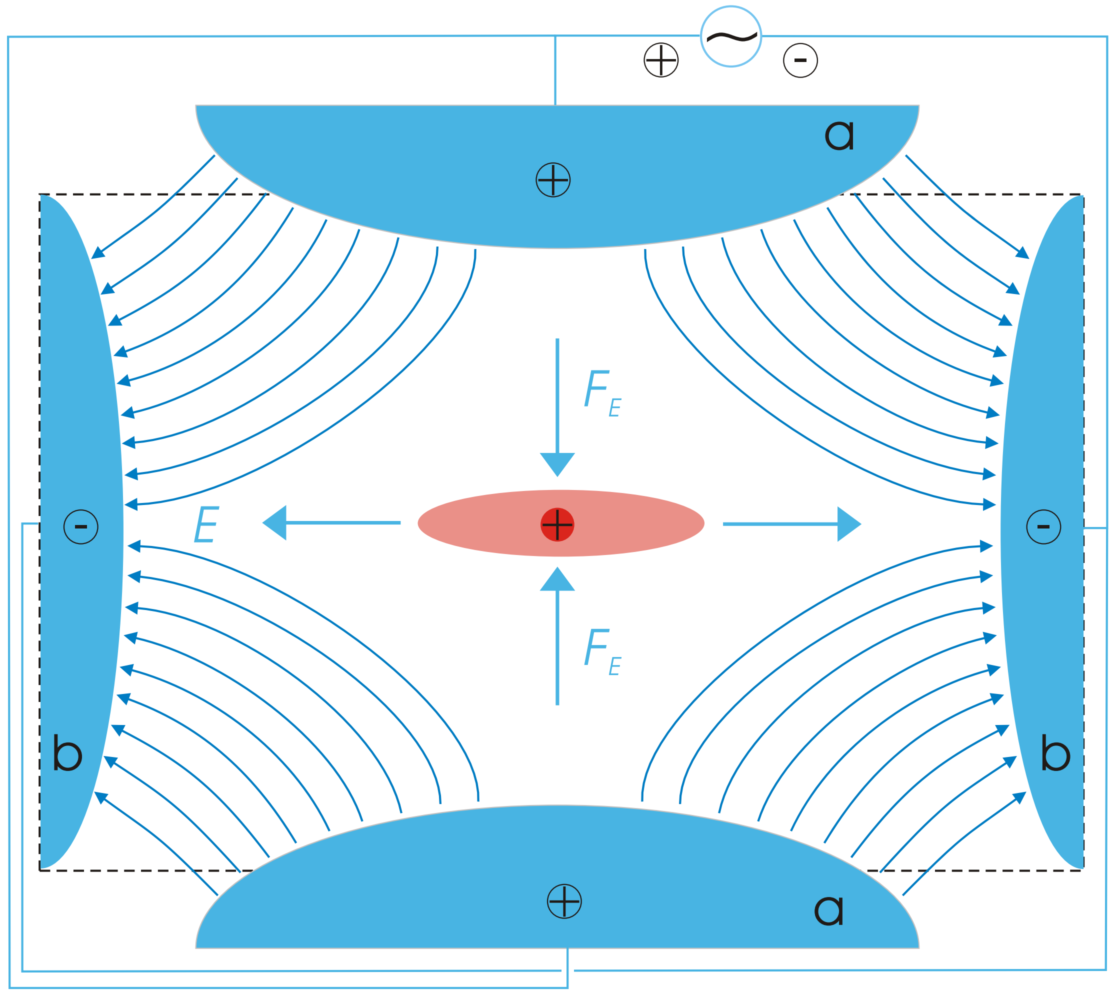
Trampa de Iones





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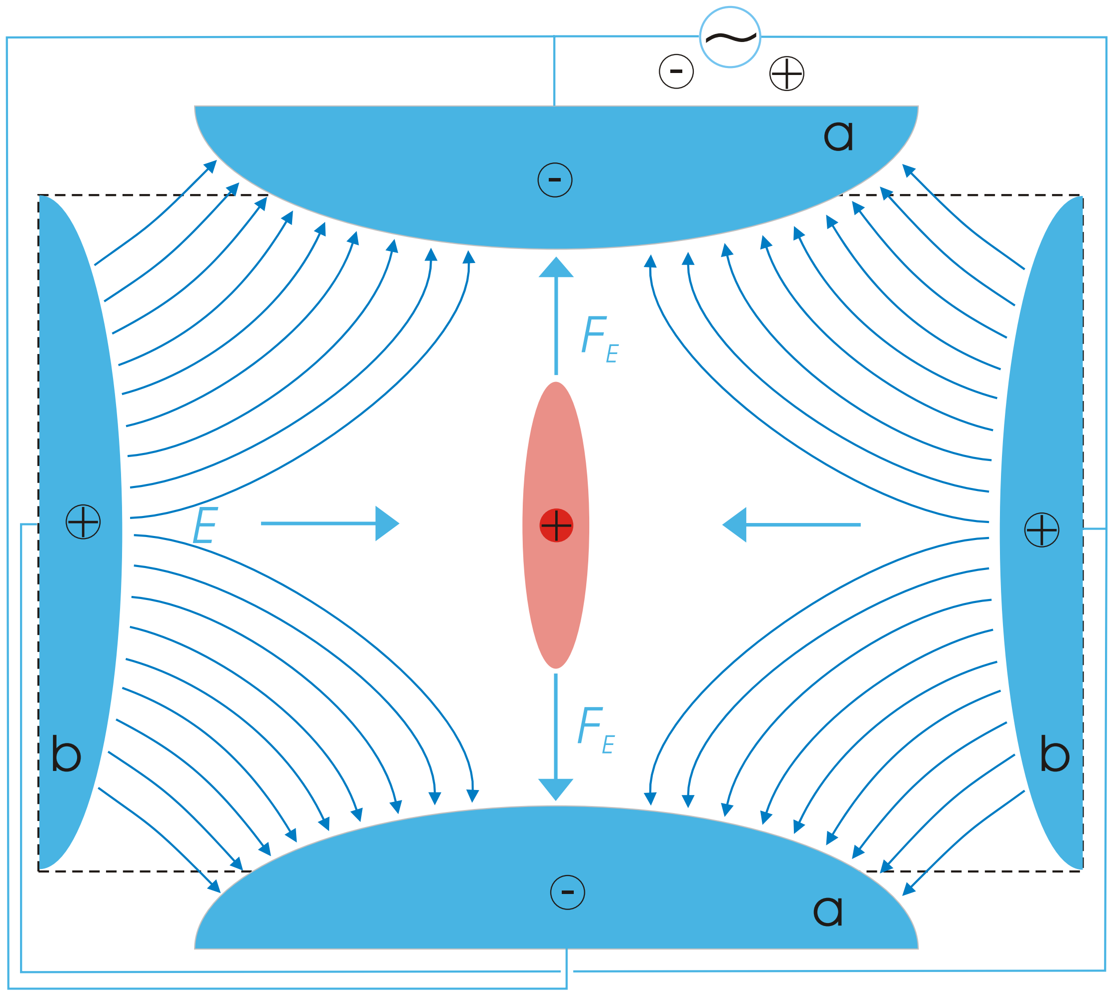

2

Implementación experimental