

Tema 2.-Postulados de la Mecánica Cuántica.

- 2.1. Estados y función de ondas
- 2.2. Representación de observables por operadores
- 2.3. Valor esperado y resultado de una medida individual
- 2.4. Significado físico de la función de ondas
- 2.5. Evolución temporal de un sistema mecano-cuántico

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Postulado 1

El estado de un sistema mecano-cuántico está completamente especificado por una función de ondas $\Psi(x,t)$. La probabilidad de que una partícula se encuentre al tiempo t_0 en un intervalo espacial de anchura dx centrada en x_0 está dada por $\Psi^(x_0,t_0)\Psi(x_0,t_0)dx$.*

Normalización de la función de ondas

$$\int_{-\infty}^{\infty} \Psi^*(x, t) \Psi(x, t) dx = 1$$

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Postulado 2

Para cada propiedad medible del sistema en Mecánica Clásica existe un operador lineal correspondiente en Mecánica Cuántica.

El experimento que se hace en el laboratorio para medir el valor del observable, se simula en la teoría operando sobre la función de ondas del sistema con el correspondiente operador.

TABLE 14.1 OBSERVABLES AND THEIR QUANTUM MECHANICAL OPERATORS

Observable	Operator	Symbol for Operator
Momentum	$-i\hbar \frac{\partial}{\partial x}$	\hat{p}_x
Kinetic energy	$-\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2}$	$\hat{E}_{kinetic} = \frac{1}{2m} (\hat{p}_x)\hat{p}_x$
Position	x	\hat{x}
Potential energy	$V(x)$	$\hat{E}_{potential}$
Total energy	$-\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + V(x)$	\hat{H}

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$(\frac{\partial}{\partial y} \frac{\partial}{\partial x})$

Postulado 3

En cualquier medida única del observable que corresponde al operador \hat{A} los únicos valores que se obtienen, son los valores propios del operador

$$\hat{H}\Psi_n(x, t) = E_n\Psi_n(x, t)$$

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Postulado 4

Si el sistema está en un estado descrito por la función de onda $\Psi(x,t)$, y se mide el valor del observable a una vez en cada uno de los sistemas preparados idénticamente, el valor medio (o valor esperado) de todas esas medidas, viene dado por

$$\langle a \rangle = \frac{\int_{-\infty}^{\infty} \Psi^*(x, t) \hat{A} \Psi(x, t) dx}{\int_{-\infty}^{\infty} \Psi^*(x, t) \Psi(x, t) dx}$$

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Si $\Psi(x,t)$ es función propia del operador \hat{A}

$$\begin{aligned} \langle a \rangle &= \int_{-\infty}^{\infty} \phi_j^*(x, t) \hat{A} \phi_j(x, t) dx = a_j \int_{-\infty}^{\infty} \phi_j^*(x, t) \phi_j(x, t) dx \\ &= a_j \end{aligned}$$

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Si $\Psi(x,t)$ no es función propia del operador \hat{A} $\Psi(x, t) = \sum_n b_n \phi_n(x, t)$

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m=1

m=1

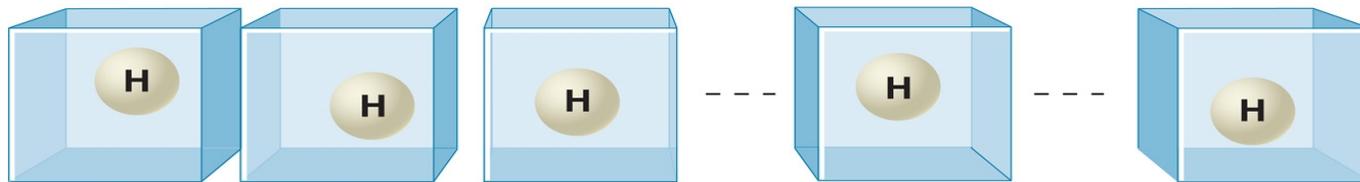
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Estado superposición de estados

$$\Psi_{\text{electronic}} = b_1\Psi_{1s} + b_2\Psi_{2s} + b_3\Psi_{2p_x} + b_4\Psi_{3s}$$

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$$\Psi_{\text{electronic}} = b_1\Psi_{1s} + b_2\Psi_{2s} + b_3\Psi_{2p_x} + b_4\Psi_{3s}$$



First measurement

E_{1s}

E_{3s}

E_{1s}

E_{2s}

E_{2p}

Each successive measurement

E_{1s}

E_{3s}

E_{1s}

E_{2s}

E_{2p}

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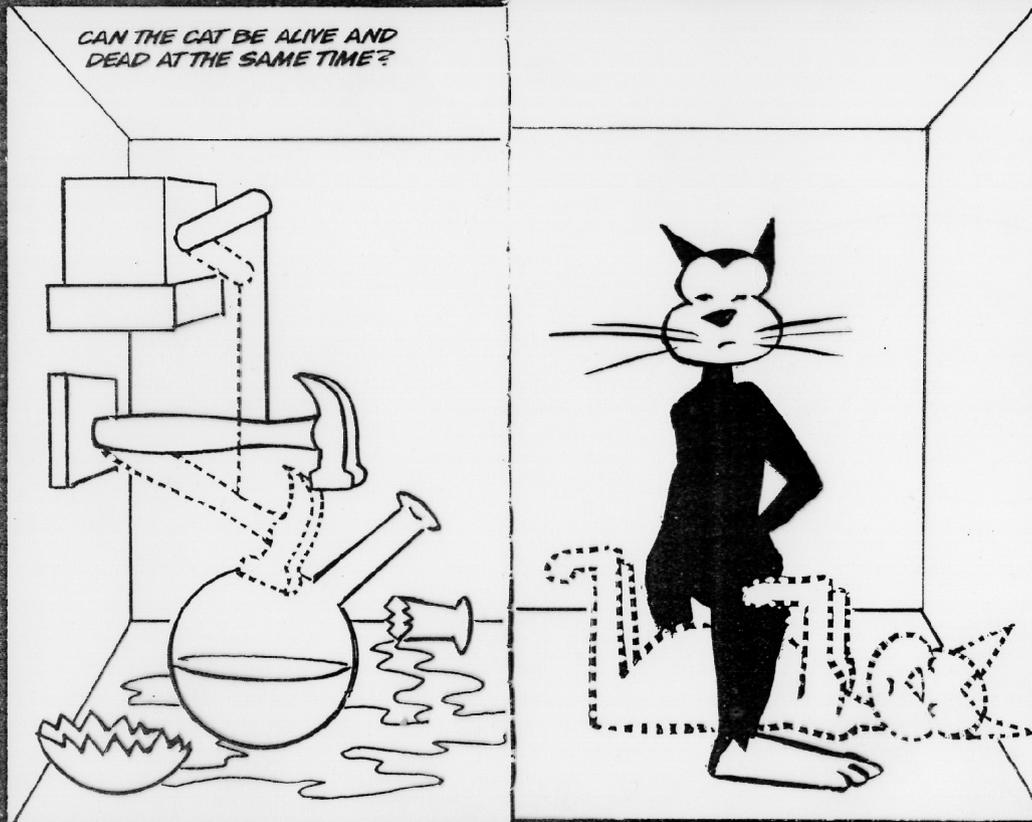
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Schrödinger's Cat . . . The Quantum Measurement Problem

About ten years after Born's papers, the notion of the probability superposition of quantum states was becoming generally accepted. Schrödinger, distressed that his own equation was being misused, created a "thought experiment" which he believed would demonstrate – once and for all – the absurdity of this concept.

Schrödinger imagined a bizarre experiment in which a live cat is placed in a box with a radioactive source, a Geiger counter, a hammer and a sealed glass flask containing deadly poison fumes. When a radioactive decay takes place, the counter triggers a device releasing the hammer which falls and breaks the flask. The fumes will then kill the cat.

SUPPOSE THE RADIOACTIVE SOURCE IS SUCH THAT QUANTUM THEORY PREDICTS A 50% PROBABILITY OF ONE DECAY PARTICLE EACH HOUR. AFTER AN HOUR HAS PASSED, THERE IS AN EQUAL PROBABILITY OF EITHER STATE . . . THE LIVE CAT STATE OR THE DEAD CAT STATE.



Quantum theory (with the Born interpretation) would predict that exactly one hour after the experiment began, the box would contain a cat that is **neither wholly alive nor wholly dead** but a mixture of the two states, the superposition of the two wave functions.

SEE, IT'S RIDICULOUS!
THE PROBABILITY INTERPRETATION OF MY WAVE FUNCTION IS NOT ACCEPTABLE!



Schrödinger thought he had made his point. Yet today, 60 years later, his so-called *paradox* is used to teach the concepts of quantum probability and the superposition of quantum states.

AS SOON AS WE LIFT UP THE LID OF THE BOX TO FIND OUT IF THE QUANTUM PREDICTION IS CORRECT, THE IMPASSE IS RESOLVED.

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Postulado 5

La evolución con el tiempo de un sistema mecano-cuántico está gobernada por la ecuación de Schrödinger dependiente del tiempo

$$\hat{H}\Psi(x, t) = i\hbar \frac{\partial \Psi(x, t)}{\partial t}$$

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Para estados estacionarios:

$$\begin{aligned} \hat{A}(x)\Psi_n(x, t) &= a_n\Psi_n(x, t) \\ \hat{A}(x)\psi(x)e^{-i(E/\hbar)t} &= a_n\psi_n(x)e^{-i(E/\hbar)t} \quad \text{or} \end{aligned}$$

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