

Het quantum-meetprobleem:

de lastige overgang van de allerkleinste deeltjes
naar de natuurkunde van alledag

Lotte Mertens

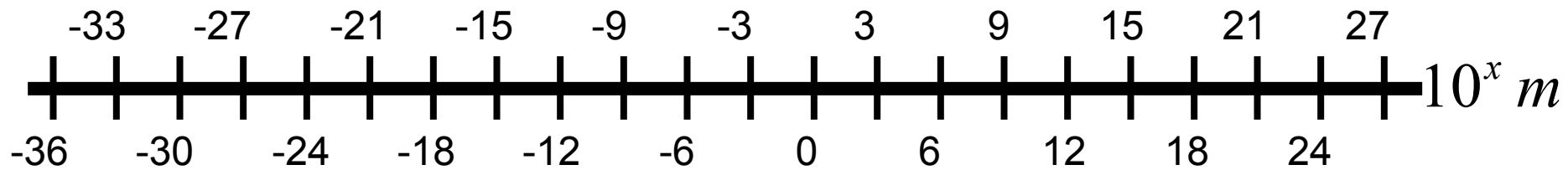
L.Mertens@uva.nl

Domeinen van de natuurkunde

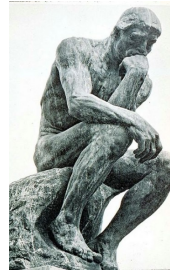
Quantum mechanica:
$$i\hbar \frac{\partial}{\partial t} |\psi\rangle = \hat{H} |\psi\rangle$$

Algemene relativiteitstheory:
$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

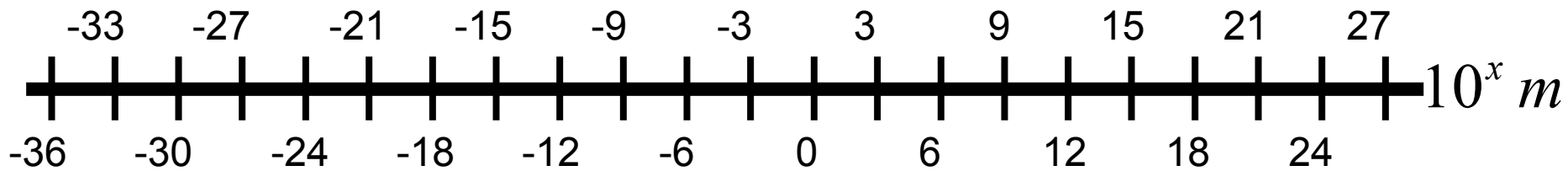
Domeinen van de natuurkunde



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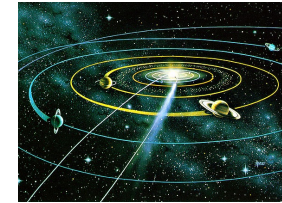
$10^0 m$



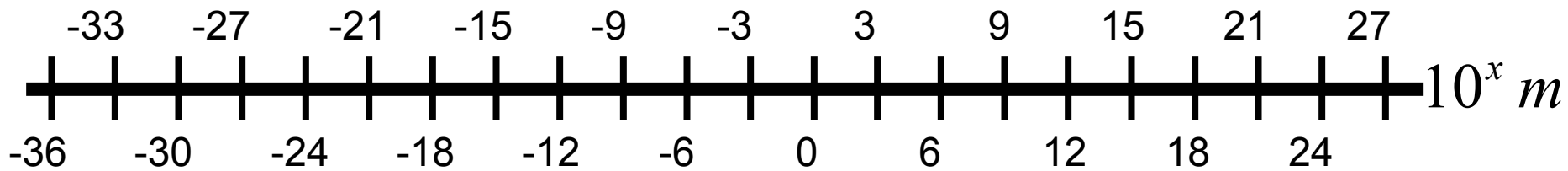
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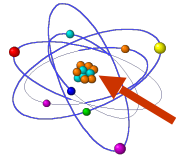
$10^0 m$



$10^{12} m$



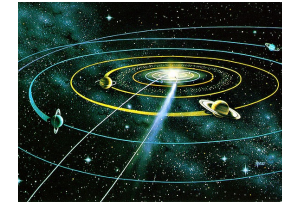
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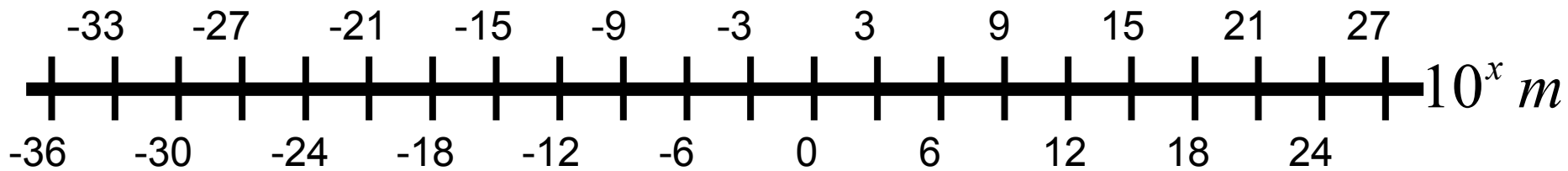
$10^{-15} m$



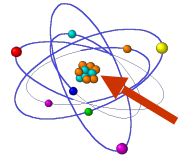
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$10^{12} m$



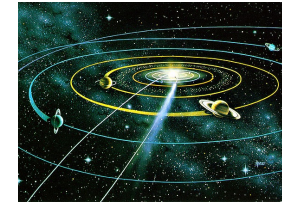
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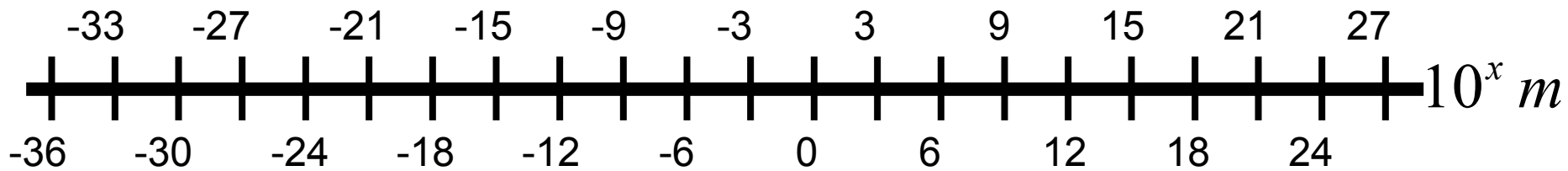
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$10^0 m$



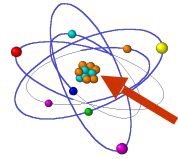
$10^{12} m$



$10^{-36} m$

l_P

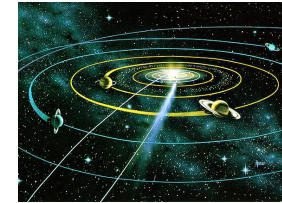
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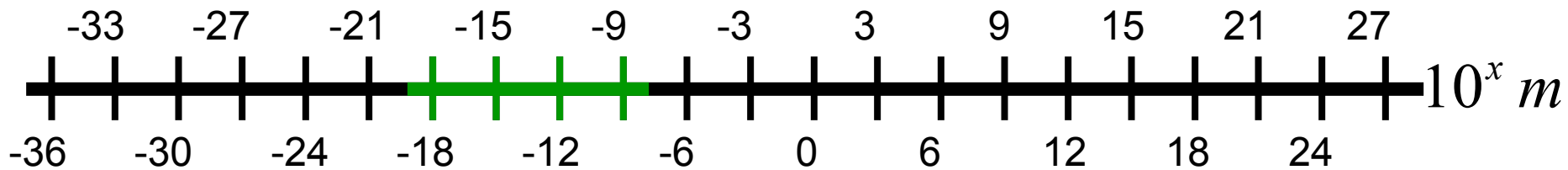
$10^{-15} m$



$10^0 m$

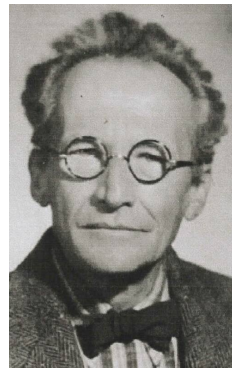


$10^{12} m$

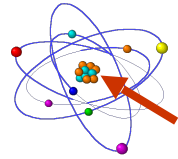


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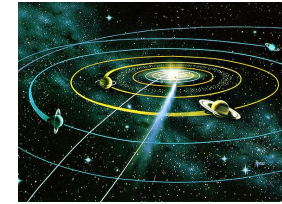
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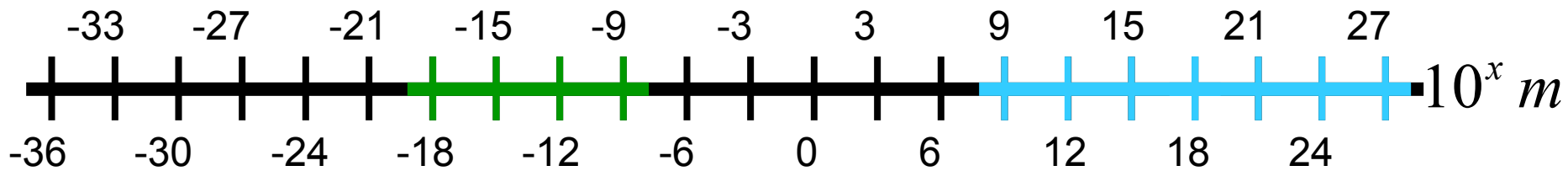
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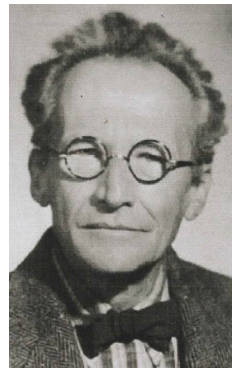


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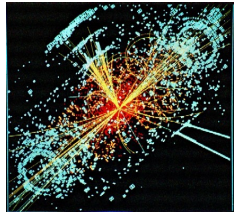


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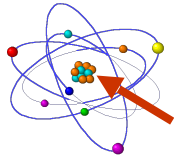
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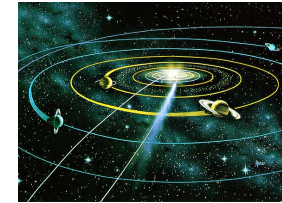
$10^{-19} m$



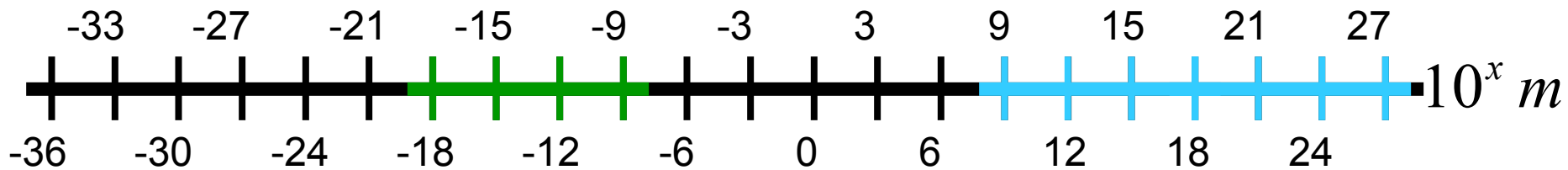
$10^{-15} m$



$10^0 m$

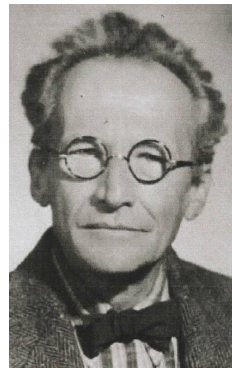


$10^{12} m$

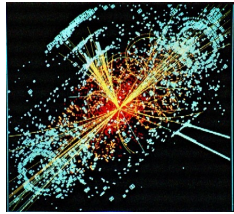


$10^{-36} m$

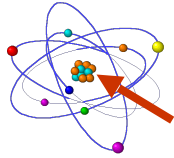
l_P



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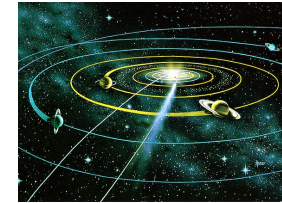
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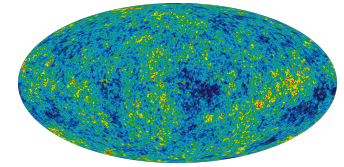
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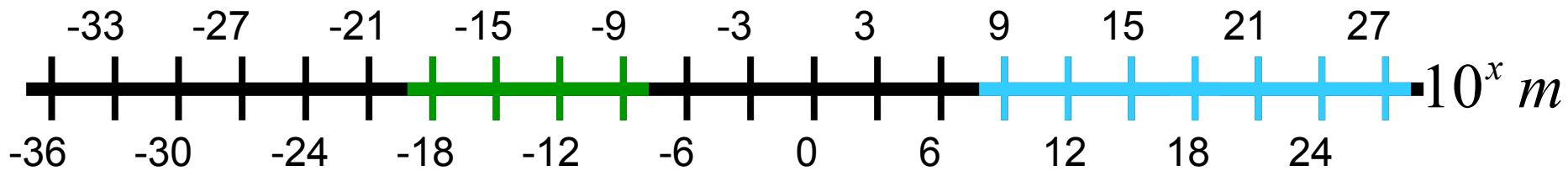
$10^0 m$



$10^{12} m$

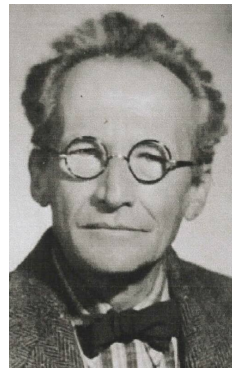


$10^{26} m$

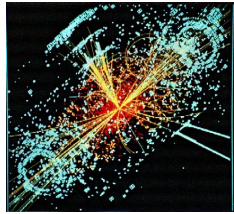


$10^{-36} m$

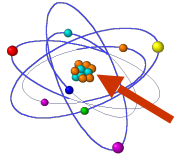
l_P



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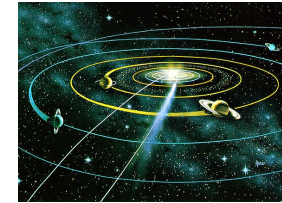
$10^{-19} m$



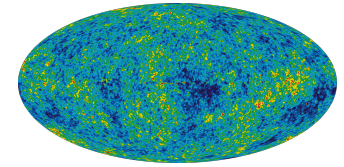
$10^{-15} m$



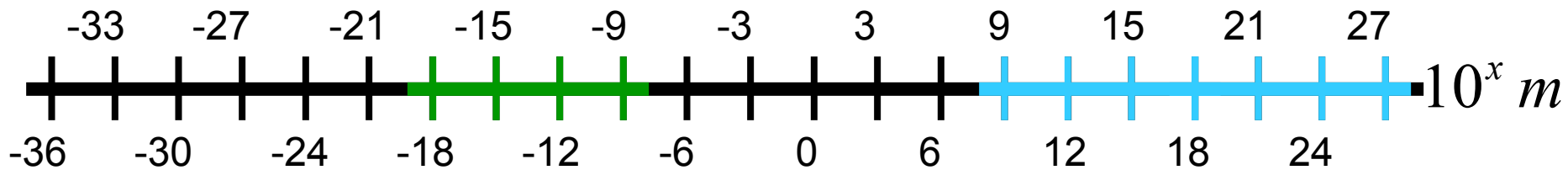
$10^0 m$



$10^{12} m$



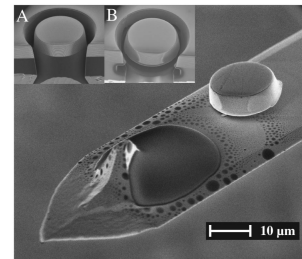
$10^{26} m$



$10^{-36} m$

l_P

$10^{-6} m$



Wat gebeurt er in het midden?

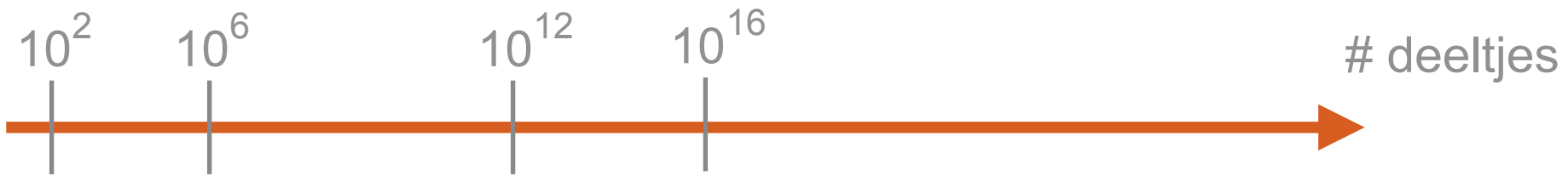
Het quantum-meetprobleem:

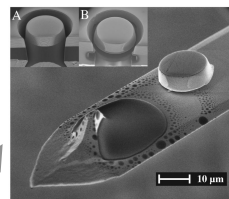
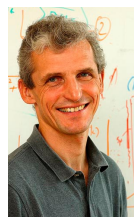
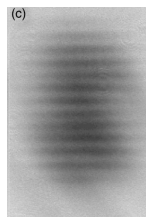
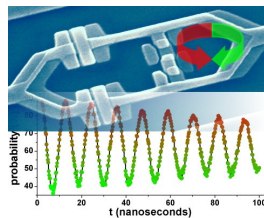
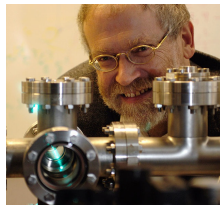
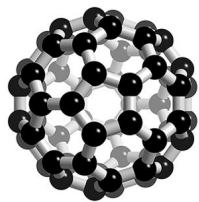
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Oplossingen

I. Wegkijken

- Kopenhagen interpretatie





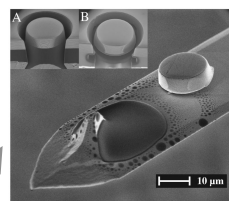
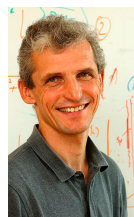
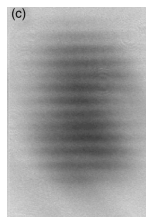
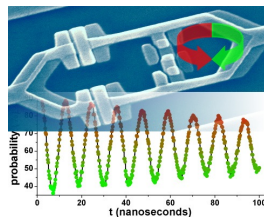
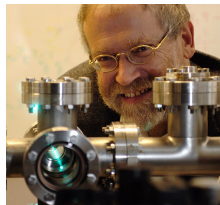
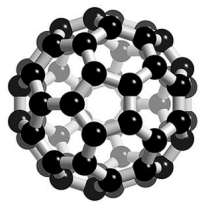
10^2

10^6

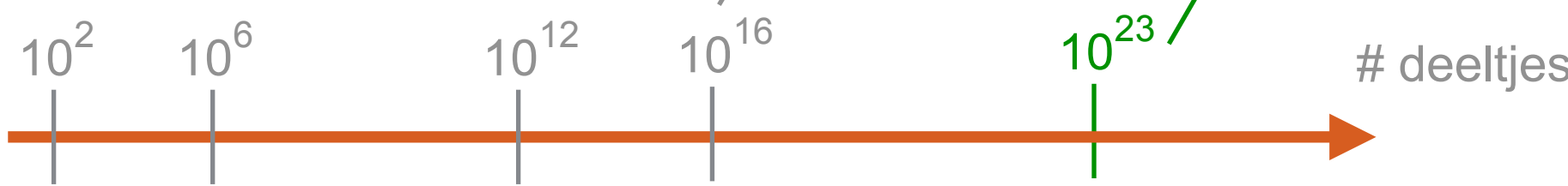
10^{12}

10^{16}

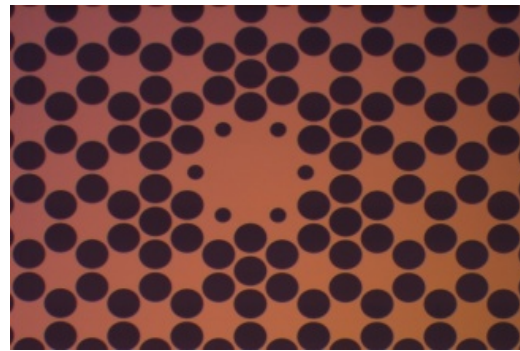
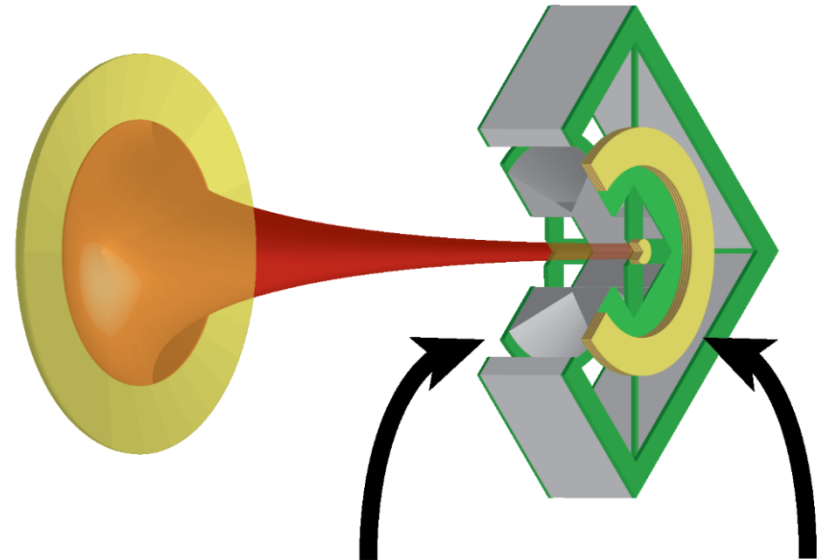
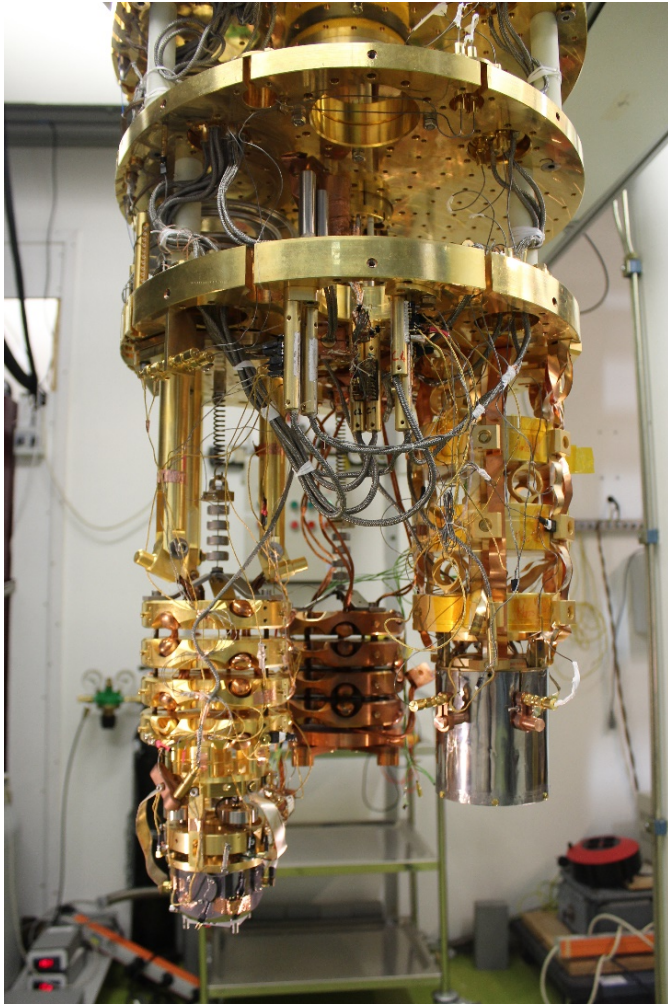
deeltjes



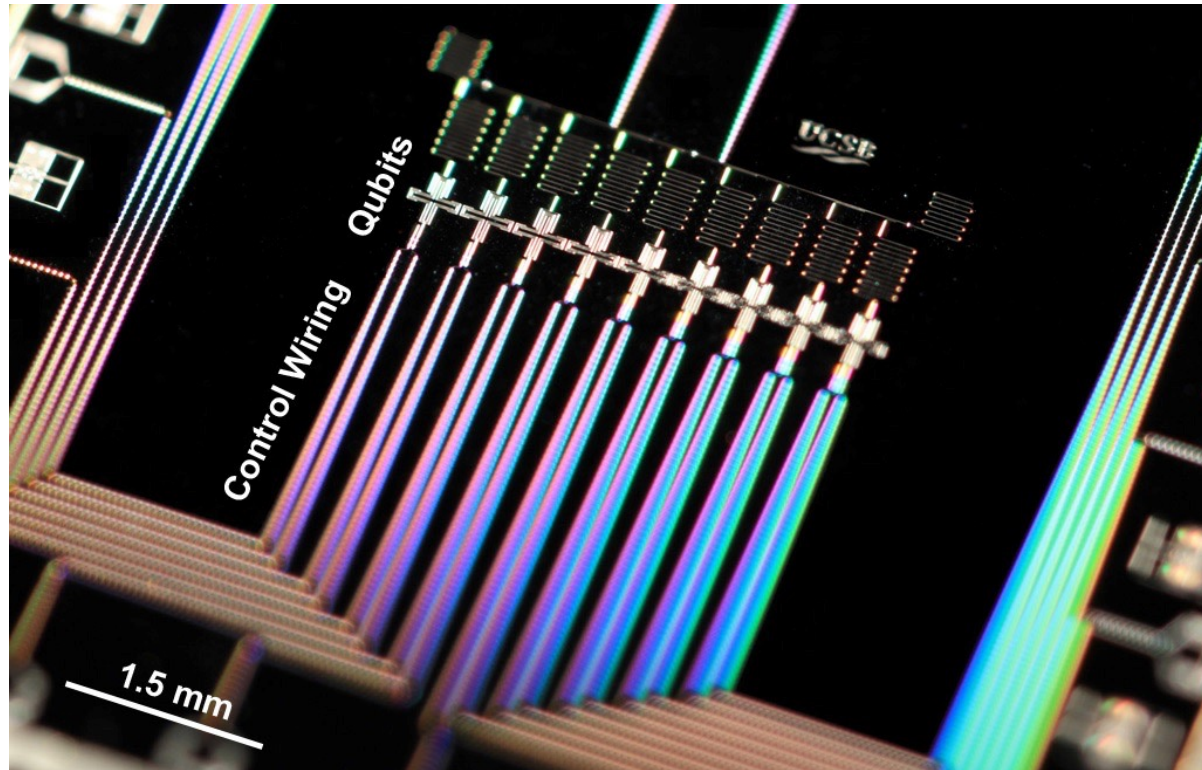
Large N
Limit ?



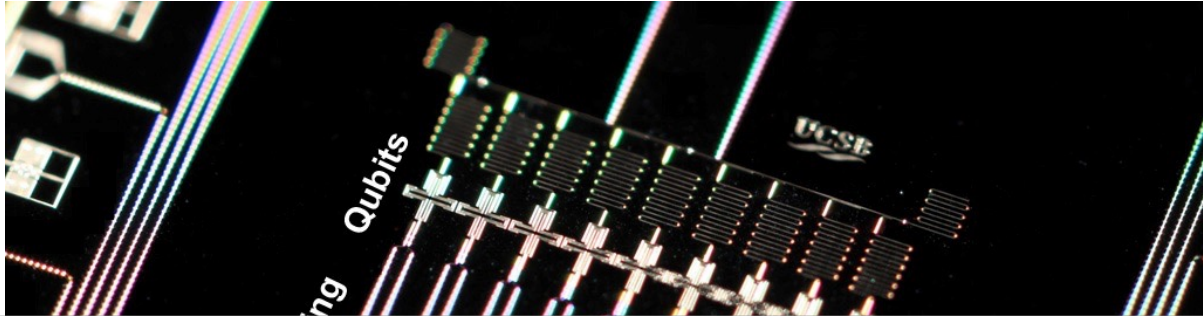
A nano-scale experiment



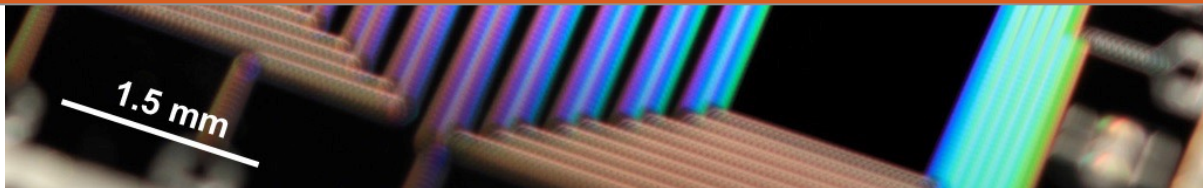
A nano-scale experiment



A nano-scale experiment



Quantum computer = Measuring device



Oplossingen

I. Wegkijken

- Kopenhagen interpretatie

Oplossingen

1. Wegkijken
 - Kopenhagen interpretatie
2. Interpretaties
 - Many worlds

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3. Aanpassen Schrödingervergelijking

Oplossingen

1. Wegkijken

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3. Aanpassen Schrödingervergelijking

$$i\hbar \frac{\partial}{\partial t} |\psi\rangle = \hat{H} |\psi\rangle \quad \longrightarrow \quad i\hbar \frac{\partial}{\partial t} |\psi\rangle = (\hat{H} + \hat{G}) |\psi\rangle$$

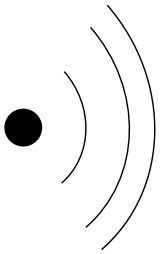
Ingrediënten theorie

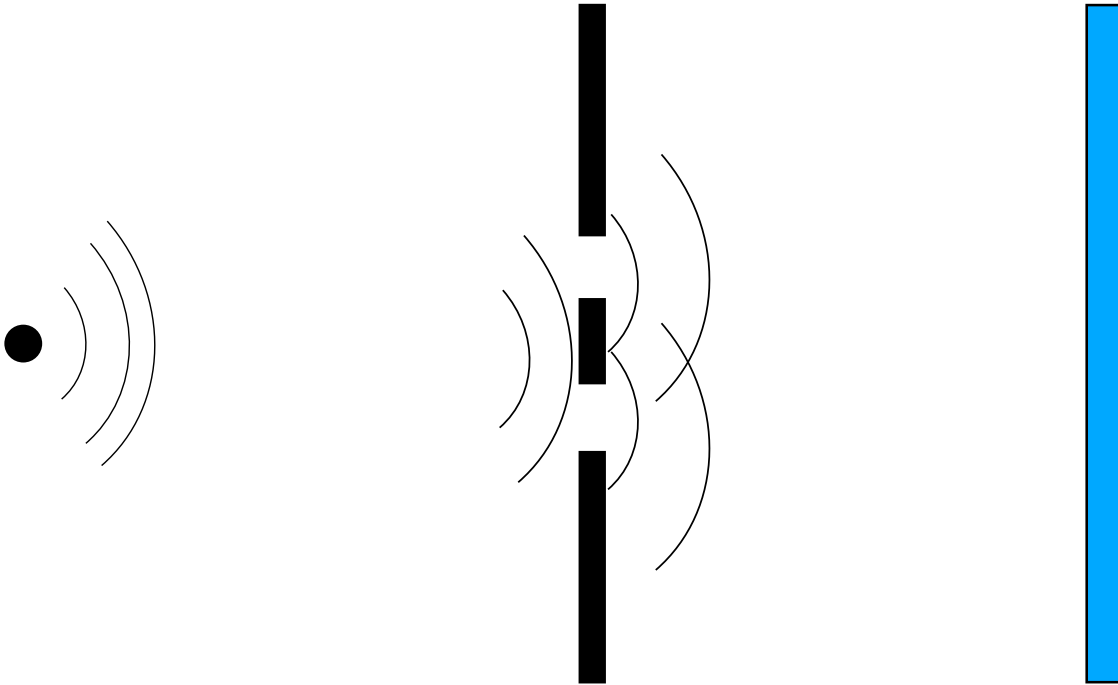
I. Gebroken tijdsinversie:

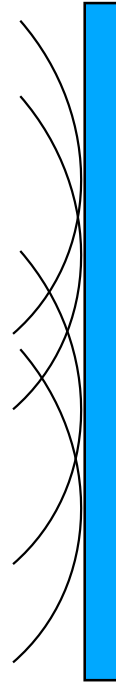
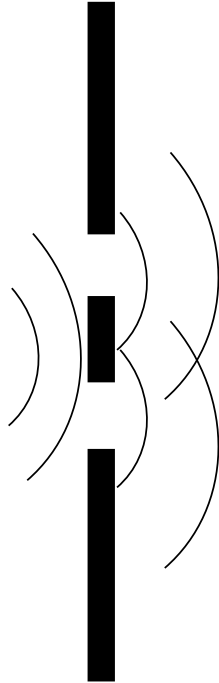
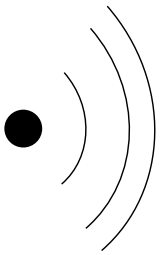
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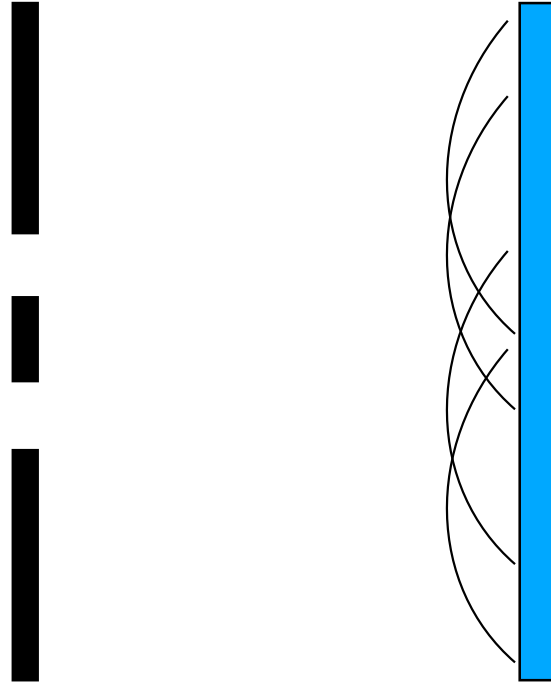


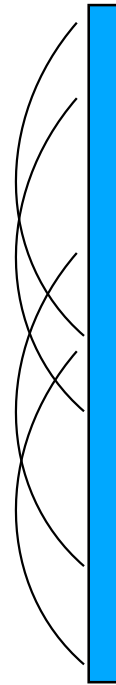
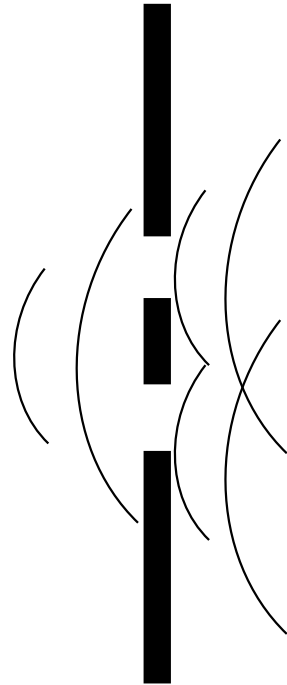


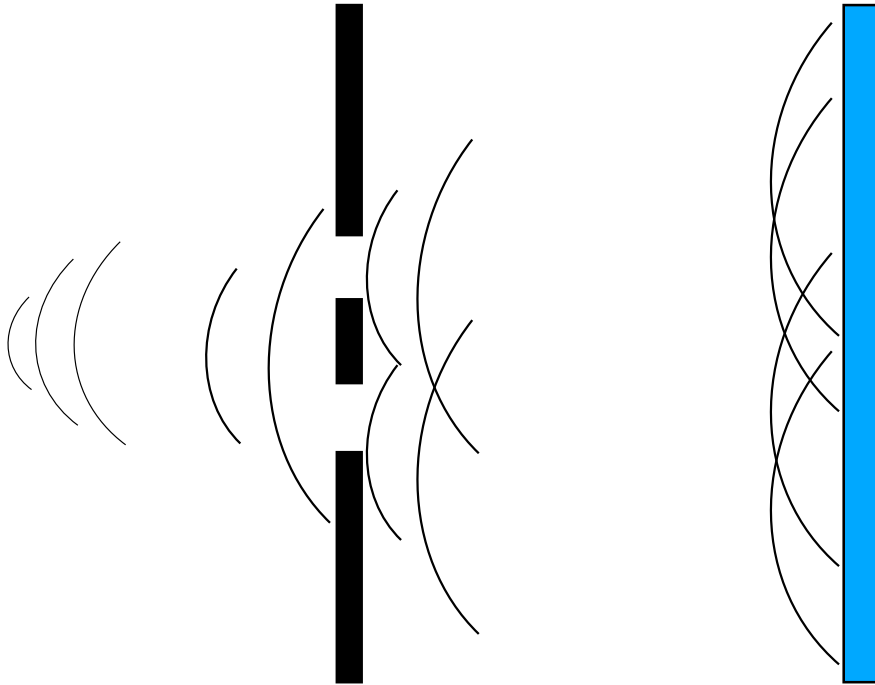


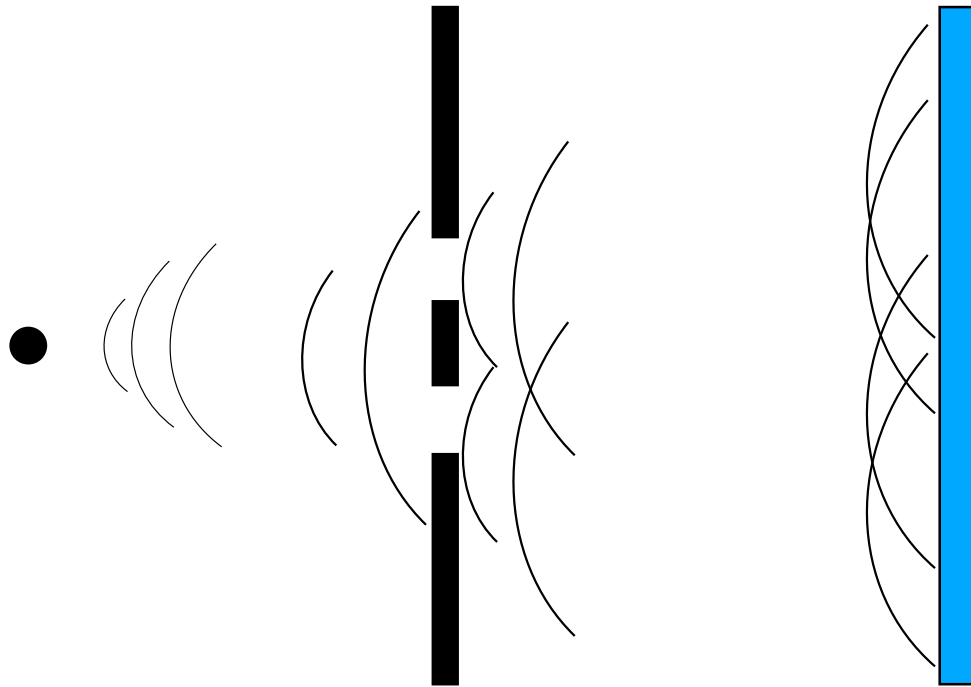




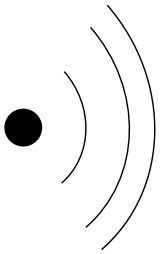


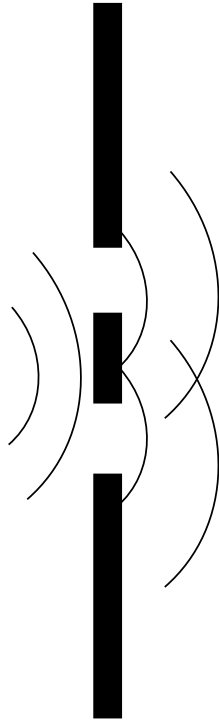
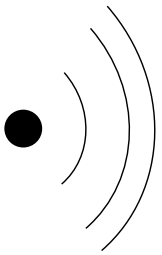


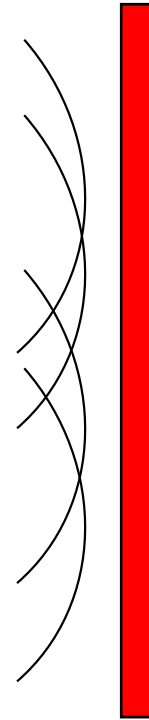
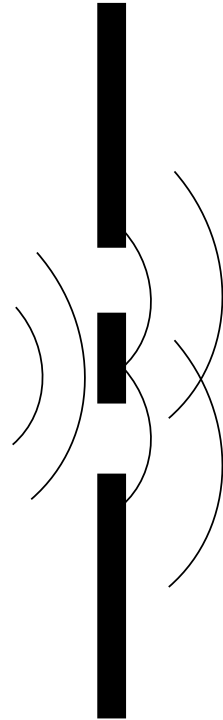
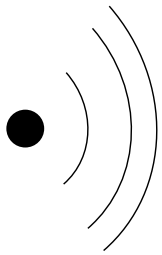




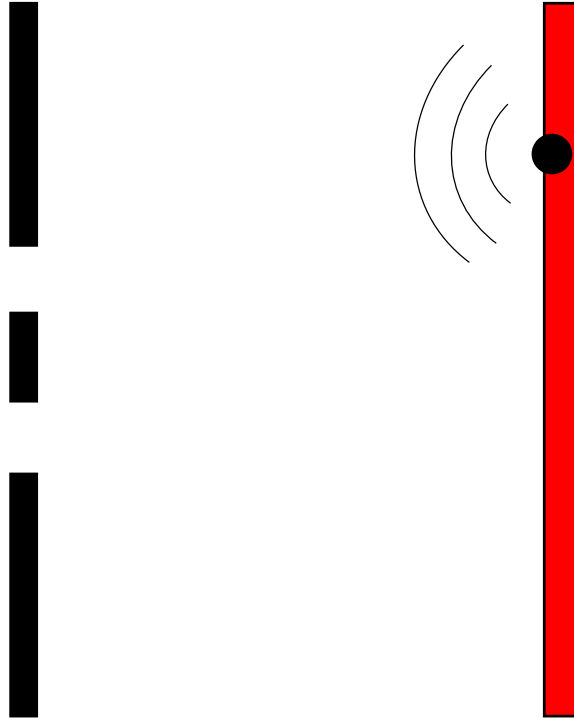


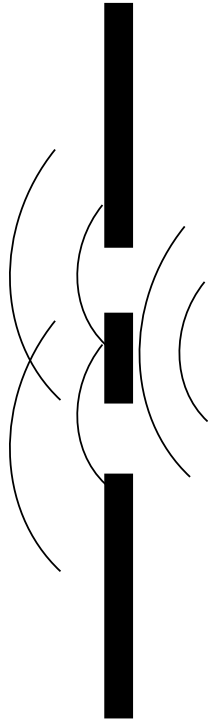


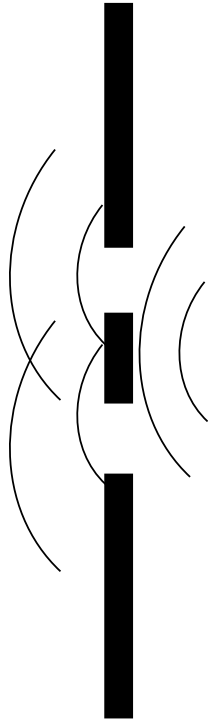












Ingrediënten theorie

I. Geen tijdsinversie:

- In QM tijd is omkeerbaar
- Een meting is dat niet

Ingrediënten theorie

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2. Niet-deterministisch

- Stochastische variabele
- Eén experiment, meerdere uitkomsten

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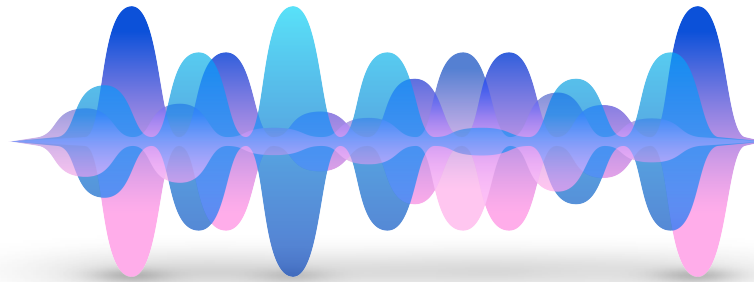
- Born regel: waarschijnlijkheidsverdeling

$$|\psi(x)|^2 = P_x$$

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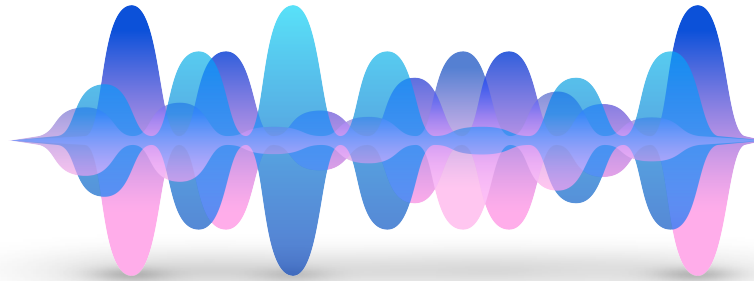
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- Born regel: waarschijnlijkheidsverdeling

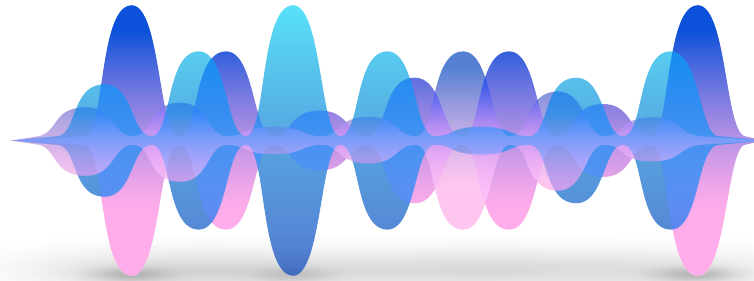
$$|\psi(x)|^2 = P_x$$



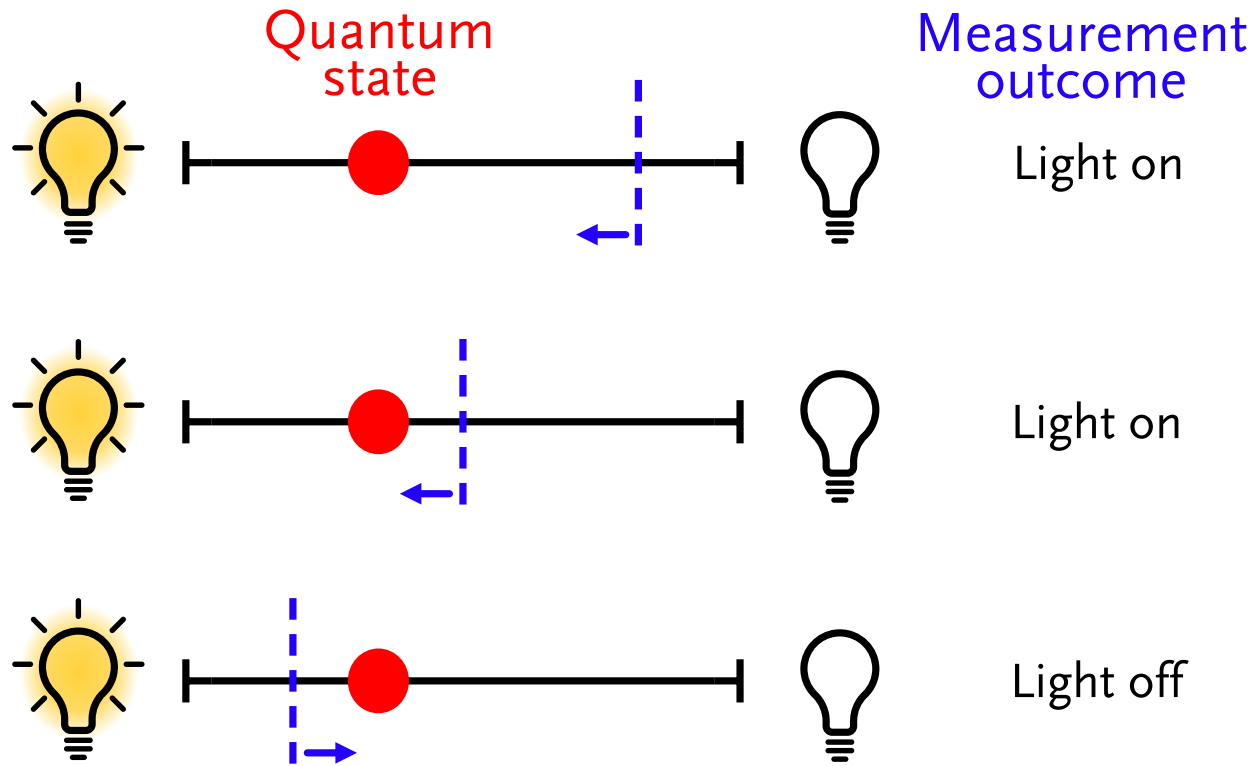
3. Niet-linear

- Born regel: waarschijnlijkheidsverdeling

$$|\psi(x)|^2 = P_x$$



Model



Nu begint het!