36th International Physics Olympiad
Salamanca, Spain
3–12 July 2005

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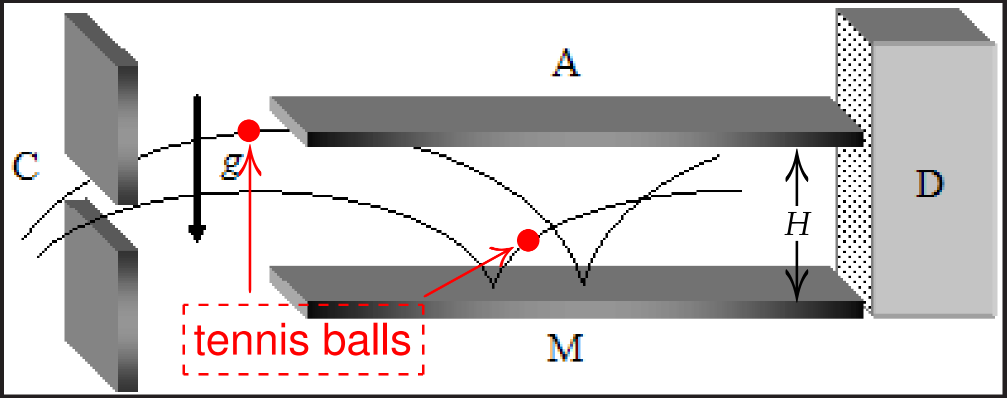
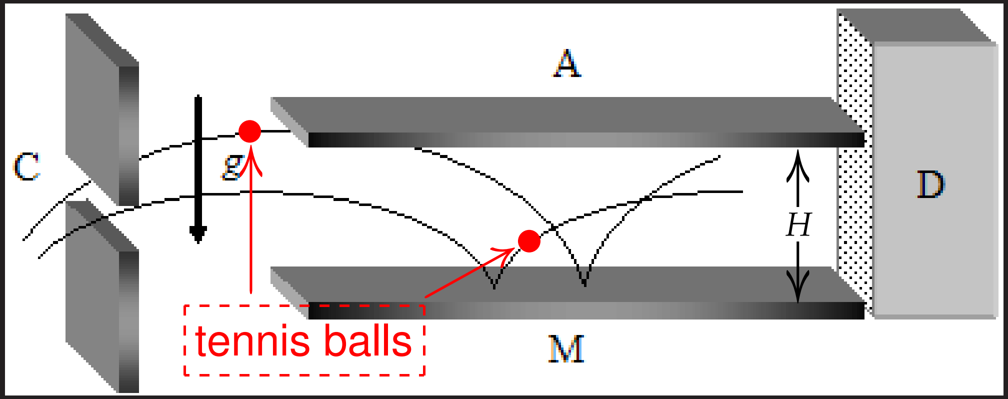
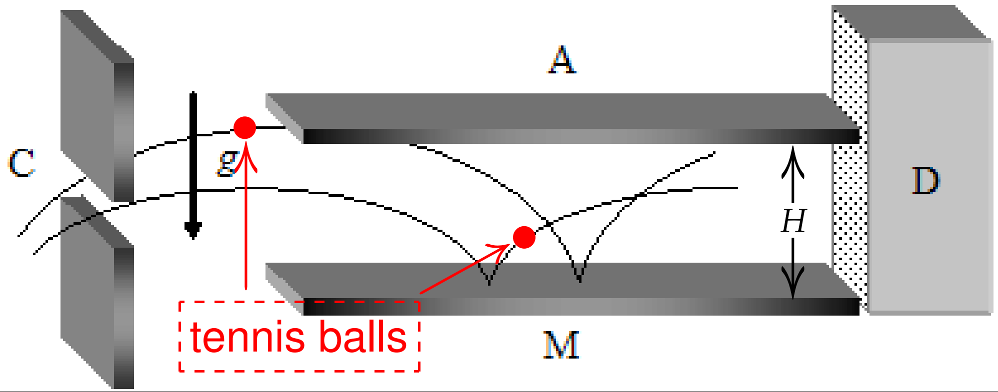
Theoretical Question 3:
"Quantum effects of gravity"


A
C
g
D
H
tennis balls
M



Classically, the cavity behaves as a vertical velocity selector



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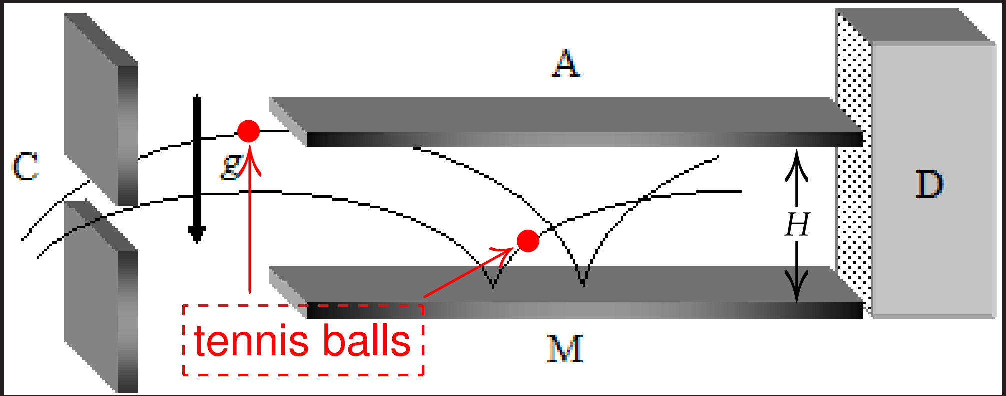
1. Balls with high v_z will eventually hit the absorber:

$$|v_z(z)| < v_{\text{max}}(z) \qquad \text{(energy conservation)}$$



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1. Balls with high v_z will eventually hit the absorber:
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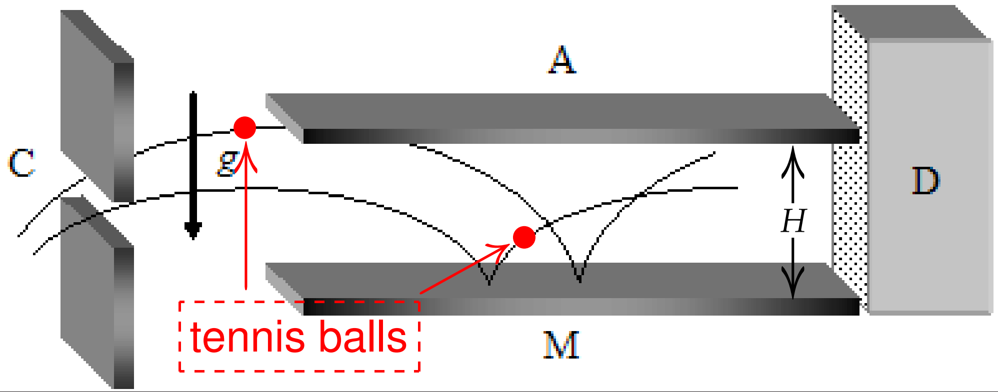
2. One up-down cycle is necessary in order to select velocities $\longrightarrow$ minimum time and length t_c, L_c



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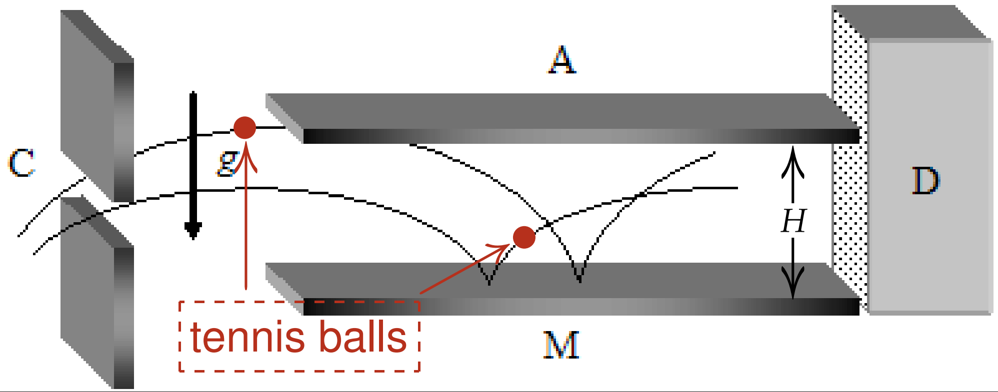
3. Number of balls at D: $N_c \propto \int_0^H dz\, 2v_{\text{max}}(z)$



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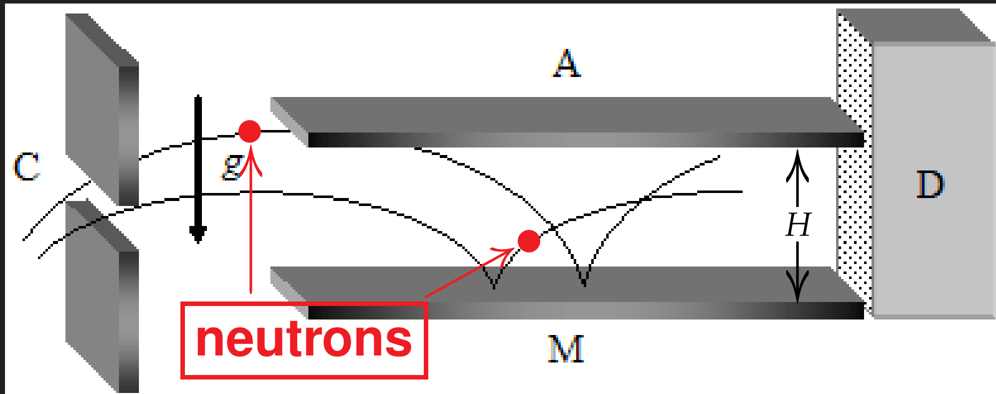

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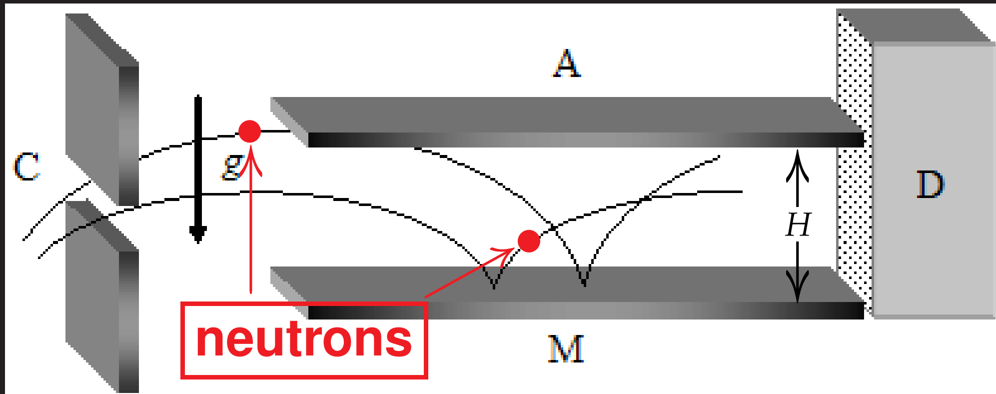

For neutrons ($mv_zH \sim h$), the cavity behaves as an energy selector

1. Energy levels $E_n = E_1 n^{2/3}$
   (BS quantization rule — PROVIDED)

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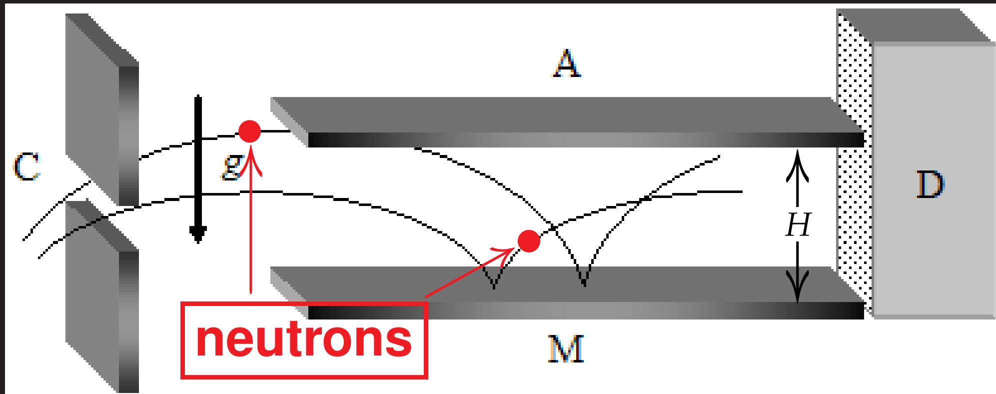

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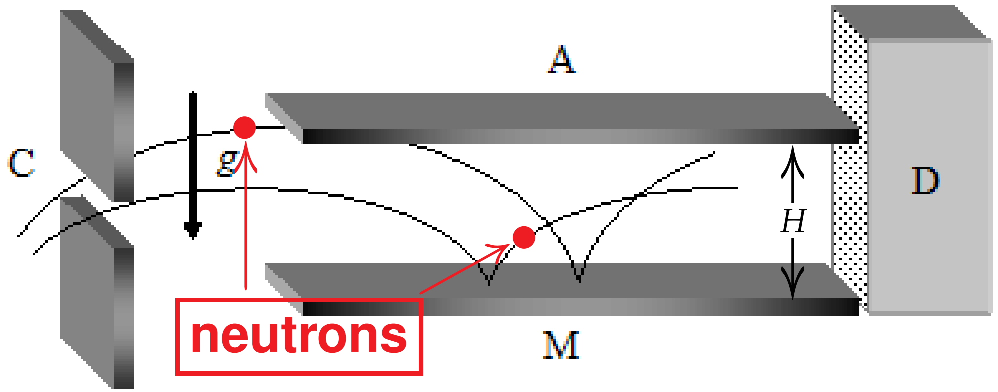

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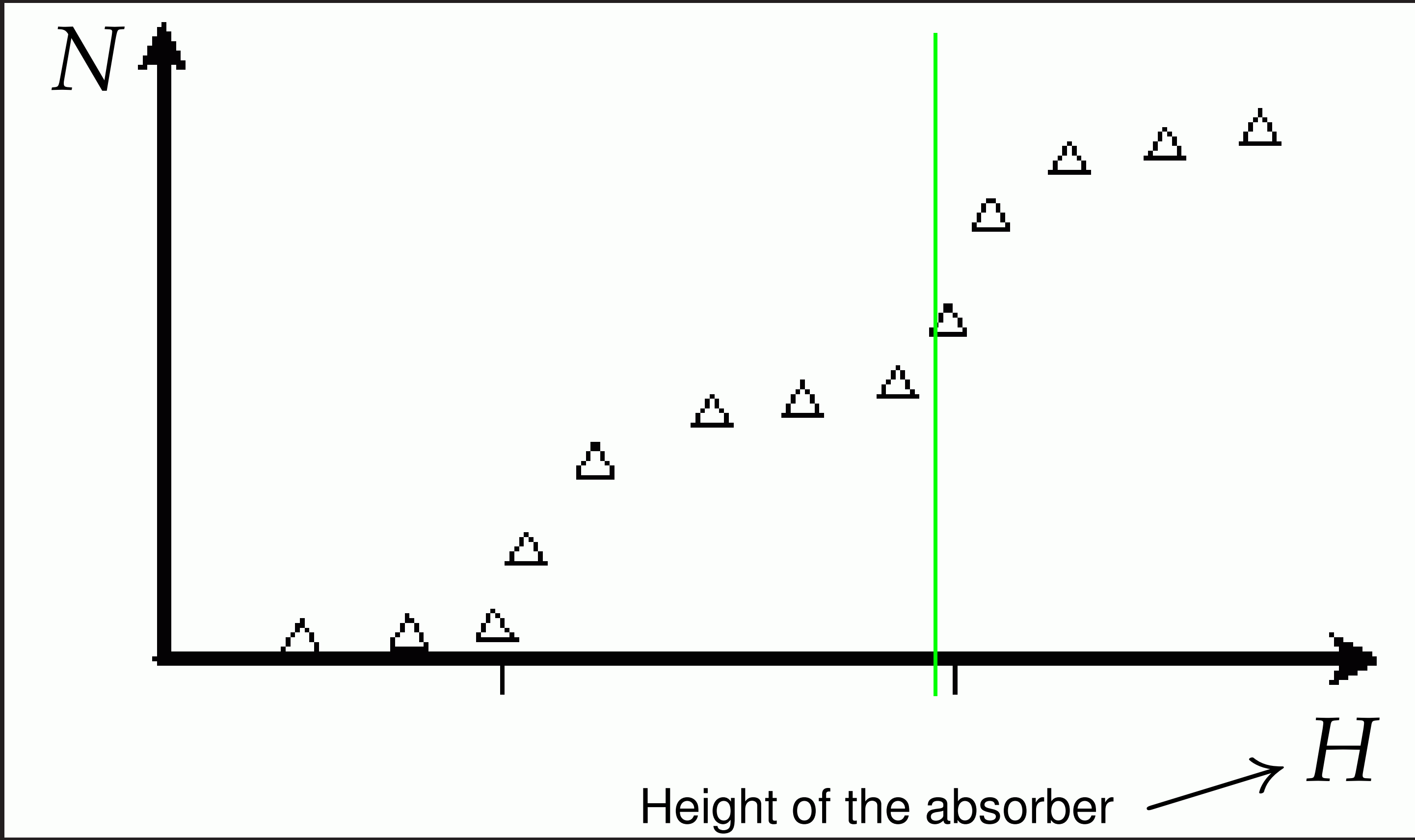
   (BS quantization rule — PROVIDED)

2. Time necessary to observe the first quantum level
   (Uncertainty relations: $\Delta t \gtrsim h/\Delta E \gtrsim h/E_1$)

3. Number of neutrons at D: $N_q = \int_0^H dz\, I(z)$
   (intensity proportional to (amplitude)^2)

Sketch of experimental data for neutron counting:



Only the first quantum sharp increase is analysed

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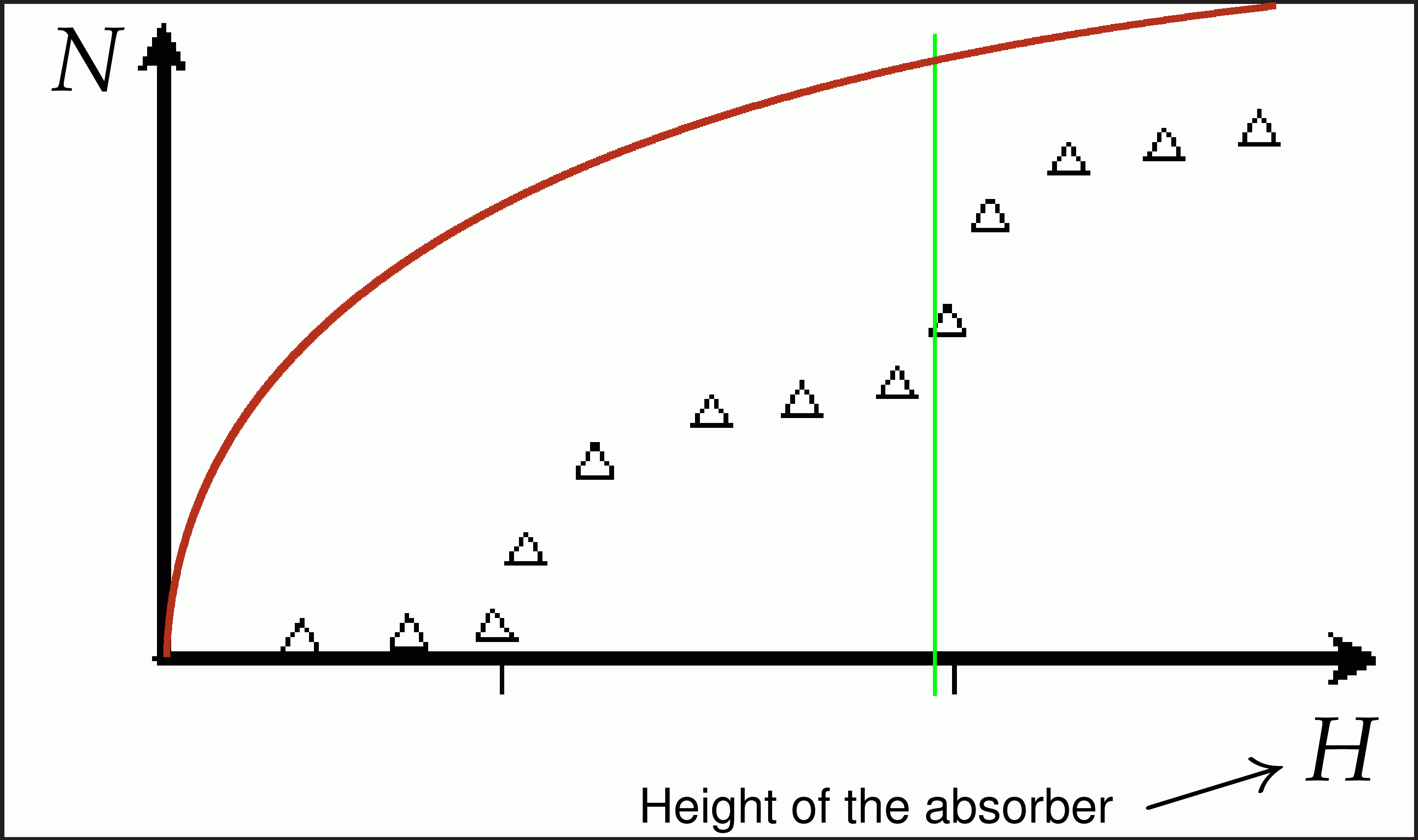

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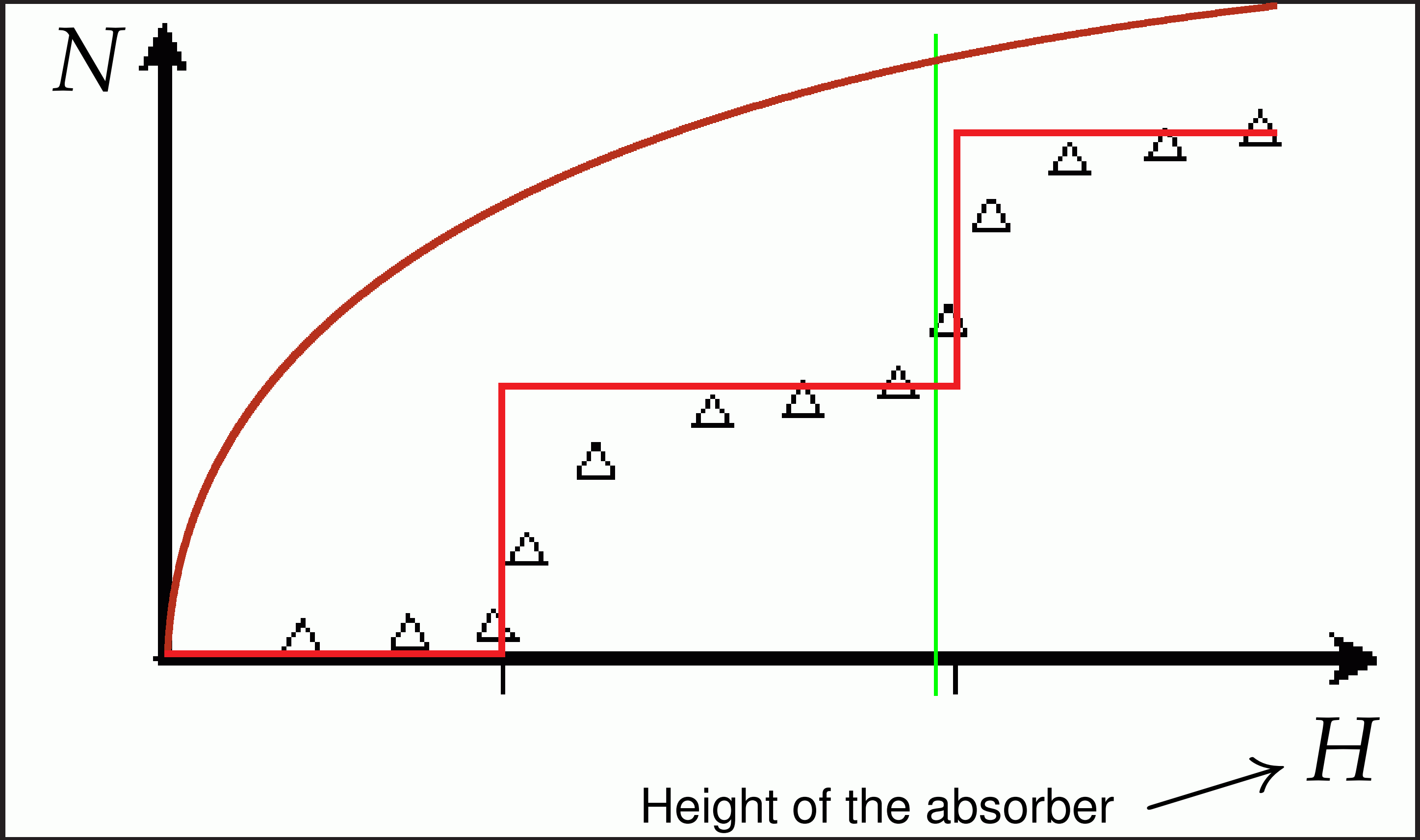

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Objective:

Compare classical and quantum predictions for neutrons in the Earth's gravitational field

Main references:

V. V. Nesvizhevsky et al.,
"(Measurement of) quantum states of neutrons in the Earth's gravitational field",

- Nature 415 (2002) 297;
- Phys. Rev. D67 (2003) 102002.

Precedent:

"Electron interference"

- 5th Iberoamerican Physics Olympiad, Jaca 2000, Spain
- 24th International Physics Olympiad, Williamsburgh 1993, U.S.A.

Concepts involved:

- ✦ Energy conservation
- ✦ Heisenberg's uncertainty relations
- ✦ Energy levels of quantum systems
- ✦ Waves: intensity proportional to $(\text{amplitude})^2$

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