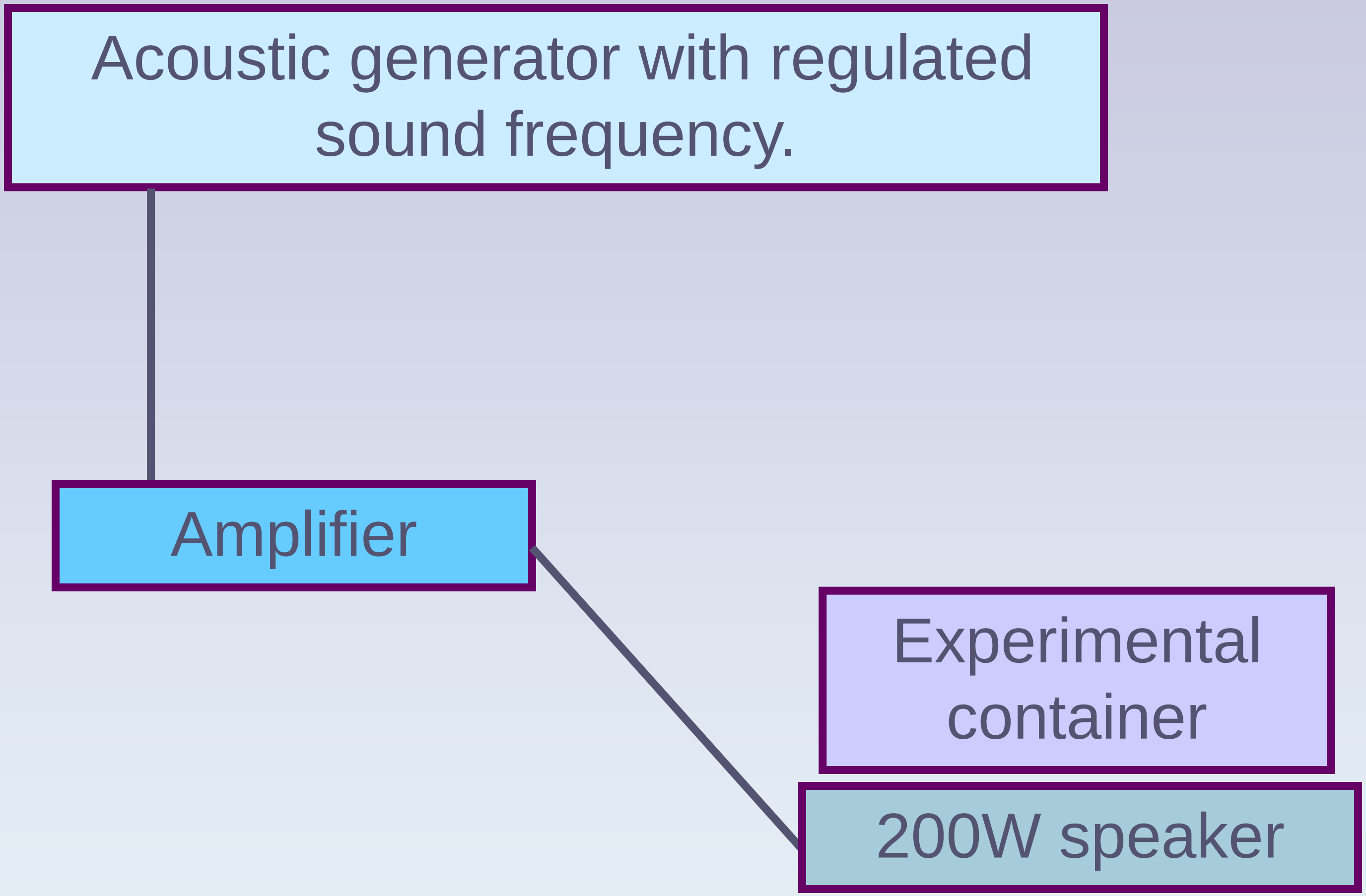
15. Brazil Nut Effect

When a granular mixture is shaken the larger particles may end up above the smaller ones. Investigate and explain this phenomenon. Under what conditions can the opposite distribution be obtained?

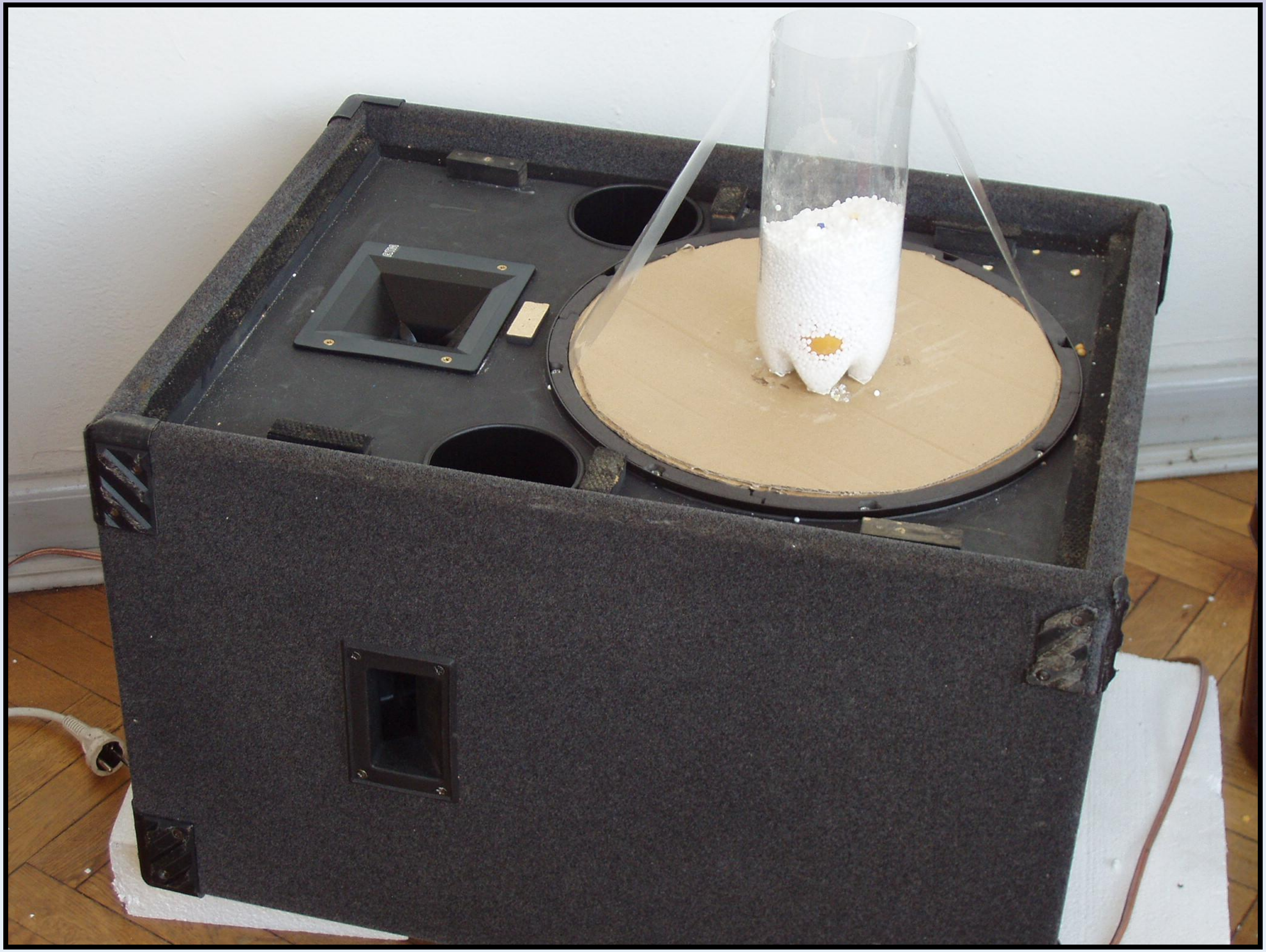
Brazil Nut Effect

Experimental setup



Experimental setup

Experimental setup

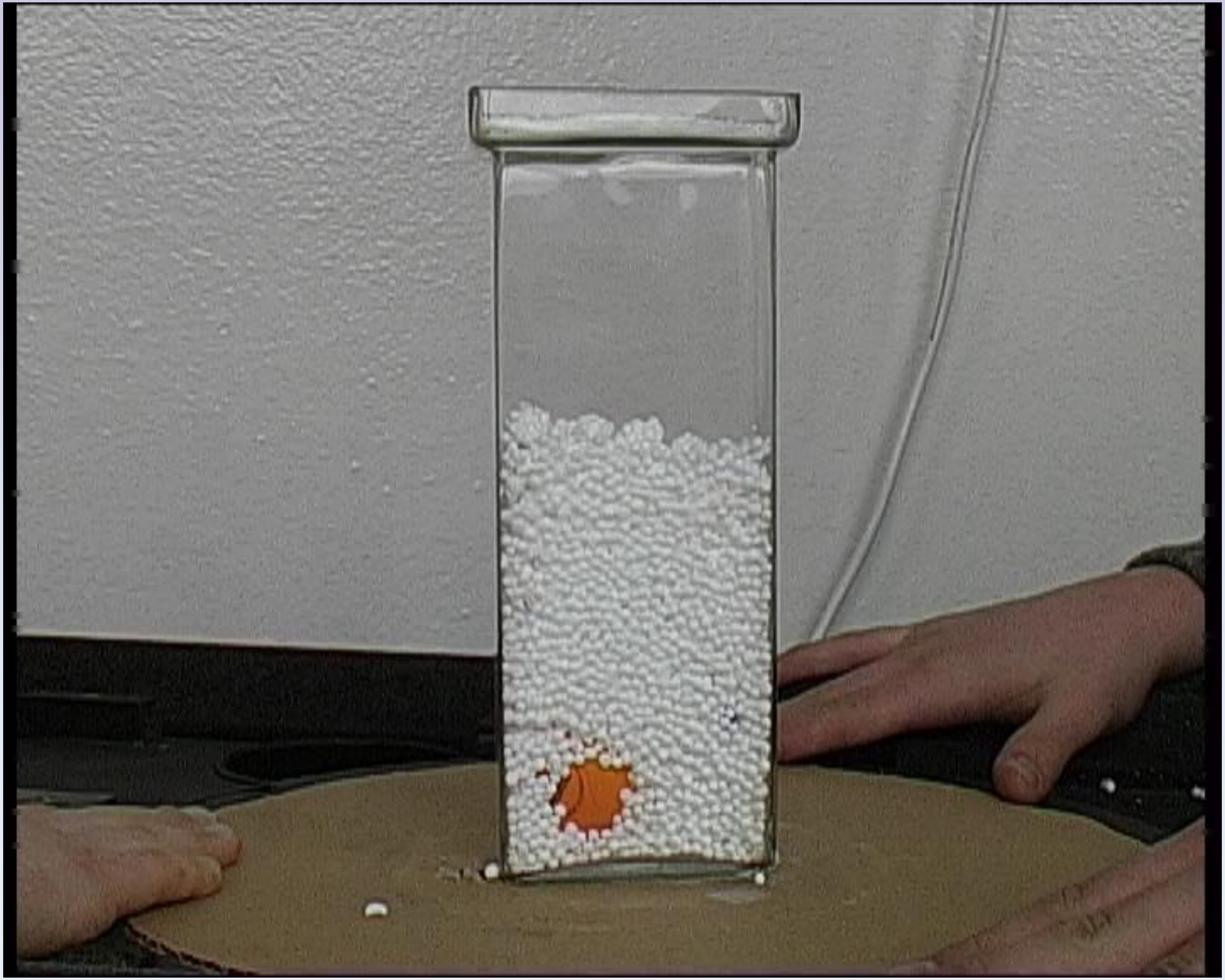


Experiments with various materials

Used substances:

Substance	Particle diameter	Particle mass
Ping-pong balls	40mm	1g
Polystyrene (Styrofoam)	3-5 mm	0,001g – 0,0001g
Plasticine balls	10-12 mm	1-2g
Pea grains	5-7 mm	0,15g

How do the particles move?



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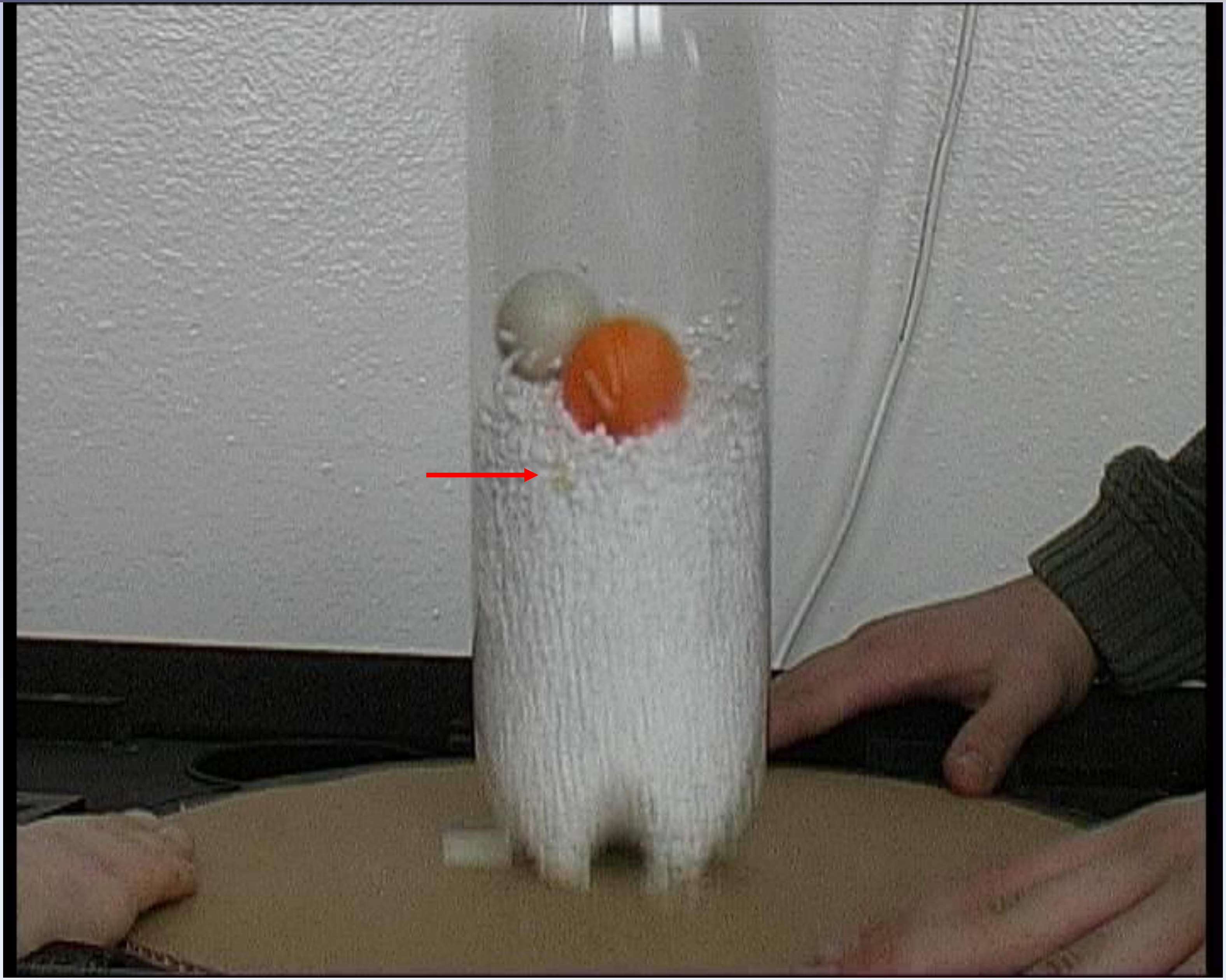

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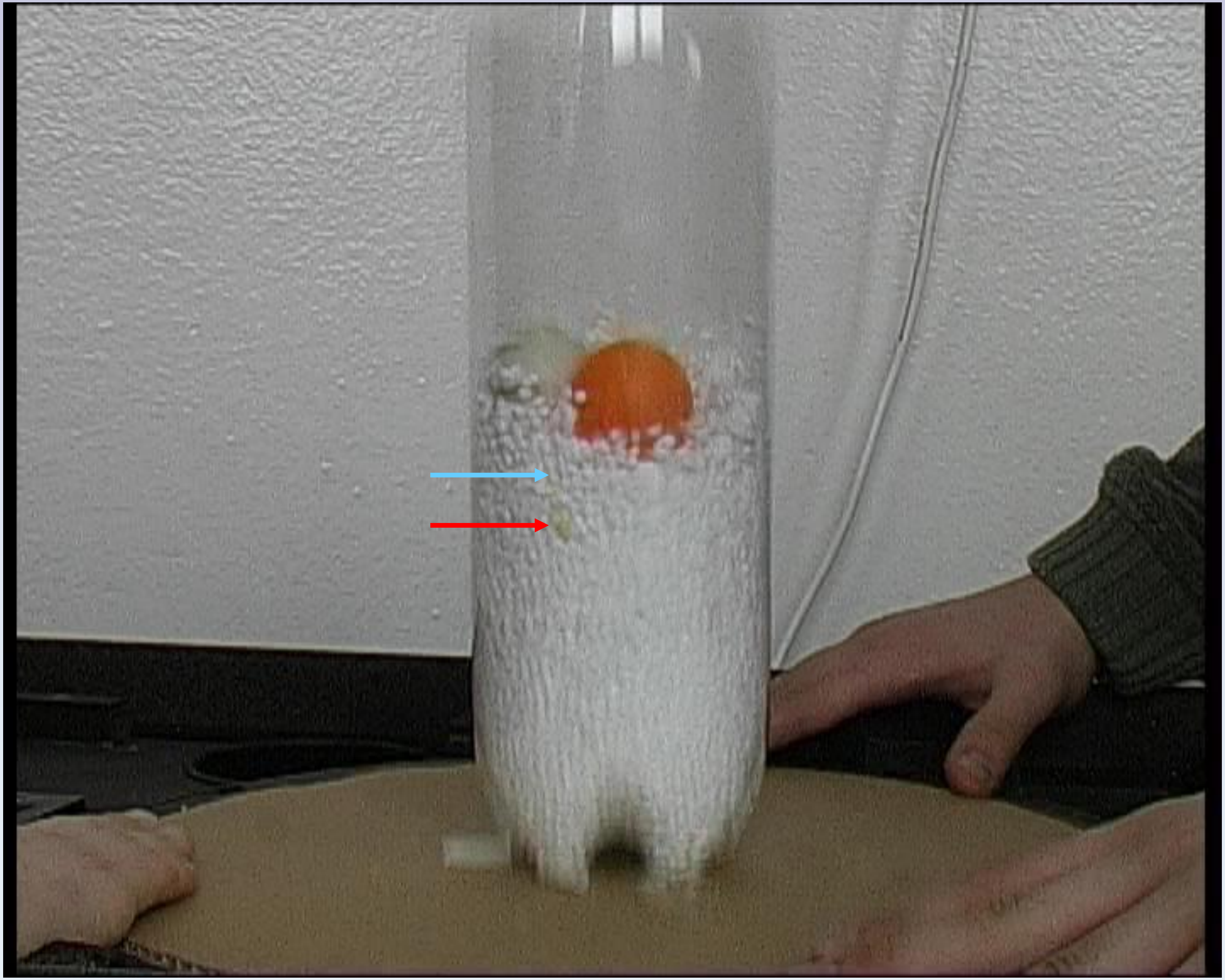

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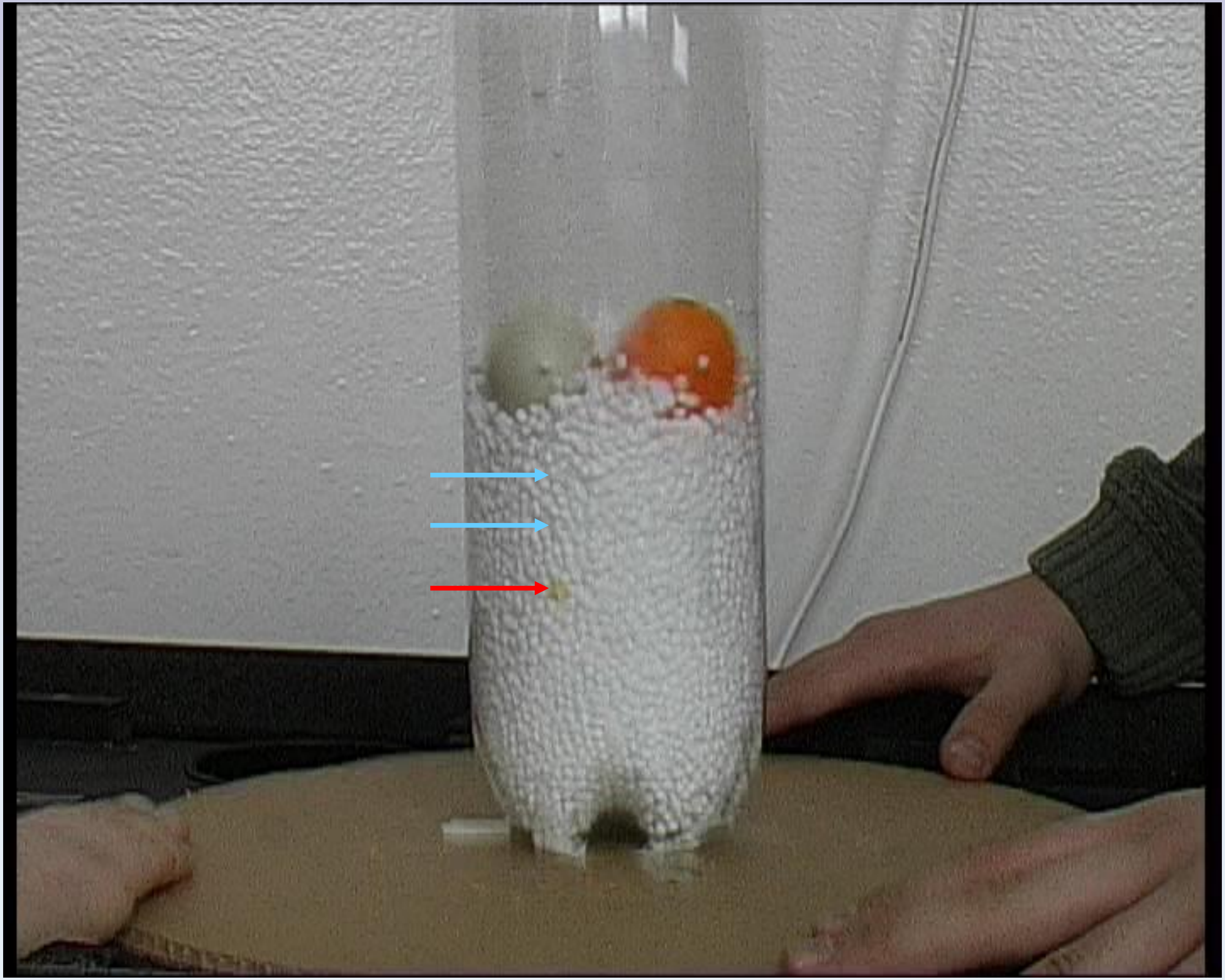

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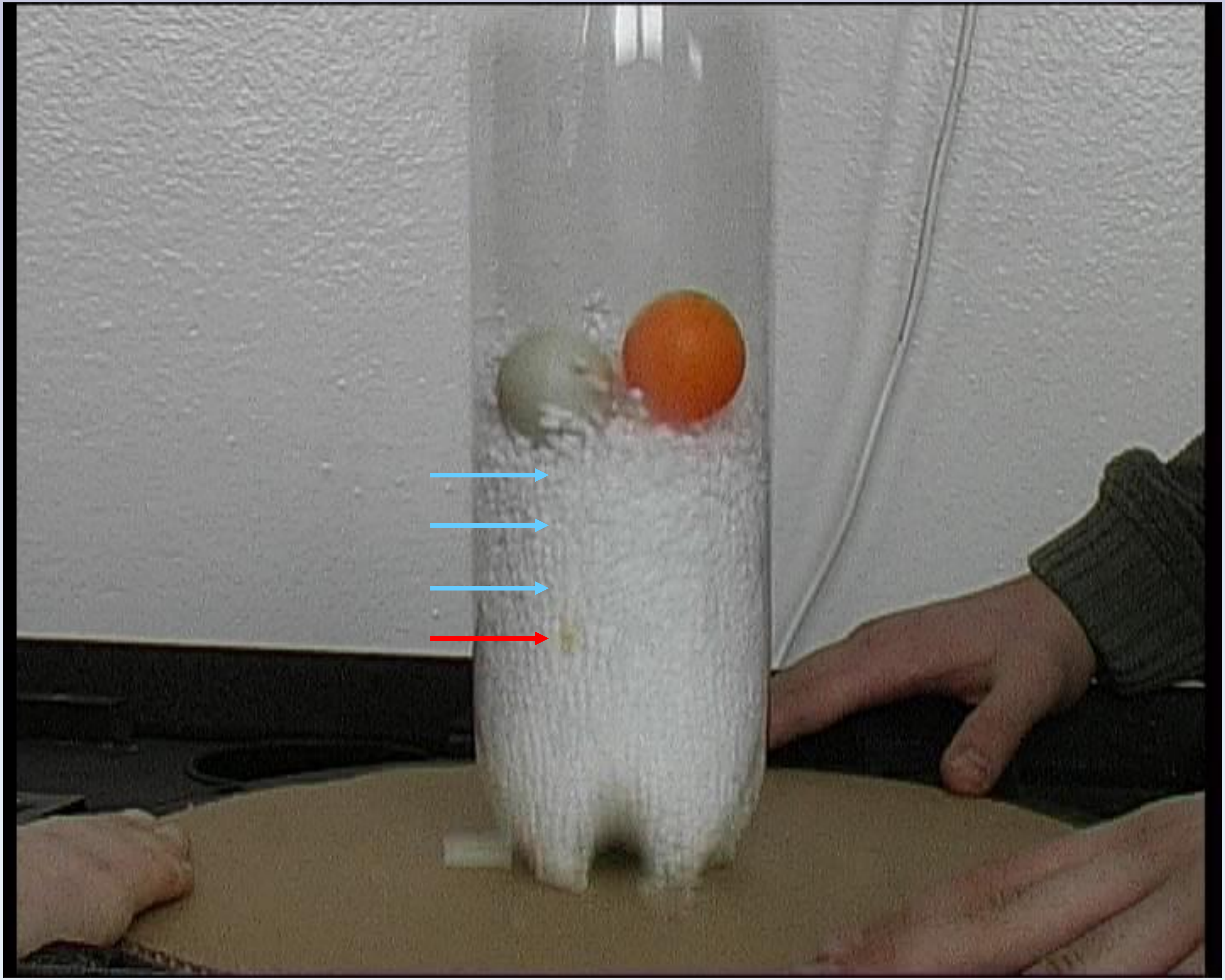

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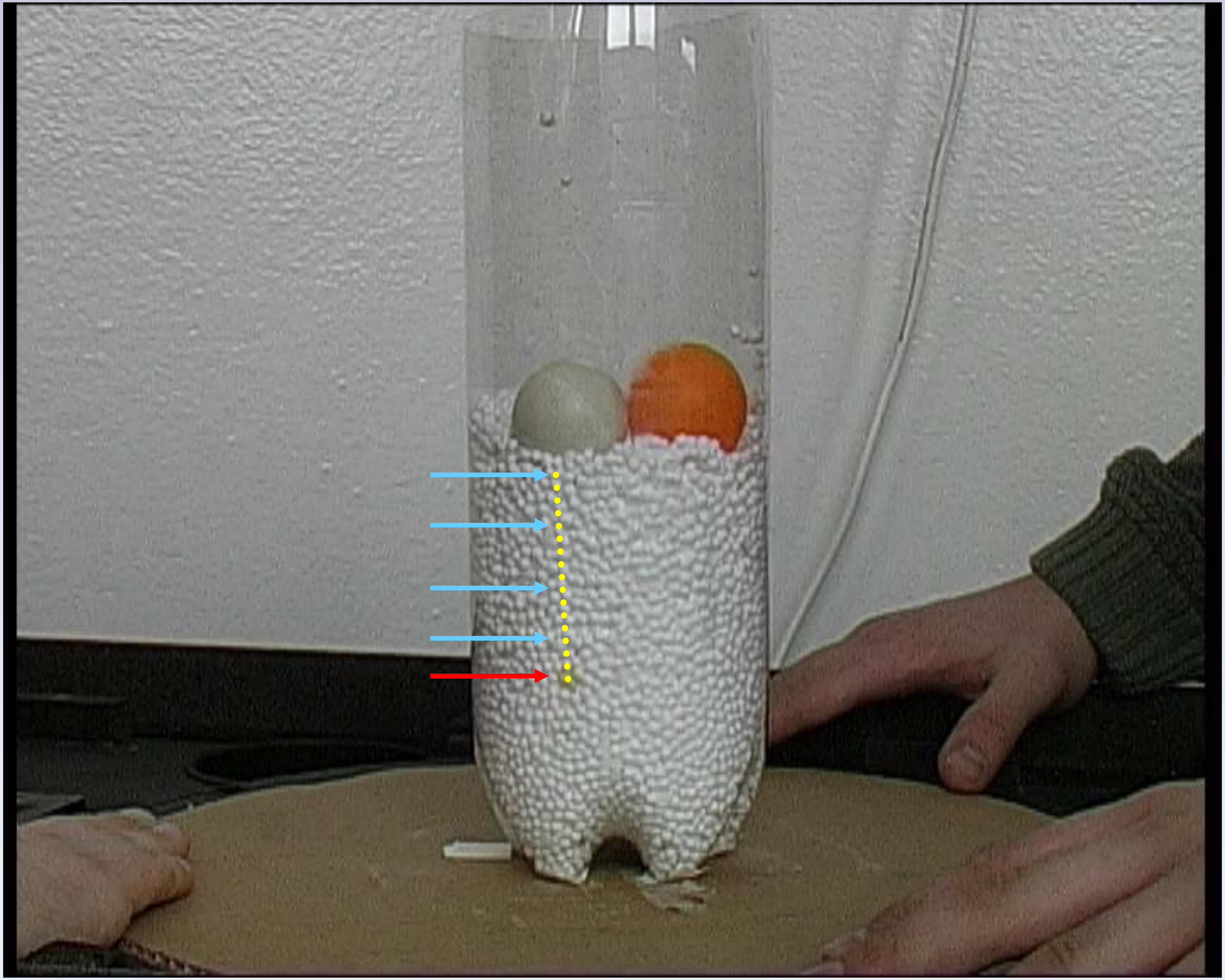
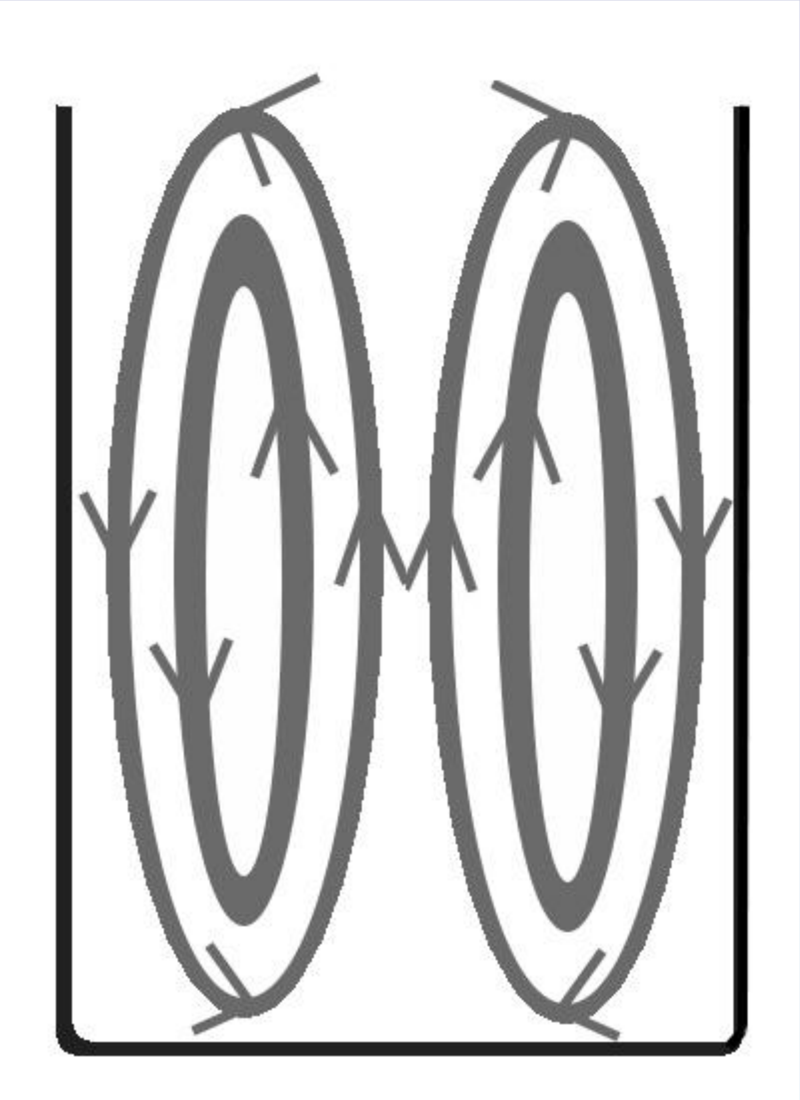


How do the particles move?

- **Creation of convective cells.**



In a container with vertical walls, particles rise to the top in the central, internal part of the mixture and „flow down” along smooth vertical walls of the container.

How do the particles move?

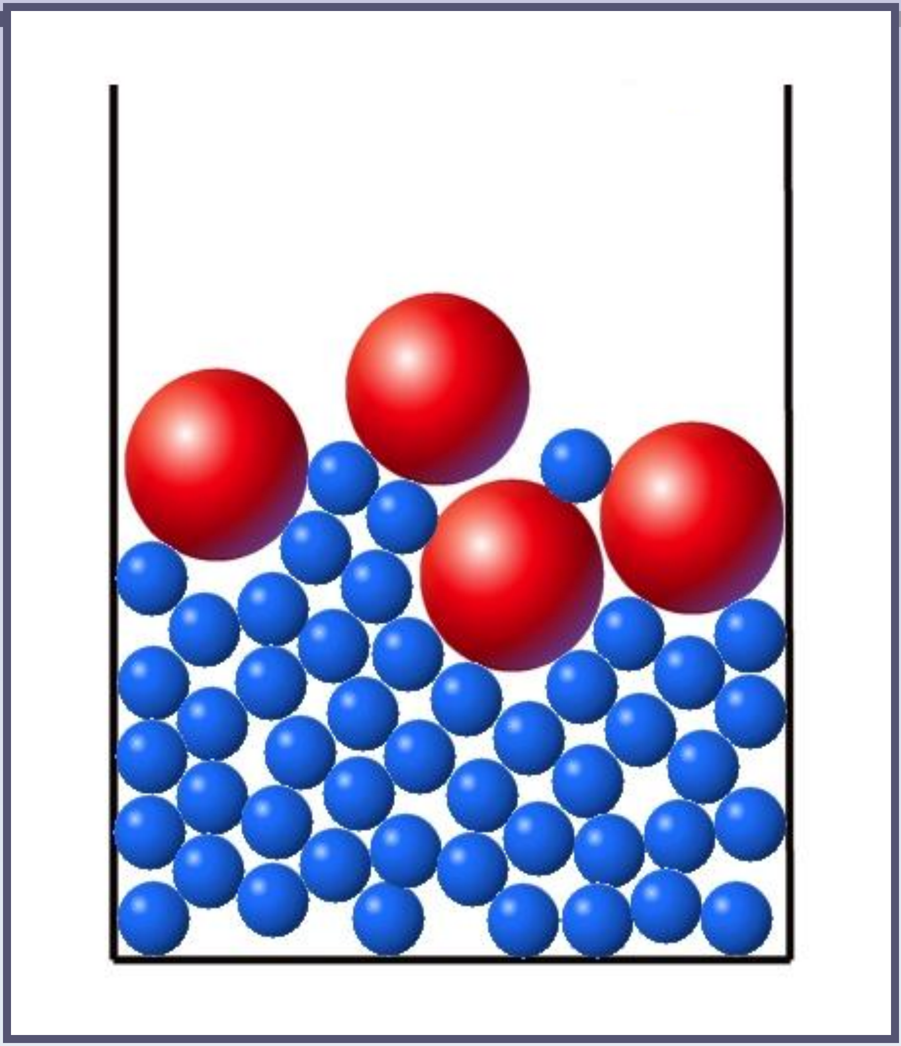
When does the reversed effect occur?

Why does it happen?

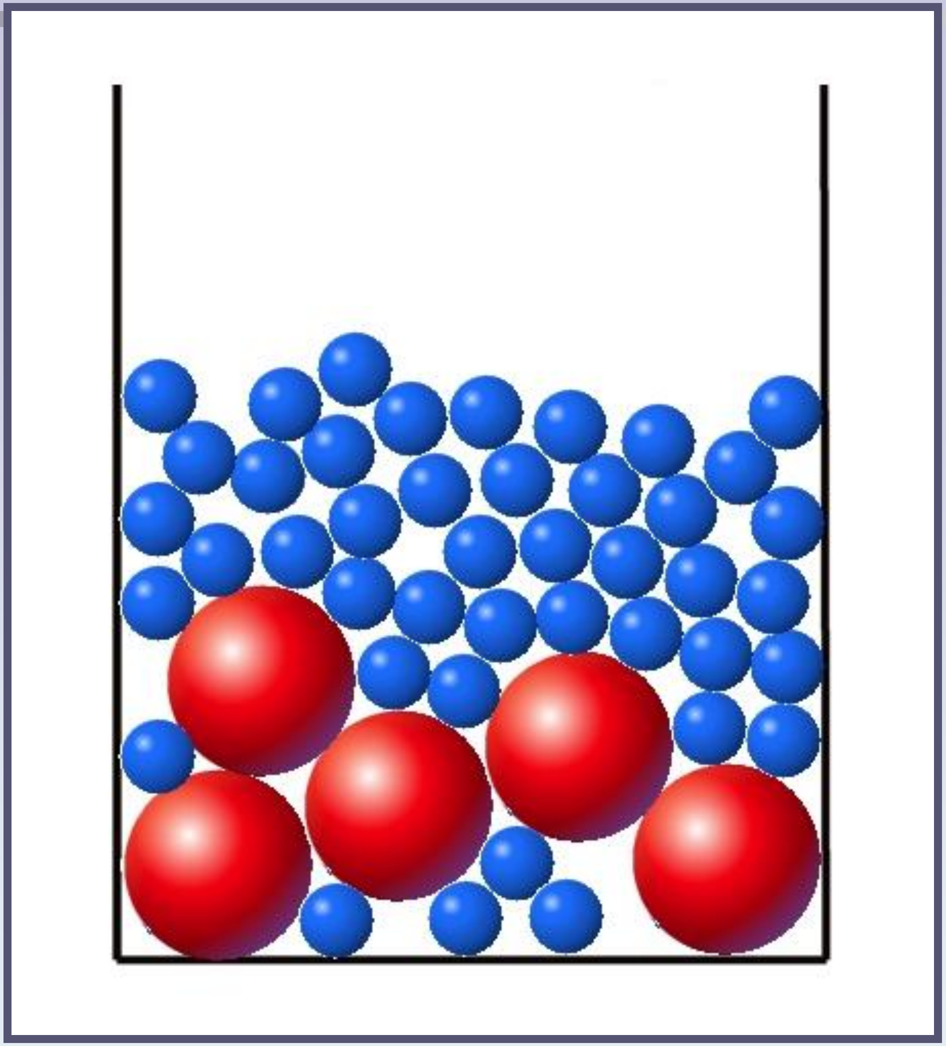
When the mass propotions are relatively big to diameter proportions, the Reverse Brazil Nut Effect occurs.

↓

Bigger particles can segregate to the bottom, smaller ones are then forced out to the top.



Brazil Nut Effect



Reversed Brazil Nut Effect

Theoretical model

To simplify the analysis, we use the description basing on the idea of temperature.

T_c Critical temperature, at which particles are fully „fluidized”.

μ Initial thickness of particles layer (measured in the units od *d*).

We use Dr Daniel Hong’s analysis.

We also use *h* as the thickness of the fluidized layer.

Particles parameters

$$m_B, d_B \qquad m_A, d_A$$

Theoretical mechanism

System is in contact with a „heater" at temperature T (vibrating base).

For each hard sphere we introduce **macroscopic** temperature T, representing its average kinetic energy, which is bound up with potential energy:

$$mgdh \approx \frac{m\langle v\rangle^2}{2} \approx T$$

If we set h=μ, we get an expression for critical temperature:

$$T_c = mgd\,\mu$$

Theoretical mechanism

If we consider a binary mixture of particles A and B, we get a proportion:

$$\frac{T_c(A)}{T_c(B)} = \frac{m_A d_A}{m_B d_B}$$

We consider a D-dimensional space.

In addition, we know:

$$\left(\frac{d_A}{d_B}\right)^{D-1} \approx \frac{m_A}{m_B}$$

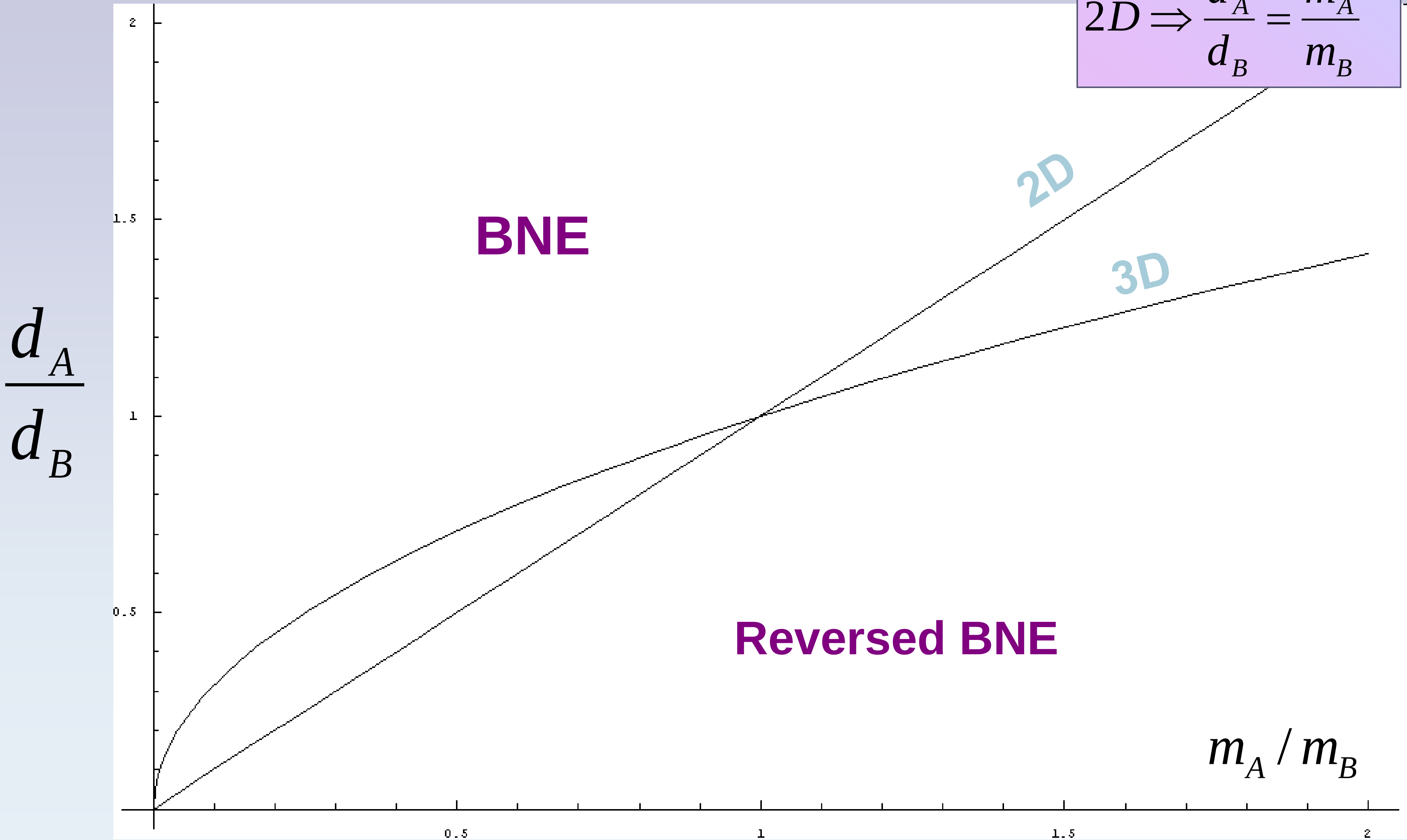
$$3D \Rightarrow \frac{d_A}{d_B} = \sqrt{\frac{m_A}{m_B}}$$

$$2D \Rightarrow \frac{d_A}{d_B} = \frac{m_A}{m_B}$$

What conditions must be satisfied for BNE?

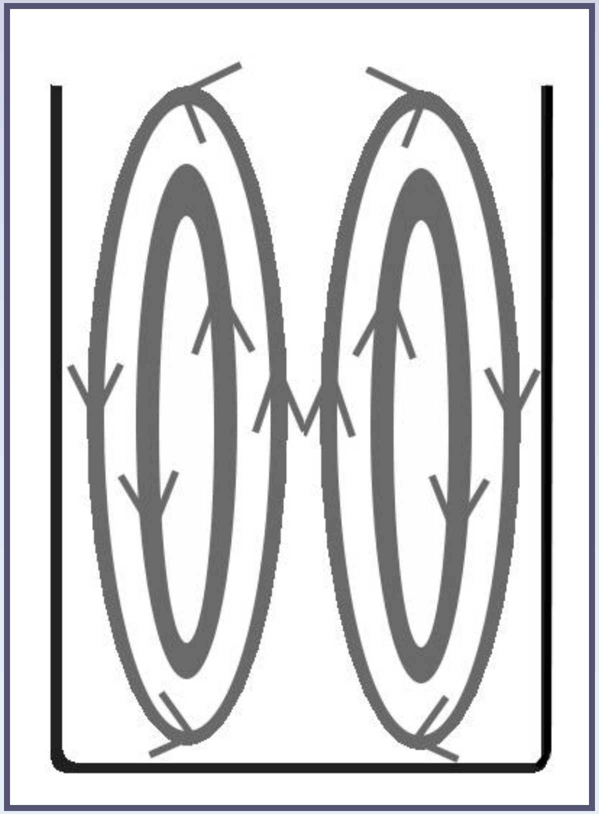
$$3D \Rightarrow \frac{d_A}{d_B} = \sqrt{\frac{m_A}{m_B}}$$

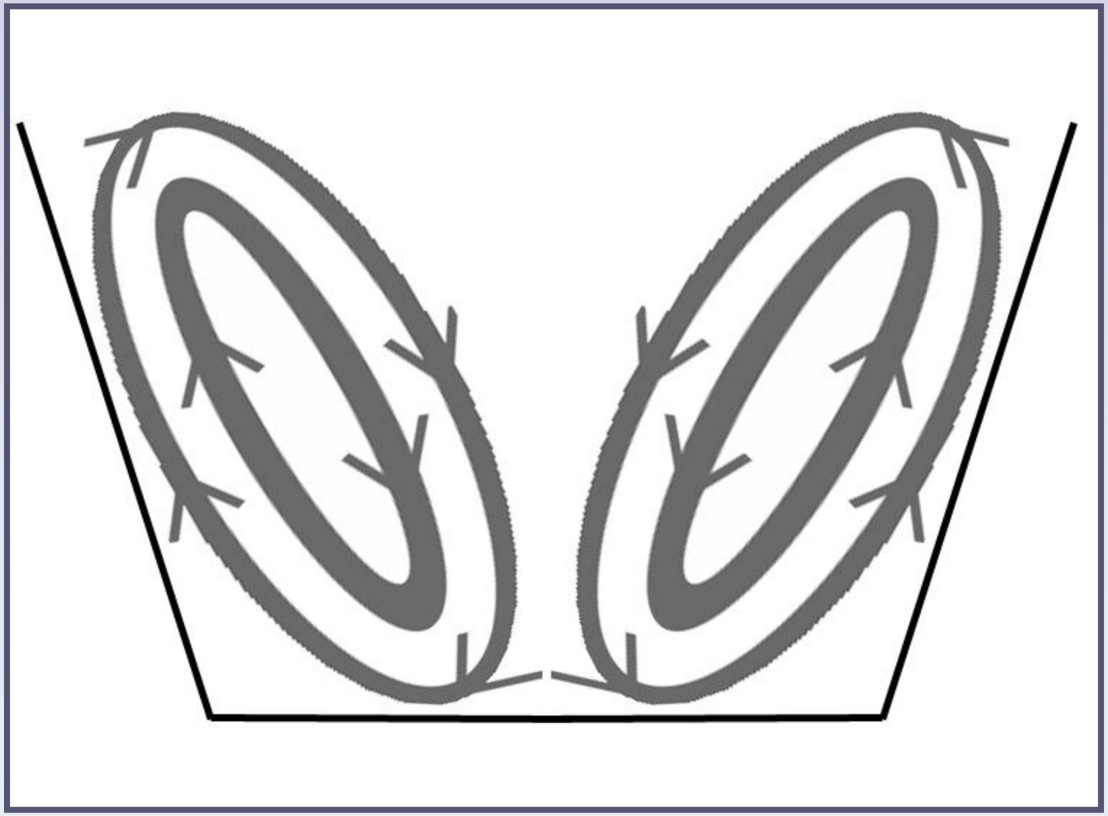
$$2D \Rightarrow \frac{d_A}{d_B} = \frac{m_A}{m_B}$$



Dependence of the effect on container geometry

- **By changing the contianer walls inclination angle, we can force the convection direction to reverse.**





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