24th International Young Physicists’ Tournament
10. Faraday heaping

When a container filled with small spheres (e.g. mustard seeds) is vibrated vertically with a frequency between 1 – 10 Hz, so called Faraday heaping occurs. Explore this phenomenon.
Presentation plan

- The required experimental setup
- Heap formation and merging processes
- The influence of acceleration, grain size and the number of layers
- Final conclusions
In order to examine Faraday heaping we built an experimental setup

Our requirements for a good experimental setup:

- **Stable amplitude** of motion
- Surface should perform **sinusoidal oscillations**
- **Adjustable frequency** and **amplitude** of oscillations
- **Horizontal orientation** of the moving surface during motion
Experimental setup
Experimental setup

- Up and down motion
- Amplitude regulation
- Electric drill
- Eccentric
Experimental setup

Stanislaw Staszic High School in Warsaw
Experimental setup

Swing wheel

Speed-o-meter
Experimental setup

- Transparent container
- Additional mass
Phenomenon presentation
Evolution of the surface

The surface is initially flat.
Evolution of the surface

Several little heaps form.
Evolution of the surface

The little heaps merge into larger heaps.

XIV Stanislaw Staszic High School in Warsaw
Processes relevant for the phenomenon

- Movement of air induces drag force
- Gravitational Force
- Friction & Collisions
Single heap stability

Plate is going up

Zero level

Heap is ascended by the horizontal plate
Air flows faster through the thinner parts of the heap. The flow of air induces the particle inward motion.
The escaping air decelerates the particles. In result of this and the latter phenomenon, particles are moved towards the center of the heap.
In result of the impact, the particles of heap are scattered along the edges of the heap.
Single heap stability

The motion of air causes the heap to „squeeze”

The impact causes the boundary particles to scatter

The theory presented is widely accepted. (among others: van Gerner et al. “Interplay of air and sand: Faraday heaping unravelled”)

XIV Stanislaw Staszic High School in Warsaw
Pressure distribution within heap

Experimental observation of Thomas and Squires (1998)
Merging of the heaps

Ven Gerner et al. "Coarsening of Faraday Heaps: Experiment, Simulation, Theory".

\[ F_a \propto L \quad F_b \propto R \quad F = F_a - F_b \propto L - R \]
The unsymmetrical shape of the heap causes it to move. This effect is responsible for heap-merging.
Dimensions of 2D container

300 mm

300 mm

1 mm
What can we achieve using 2D setup?

0 cycles
37 cycles
93 cycles

136 cycles
327 cycles
520 cycles
Checking the assumption of the theoretical model

Merging heap

\[ \alpha = \beta \]

Nearly merged heap

\[ \alpha < \beta \]
Further observations

WSTAWIC FILMIK CAPTUrE
szybKO.WMV
“Convection” in a heap

The trajectory of granular particles resembles the shape of convection roll
Diameter of particles - ordinary sand

Average particle size: 0.5mm

The values were obtained on basis of image analysis using Fiji program. The amount of grains studies was about 2000 in each case.
Diameter of particles - aquarium sand

Average particle size: 1.0mm

The values were obtained on basis of image analisys using Fiji program. The amount of grains studies was about 2000 in each case.
Diameter of particles – mustard seeds

Average particle size: 2.0mm

The values were obtained on basis of image analysis using Fiji program. The amount of grains studies was about 2000 in each case.
Parameters decisive to the problem

Maximal non-dimensional acceleration: \[ \Gamma = \frac{A \omega^2}{g} \]

- \( A \) – amplitude of oscillation, \( \omega \) – frequency of oscillations,
- \( g \) – gravitational acceleration

The number of layers of granular matter

\[ N \]
„Phase” Diagram of Faraday heaping

Aquarium sand

Amplitude [mm]

Other Phenomena

Faraday Heaping

Solid

XIV Stanislaw Staszic High School in Warsaw
„Phase” Diagram of Faraday heaping

Aquarium sand

- Lower boundary 570g
- Lower boundary 800g
- Upper boundary 570g
- Upper boundary 800g

Other Phenomena

Faraday Heaping

Solid

\[ \Gamma = 3.1 \]

\[ \Gamma = 1.2 \]
„Phase” Diagram of Faraday heaping

Oridinary sand

- Lower boundary 200g
- Lower boundary 400g
- Upper boundary 200g
- Upper boundary 400g
- Faraday Heaping
- Other Phenom.

Amplitude [mm] vs. $\omega^{-2}$ [s$^2$]

XIV Stanislaw Staszic High School in Warsaw
"Phase” Diagram of Faraday heaping

\[ \Gamma = 2.8 \]

\[ \Gamma = 0.4 \]

Ordinary sand

Faraday Heaping

Solid

Other Phenom.

Upper boundary 200g

Upper boundary 400g

Lower boundary 200g

Lower boundary 400g

XIV Stanislaw Staszc High School in Warsaw
„Phase” Diagram of Faraday heaping

Aquarium sand

- Lower boundary (A = 6mm)
- Lower boundary (A = 3mm)
- Upper boundary (A = 7mm)
- Upper boundary (A = 9mm)

Other Phenomena

Farady Heaping

Solid

Number of Layers N

XIV Stanislaw Staszic High School in Warsaw
Summary

- If granular material is vibrated vertically, Faraday heaping may occur.
- The main factors determining the Faraday heaping process are: air drag and collisions with surface.
- The process of heap-merging, the formation and stable state of a heap are qualitatively understood.
- The major parameters in the phenomenon are: the diameter of the particle, the acceleration, amplitude, number of layers.
Literature


• Henk Jan van Gerner et al., ”Interplay of air and sand: Faraday heaping unravelled”, Physical Review Letters, 2007

• Peter Eshuis et al., ”Phase diagram of vertically shaken granular matter”, Physics of Fluids, 2007
Other phenomena observable using our experimental setup

„Exploding” Faraday heaps
Other phenomena observable using our experimental setup

Undulations
Other phenomena observable using our experimental setup

Oscillons