Problem list for the XV-th edition of the International Physicists' Tournament

In order to stimulate creativity and interesting discussions, all the problems have been formulated as open physics questions with a statement that is not too stringent. Therefore, there is no uniquely favored understanding of the problem conditions and it is up to each team to interpret the conditions in a way that is both interesting from a physical perspective and coherent with the problem statement. It is assumed that every phenomenon will be studied theoretically and, whenever possible, experimentally, with the aim of proposing and validating a model that explains the phenomenon and its dependence on the most relevant parameters. Teams are encouraged to carefully consider their time budgets, so as to strike a balance between the number of problems that are studied and the depth with which each problem is investigated. All experiments should comply with local safety regulations and care should be exercised when dealing with dangerous equipment and substances. Teams are solely responsible for any damage or injuries incurred while working (or thinking) on the problems.

1. Match counting
How accurately can you determine the number of matches in a matchbox from the sound it makes when you shake it? Can the same methods be applied to a box containing chewing gums?

2. Singing ice
Most of us have tried to make pebbles bounce from the surface of a lake or a river. But if the surface is frozen, the pebbles produce a peculiar sound when bouncing, similar to the sound produced when skating on thin clear ice. Study this phenomenon. Describe quantitative characteristics of the sound and how they depend on the pebble, environmental, and launch parameters.
https://youtu.be/bvdDASjNJmQ https://youtu.be/v3O9vNi-dkA

3. Honey holding on to a spoon
One may prevent honey or other viscous fluids from dripping off a spoon by rotating it around its long axis. But if one tries the same trick with water it does not work. Investigate how the liquid properties determine whether one can observe this phenomenon. https://youtu.be/acfPH5RZplI

4. Stuck metallic spheres
Fill a bottle with small metal/plastic spheres with diameters of the same order of magnitude as the size of the opening. Try to pour the spheres out of the bottle by turning it upside down. Similar to pouring salt from small openings, one can see that after a certain time the spheres become stuck and stop pouring out. Investigate the phenomenon. What is the average time it takes before the system becomes stuck? What bottle shapes can prevent the system from getting stuck?

5. Pringles stack ring
It is possible to build structures by stacking Pringles on top of one another in various configurations. What are the physical parameters that allow some geometric patterns to be constructed? What is the largest stack ring that can be built? What maximal weight can it support? https://youtu.be/Sp47lvGR8Ek

6. Flapping flag
Study a flag (or any piece of fabric and other sheet materials) hanging down while being subject to a uniform wind. Under what conditions does it start flapping? Build the most accurate anemometer based on the sound of the flapping flag.

7. Gravity defying lip gloss
Under certain circumstances, lip gloss appears to defy gravity. Investigate this phenomenon. What is the highest velocity of ejection, maximal branch length, and longest shooting distance of a typical commercial lip gloss? https://youtu.be/_4VgQo-bAnY

8. Mendocino meter
The Mendocino motor is a solar-powered magnetically levitated electric motor. Can one make a precise illuminance meter based on this motor? https://www.youtube.com/watch?v=HA15RPNtYpc

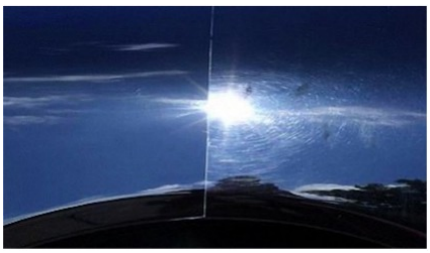
9. Spinning droplets
One can make small water droplets rotate over a hydrophobic surface by making various hydrophilic patterns over them. What properties of the liquid (not necessarily water) can we extract from this type of experiment? Optimize the setup to maximize the rotational speed of the droplets.
https://www.youtube.com/watch?v=nzhjBFhEwvg

10. Magnetic gears
The coupling of mechanical gears is usually done through their teeth, but an equivalent mechanism can be made using magnets, so that the gears do not touch each other. Explain how the device works and explore its limitations. How does it depend on the arrangement of the magnets?
https://www.youtube.com/watch?v=1w5Ol05blLE

11. The chalk trick
It is possible to draw continuous lines in a blackboard with chalk. However, by changing the angle of contact, the line drawn on the board becomes a dotted line, though the movement is still continuous. What parameters from the relative movement between the chalk and the board can be inferred from the resulting trace? Is it possible to infer anything about the dimensions of the chalk?
https://www.youtube.com/watch?v=hbWeSHbL-rM

12. Dancing lights
Put a membrane with a mirror over a speaker. Then project the reflection of a laser pointer over a screen. By driving the speaker with single or multiple frequencies you may observe lines and shapes projected in the screen. Given a closed trajectory in 2D of a single line, find the input on the speaker required to "paint" the line. Can you also "rotate" the line as you desire? Investigate the limitations. https://youtu.be/rYrdiQckGhw?t=190

13. Glass halo
Glittering circles can be seen when light from a source with small angular size passes through a glass. On closer examination they appear to be composed of small scratches and structural inhomogeneities. In some cases, specific rays can be seen, diverging from the light source (left part of the photo). Under which conditions can such circle halos and lines can be seen? Investigate their geometrical properties and what shapes you can engineer.



14. Bubble love and tensions
When two soap bubbles collide, they may rebound or coalesce. Find the conditions for both phenomena to occur. https://youtu.be/BRe9M1lF4Hs?t=200

15. Fire-shot-fire
It is well known that a directed air blast can suppress a fire. Usually, such air blasts are directed by guiding the air through a pipe. Determine the parameters of the pipe to extinguish the fire from a maximum distance (measured from the end of the tube closest to the fire) using only your breath.
Perform experiments on the fire from a candle
http://www.youtube.com/watch?v=x5-O3ffWso8

16. Unstable levitation
It is possible to levitate a magnet stably without a superconductor or control system using a magnet rotating at high speeds. Investigate the limitations and determine if it is possible to levitate two magnets at the same time. The levitated magnets should not touch each other. https://youtu.be/V5FyFvgxUhE

17. Graphite plasma lamp
When a graphite rod is placed in a microwave oven, one can observe plasma formation at the tip of the rod. Investigate the duration of the phenomenon and the influencing parameters (microwave power, rod geometry and material, volume of the containment bowl, etc.). Investigate the duration of the plasma phase without burning the graphite rod: can we create an infinite lamp?
https://youtu.be/e4h-bycHuRM

Many thanks to all the people who took part in the problems proposition and selection!

August 30, 2022

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