List of problems for the XIII 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. Nuclear mousetraps

An array of mousetraps and ping-pong balls results in a chain reaction. Construct a model for the macroscopic dynamics of such a system, identifying all relevant parameters, and determine the spatiotemporal behavior of the mousetrap excitation probability, and the threshold mousetrap density for the chain reaction to occur. https://youtu.be/IQJMyO6cfMo, https://youtu.be/wJ2NMD3VWio

2. Pop-Pop away

The Pop-Pop boat is a small toy powered by a candle. Its engine is very simple, since it is just made of a boiler. Propose a boat design that maximizes the travelled distance using a tealight candle. Estimate the energy conversion efficiency of your boat.

3. Dirty racing

Investigate the distance a ball travels on a horizontal surface of wet sand before coming to rest if initially it was subjected to translational motion parallel to the surface. How does this distance depend on the ball material (wood, metal, rubber etc.), its initial velocity and other relevant parameters?

4. Hydraulic jump white hole

When a steady stream of water from a tap hits the sink, the water spreads in a circular disc bounded by a region where the water height is greater than its surroundings, as seen in the Figure. This so-called hydraulic jump is analogous to a white hole, the time-reversed version of a black hole, in the sense that surface waves cannot enter the disc against the flow, whilst there is a natural outward flow. Explain the physics behind the hydraulic jump, and how its properties can be matched to those of a white hole. Perform an experiment in order to verify the correspondence. Is it possible to make a hydraulic jump with liquids other than water? When does the white hole analogy break down?

5. Distant thunder

What parameters of thunder can one reconstruct from a photograph of lightning? How does the answer change if a silent video recording is used instead? Conversely, what parameters of lightning can one reconstruct from an audio recording of thunder? https://youtu.be/qQKhlK4pvYo?t=285

6. The finger of death

Under some conditions, a stalactite of ice known as a *brinicle* can form underneath the frozen surface of an ocean. Reproduce the phenomenon on a laboratory or home scale, and study the brinicle growth rate and its final size. https://youtu.be/lAupJzH31tc

7. Vegetable electricity

Some internet posts suggest that it is possible to generate electricity from photosynthesis by using a metallic network that winds through the roots of a plant. In response, a skeptic may claim that the setup is just a voltaic pile, and that therefore, photosynthesis is irrelevant. Explain the phenomenon and specifically determine whether photosynthesis is indeed involved. Determine the main factors affecting the phenomenon, and optimize them so as to generate the maximal power per unit of soil area. https://youtu.be/5QY-E0gzW90

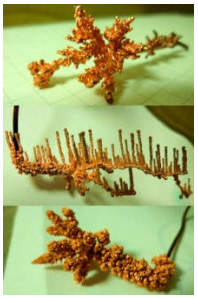
8. Heavy parachute
Is it possible to build a magnetic parachute to protect a load from impact when landing on a non-magnetic metallic surface? How should it be built in order to minimize the impact damage? What are the limitations of your parachute? https://youtu.be/sENgdSF8ppA?t=80

9. Solar retraction motor
A solar retraction motor works by using the thermal shrinkage and relaxation of polyethylene or other materials. Investigate the maximal rotation speed and maximal power of these types of motors, and explore ways to maximize their efficiency using commonly found materials. How do these quantities scale with size of the motor? https://youtu.be/VQqpnAKf9cM

10. Rolling pasta
When spaghetti is rehydrated on a wet cloth, the noodles gradually acquire a curvature that persists even when they are taken out to dry, and they will start moving with some velocity. Investigate the noodle movement and its shape dynamics. Is the phenomenon present for other common shapes of pasta, such as linguine, bucatini or lasagna? https://youtu.be/NyewlvPgxxg

11. The spinning washer
A washer on a vertical steel rod may start spinning instead of simply sliding down. Study the motion of the washer, the sliding-spinning transition, and determine the terminal velocity. https://youtu.be/oD6yxsCkkpg

12. Metallic forest
In the electrolysis of aqueous solutions of metal salts, fractal-like dendrites can begin to grow gradually on the electrodes. How can the dendrite shape and fractal dimension be controlled by choice and variation of the setup parameters?



13. Branching light
When a laser beam passes through a thin film (e.g., soap bubble film), random filaments of light are created by effect known as branch flow. Explain the phenomenon. Can one design a medium to produce specific branching patterns? Can it be extended to other wave phenomena (water waves or sound waves, etc.)? https://youtu.be/UNCNp1tBqKY

14. Ice clock
An ice cube inside a mix of vegetable oil and baby oil will remain between the two liquids because of its density. As the ice cube melts and releases trapped bubbles, it goes up and down periodically in an intriguing way. Can this experiment be turned into a clock? What would be its longevity and precision? Optimize the setup parameters (shape, temperature, composition, length scales, etc.) to obtain the maximal clock precision. https://youtu.be/rEstw8LLMpY

15. Burning bottle cutter
It is possible to cut glass bottles into two pieces with a string using fire and cold water. What is the physics behind this effect, and how can one optimize it? Is it possible to cut out a shape in the glass that is more complex than a simple straight line? https://youtu.be/luUK8T_8FNc?t=294

16. Graphite lamp
Devise the most energy efficient lamp possible using the graphite rod from a pencil. Investigate how the intensity and duration of the light depend on the hardness of the graphite and other relevant parameters.

17. Quantum-droplet analogy
Small droplets on the surface of a vibrating liquid can exhibit quantum-like behavior in analogy with the so-called pilot wave theory. Construct an experiment to test as many quantum analogies as possible, and discuss the theoretical and experimental limitations of this analogy. Can the analogy be pushed to cover phenomena involving entanglement, such as Bell inequality violations? https://youtu.be/WlyTZDHuarQ

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

11th September 2020 _____Vladimir Vanovskiy, IPT DC Secretary