List of problems for the XIV 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. Physics of math

Build a device (no calculators and computers please) that can be used to compute some famous mathematical constant in the most physically ingenious way. Optimize the accuracy of your device. Note that there are, in addition to for instance π or e, many other interesting constants such as Apery's or Feigenbaum's constants.
Example for π: https://youtu.be/HEfHFsfGXjs

2. Airbounce

When a Frisbee is thrown in a certain way it can be made to bounce in mid-air. Study the physics of this phenomenon. https://youtu.be/yXmcIzrZIu8

3. Noise FM

Amplitude, frequency and phase modulations are old robust methods to transfer information via electromagnetic waves. Propose a method to encode information in such a way that the signal will be indistinguishable from the background noise for an uninformed outsider. Propose and implement a setup giving maximum transfer rate and signal-to-noise ratio at some transmitter-receiver distance.

4. Filled ball

A ping-pong ball that has been partially filled with some fluid or sand will bounce much lower than a filled one. Explain this phenomenon. How does the height of the bounce depend on the relevant parameters?
https://youtu.be/tGDj783Y6kQ?t=85

5. Sparkler

Investigate the burning process of a sparkler. How far can the sparks fly? What determines the size of the flame? https://youtu.be/0K_1runDNnM

6. Flat Earth

Propose an experiment using only a camera and/or the sensors of your smartphone to prove or disprove the flat Earth hypothesis. Using the same equipment, estimate the size of the Earth with as high accuracy as possible.

7. Washboard roads

When an unpaved road (usually sand or gravel) is used by many cars, a wavy pattern is formed causing strong discomfort for the drivers. Study how the wave parameters depend on the properties of the granular material and on the average speed of the cars. Is there a safe way to drive fast on this type of road? https://practicalmotoring.com.au/4x4/how-are-corrugations-formed/

8. Ferrofluidic patterns

When ferrofluid is placed in a rotating magnetic field, strange patterns may appear. Investigate the shape of these patterns and characterize them in terms of the relevant parameters.
https://youtu.be/-NgEblHXwJo

9. Electrostatic lighter

Ancient people used to make fire by rubbing wood. Propose an alternative setup, based on electrostatic effects, made from materials available to Bronze age people. Make a device capable of setting fire using just static electricity in the shortest time possible to a piece of wood.

10. Droplet sandy fingerprints

When droplets fall on a surface covered by a layer of sand, interesting patterns are formed. Study the formation process. What parameters of the droplets can be inferred from the resulting crater?

11. Smashing spheres

Smashing two steel spheres together with a paper in between at the point of collision, produces enough heat that it burns off the paper. Conducting the same experiment with aluminium foil, you will observe concentric rings on the foil after collision. Study this phenomenon. Can it be observed for other materials?
https://youtu.be/I4cVADCfHQY

12. Inverse coffee cup vibration problem

If you tap the top of a coffee cup with a spoon you will notice that the sound strongly depends on where you tap. Knowing the cup geometry one can predict the frequency spectrum of the emitted sound when tapping at different points. Consider now the inverse problem and find an experimental technique to reconstruct the cup geometry from the emitted sound. What is the minimal knowledge about the cup geometry needed to make the problem solvable?
https://youtu.be/MfzNJE4CK_s?t=333

13. Chaotic magnetic pendulum

Consider a pendulum consisting of a magnetic bob attached to a string. If the pendulum is allowed to swing over a structure of permanent magnets, it will display complex motion. Study the pendulum dynamics and its dependence on the number of permanent magnets and their arrangement.
https://youtu.be/yQeQwwXXa7A

14. Rising in the bulk

If a vessel containing granular material is shaken appropriately, an item placed at the bottom will ascend upward through the material and emerge at the top. Explain the phenomenon and devise the most energy efficient shaking technique to raise the item up. https://youtu.be/GPaneRyQp6A

15. Galileo method

What is the maximum height a piece of chalk might be dropped without breaking for a given surface? Which parameters does the height depend on? Are there any dropping or throwing techniques which minimize the breakage probability?

16. Midnight Special

Liquid crystal displays can be used as diffraction gratings. What information about the display structure can be retrieved by studying the diffraction pattern? This could comprise pixel density, subpixel structure, pixel shape and fabrication technology.

17. Resistor thermodynamics

Thermal electrons in a resistor can be treated as a closed thermodynamic system where the electrons are interacting with the rest of the conductor held at finite constant temperature https://doi.org/10.1103/PhysRev.32.110. Create an experiment which allows you to investigate the thermodynamic properties of such a system using an electronic signal. Which thermodynamic quantities can you measure?

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

10th September 2021 _____Vladimir Vanovskiy, IPT DC Secretary