Problems for the Online-German Physicists' Tournament 2020

1. Rotating a Basketball on the fingertip

What is theoretically the longest time that a person can rotate a basketball on her or his finger before another impulse is required to maintain the rotation?

Possible questions to start the exploration
• How can an ideal rotation of a basketball on the finger be achieved?
• What is the maximum momentum that can be transmitted to the ball by “hitting” it?
• When does a rotating ball fall off your finger?
• What role do "compensatory movements" of the finger play?

Video of a rotating Basketball: www.youtube.com/watch?v=ze6hNrkdrYs

2. Acoustic rain gauge

Raindrops falling on a metal plate: Typically one can distinguish heavy rain from slight drizzle by means of its characteristic sound. Try to construct a rain gauge using your smart phone and a metal plate.

Hint: Rain drops make a noise on the metal plate which depends both on their size and on the number of hits per area (frequency).

3. Towerjumping for scientists

From a physical point of view, how do you best jump from a 10m high tower into water to avoid injuries during the jumping phase and the impact phase? Do not jump off the 10m tower and try for yourself, but instead carry out your investigations and experiments by miniaturizing the problem (e.g. factor 1:10) and perform appropriate experiments and model considerations.

Possible questions to start exploring
• Is the largest or smallest possible impact area better?
• How does a person “fall” from a height of 10m? How does a body rotate if it would be a wooden block?
• What kinetic energy do people achieve after 10m of free fall?

4. Zebra cake

Bake a zebra cake: Beat the yolk with vanilla sugar/vanilla essence until the mixture is creamy. Add oil and water, mix again, and add flour and baking powder. Subsequently stir in the beaten egg whites. Separate the batter into two equal parts, add cocoa powder to one part (dark batter) and keep the other part plain (bright batter). Then deposit in the middle of a round baking pan the amount of one spoon of each type of batter on top of each other in an alternating sequence. Bake for about 50-60 minutes at 175°C.

Investigate and explain the resulting pattern inside the cake (see figure).
• What happens if you deposit batter like this at several equally spaced spots (e.g. 4 positions) inside the circular area of the baking pan?

Recipe: 5 eggs, 250 g sugar, 1 package vanilla sugar, 250 ml flavourless oil, 125 ml warm water, 375 g flour, 1 package baking powder, 2 tbsp cocoa powder.

5. Sound of water in a water kettle

Investigate how and to which extent sound measurements can be used to determine the temperature of water below the boiling point when being heated up in a water kettle.

6. The bulletproof waterwall

If you hit the water in the pool with your hand, it is possible to create a water wall that can stop the flight of inflated pool balls. Is it also possible to stop heavy balls like table tennis balls or even bullets?

Possible questions to start the exploration
• What kinetic energy does a thrown ball have?
• What mass can a water wall created by hitting water reach?
• How does water slow down the movement of objects?

Video of a waterwall www.youtube.com/watch?v=eOrZnWcnFsw

7. Fascinating caustics of reflected sunlight

The figure on the right depicts one of many typical sights of a fascinating optical phenomenon. Features like these may often be observed when sunlight is reflected from windows and the reflected light is projected on nearby walls, e.g. of buildings on the opposite side of the street. The geometry of those features can vary from crosses surrounded by rings or rhombuses to more or less circular or elliptical shapes and many more. The best conditions to observe the phenomenon is a low sun.

Design a laboratory experiment or a hands-on-experiment in order to observe the phenomenon.

Investigate the phenomenon experimentally as well as theoretically. Try to model and to investigate more than only one geometry.

References:
www.uni-muenster.de/imperia/md/content/fachbereich_physik/didaktik_physik/publikationen/lichtkreuze_in_lichtkreisen.pdf

8. Fizzy bottle overflowing

Shaking a bottle with sparkling water results in a high pressure inside the bottle. After a while, the gases redissolve. Try to find out, why dissolved gases (normally in equilibrium with the water) get out from the solution upon shaking.

• Which parameters (like intensity of shaking, shape of the bottle, type of gas, type of liquid, temperature etc.) could control this phenomenon.

9. Floating crystals

If a large number of small balls is floating on the water surface, a crystalline pattern can be observed, see, e.g.,
en.wikipedia.org/wiki/Shade_balls
www.nationalgeographic.com/news/2015/08/150812-shade-balls-los-angeles-California-drought-water-environment

• How do waves affect the defects in these patterns, the self-diffusivity of the balls, and possible anisotropies in the structure or the dynamics?
• What kind of ordered or disordered structures can be observed if two types of balls with different diameters are mixed?

10. Experiments at breakfast time

For cooling down hot coffee (and of course for a better taste) one usually adds some cold milk. Let's assume the coffee should be cooled down to a tolerable temperature within 5 minutes:

• Is it more useful to add the cold milk first and wait then for 5 minutes or to wait first for 5 minutes and add the cold milk afterwards?

Investigate the problem experimentally as well as theoretically.

11. Investigating „Cartesian Devils"

When demonstrating the behavior of a „Cartesian Devil"/"Cartesian diver", that experiment requires a large plastic bottle and a "diver": either the famous hand blown glass toy from Thuringian forest or simply a small, rigid tube, open at one end. For example, tubes with baking aroma inside are well suited for making a diver.

• When the Cartesian Devil, filled with water and air, is put in the plastic bottle, filled with water, and when the bottle is pressed, the devil sinks down.
• By modifying the setup, it is also possible to let it rise. How is this possible?

Investigate different possibilities of suitable modifications in order to let the devil rise and discuss the physics behind.

12. Cutting ice blocks

If you hang a thin wire with weights over an ice block, the wire moves through the ice. The usual explanation argues with the lowering of the melting point by pressure. But is this really true? Try to verify or falsify this explanation. Consider alternative reasons. One hint could be that ice is plastically deformable, as is known from glaciers.