THE 49th—21st INTERNATIONAL—RUDOLF ORTVAY PROBLEM SOLVING CONTEST IN PHYSICS

26 October— 5 November 2018

1. The people of Gummy Beach often use the thin gummy layers which are created as a byproduct of gummy material production, for repairing their clothes or as wrapping small items. Mynden Lee ben Canal, the leading physicist of Gummy Beach, observes that children play with balls, shaped out of creased elastic gummy layers. From a closer observation, it is evident that most of the volume of the ball is air, that is, the elastic layers do not fill up much of the ball.

   The structure of the ball rises Canal's interest, specifically, which is the dimension D (known as Hausdorff dimension outside of Gummy Beach) characterizing the object. The latter can be interpreted as follows: Let us choose a spherical volume with radius r, within the surface of the ball, such that r is much larger than the layer thickness d. Make a statistical average (in some appropriate way) on the mass within the sperical volume, $m(r)$, and if the result can be approximated with the formula $m(r) \approx kr^D$, then the parameter D is the dimension.

   Canal wishes to determine the exponent D, but unfortunately he is weak on instrumentation: having only a stopwatch, a ruler, a metallic slope, and a self-fabricated gummy ball with a approximately spherical shape. The experimental setup is such that from the slope of height h the ball rolls down without slipping, reaching velocity v. Let us try to follow his way of thinking, and express the value of D from the experimental parameters. Neglect air drag and friction.

   Suggestion: If you have time, make experiments (having no gummy sheets) with balls creased from aluminum foil! For these tests, all instruments besides those described above can be used. If the ball does not roll properly, the surface may be smoothed carefully.

   (Ákos Gombkötő)

2. The speed limit is $V = 50$ mph on a straight road. At some moment, a roundabout is built on the road, with a radius R. How much longer is it going to take for a car driver to complete that section of road with the roundabout, compared to the original straight road? How does this depend on the radius R? Make a graph showing the amount of lost time as a function of the radius R! With the help of Google maps, find a few real roundabouts, and measure their radii, and put these on the same plot! What should be the radius R in order for the driver to lose the maximum amount of time (compared to the straight road)? What should be the radius R for the driver to lose the minimum amount of time? What is the value of the minimum and maximum time lost, in seconds? How do these two special radii depend on the speed limit V?

   Conditions: the driver proceeds always as fast as possible, respecting the speed limit, strictly on the midline of the road (no shortening!). Consider only one car; there is no other car, traffic, or jam. The center of the roundabout is precisely located on the line of the original straight road. The absolute value of the acceleration of the car should never exceed $a_0 = 2$ m/s^2. The driver proceeds from the straight section to the roundabout using a circular ramp with the same radius R, which is smoothly joining both the straight section and the roundabout. Please give numerical results as well, not only formulas!

   (Gábor Veres)

3. An object with mass m is attached to the end of a horizontal rope of length L. The rope is always under tension. The mass of the rope is negligible. We start to move the free end of the rope with velocity v perpendicular to the initial direction. The object is slipping with finite friction on the horizontal plane. How does the motion depend on the velocity of the pulling?

   (István Szabó)

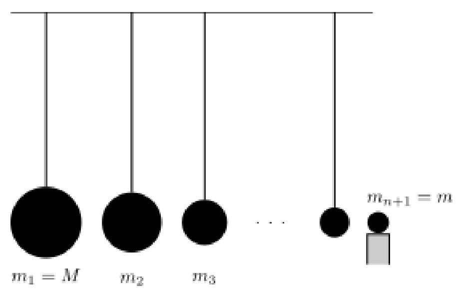
4. Legends say that certain Australian aboriginals can throw a boomerang 100 meter, in such a way that it returns to them. Let us investigate the possibility of this, with a simplified model. We may assume, that the effect of gravity is negligible for the duration of the boomerang throw, the center of mass of the boomerang moves approximately in a horizontal plane, along a circle. Give the radius of the circle as a function of the parameters describing the throw and the boomerang itself. Decide whether the legend is possible, and which are the decisive parameters to make it possible.

(Ákos Gombkötő)

5. The mass of n pendulums, as shown on the figure, closed by the ball on the holder, are decreasing according to a geometric sequence. The first one has mass $m_1 = M$, whereas the last ball on the holder has mass $m_{n+1} = m$. We hit the first one with velocity v_1 to the second, which hits the third, and so on.

   a) What will be the initial velocity v_{n+1} of the last one, after the elastic collisions? How large can this velocity be if the number of pendulums is increased, with fixed M and m?

   b) In reality, the collisions are not perfect, that is, the coefficient of restitution k (the ratio of the velocity after and before the collision in the center of mass system) is always a bit smaller than 1. How far can one increase the velocity of the last ball with optimal choice of the number of pendulums, assuming that $k = 0.99$ and $m = 10^{-4}M$?



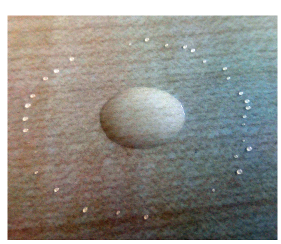
(Károly Vladár)

6. A thin rod leans to a wall in a stable position, with a small angle α relative to the vertical direction. The length of the rod is l. At a distance kl measured from the end of the rod contacting the floor, the rod is transversally pressed with a small displacement δ. We observe then, after releasing, that the rod is pushed away to some extent from the vertical wall. Let us build a simplified model and find the condition expressed with the parameters of the rod and the change of the shape, when the rod falls in the direction opposite to the wall.

   The density of the rod can be assumed to be small, so that the weight is negligible relative to the relevant effects of elasticity. Assume also that the equilibrium shape of the rod is straight. During the calculations, we can assume that though the transversal waves die out quickly, the rod stays within the limits of linear elasticity, and also that the original pressing is localized in a single point.

(Ákos Gombkötő)

7. During an exam, water droplets were falling on the table from a malfunctioning air conditioner. As seen on the photograph, around the large droplet there is a neat ring of smaller drops. How does this ring form, and which parameters determine its radius?

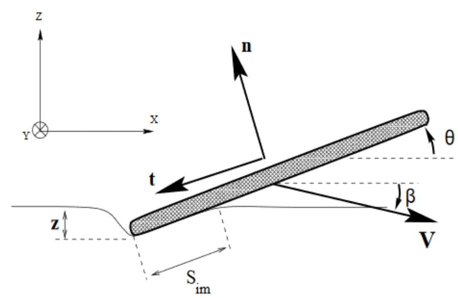


(István Szabó)

8. A closed, cylindrical container filled with water (at room temperature) contains a small air bubble of normal pressure and volume $V = 1\ \mathrm{cm}^3$. The container is slowly started to be rotated with small angular acceleration around its symmetry axis in complete weightlessness (at a space station). When the angular speed of the container reaches the value $\omega = 30\ \mathrm{s}^{-1}$, it is kept constant. Find the stationary shape of the air bubble and give its characteristic sizes. The surface tension of water is $\sigma = 0.07\ \mathrm{N/m}$.

(Máté Vigh)

9. Throwing a flat stone in a proper manner, multiple bouncing—skipping—can occur before the stone sinks. Let us try to estimate the number of skipping as a function of the parameters of the throwing. Is there an upper limit for the number of bounces?



We can approximate the stone with a solid, flat cylinder or prism with mass M (base with square or circle). The water is horizontally flat, we can neglect any wind or waves.

Note: The collision of the stone and the water can be viewed as a high Reynolds number process, the force acting on the stone by the water surface is:

$$\mathbf{F} = \frac{C_l}{2}\rho_w V^2 S_{\mathrm{im}}\,\mathbf{n} + \frac{C_f}{2}\rho_w V^2 S_{\mathrm{im}}\,\mathbf{t},$$

where V is the velocity of the stone, C_l and C_f are dimensionless coefficients which can assumed to be independent from the inclination angle. The water density is ρ_w, S_{im} is the immersed surface of the stone, and $\mathbf{n}$ and $\mathbf{t}$ are the unit vectors according to the figure.

(Ákos Gombkötő)

10. Running a car at constant speed requires constant power from the engine, since, contrary to the first law of Newton, the motion implies energy losses. These are usually described invoking air drag and rolling resistance.

For cars moving in rain, additional physical phenomena will arise, which can increase the power needed to move the vehicle.

Which are these extra slowing phenomena? Estimate the energy drawn by the specific effects as a function of the speed of the car.

One does not need to consider such facts that the driver may run slower, or multiple cars may jam, in bad weather—let us study the case of a lonely car at constant velocity!

(Károly Härtlein)

11. Water from stones! Such is the slogan for a terraforming competition, which focuses foremost on air wells. Our question: Approximately how much water can be condensed daily from the athmosphere: a) on a windless day, b) on a gusty day?

Use realistic parameters for the approximation. Estimate the minimal distance r between two airwells, in which case they function independently. Calculate for: Ireland, Hungary, and the desert Sahara.

(Ákos Gombkötő)

12. There are two kinds of icebergs. One is glacier ice falling into the sea from the glaciers, the other is the sea ice, the frozen sea water. The captains of the icebreakers can distinguish them by a quick glance. The glacier ice is very hard, the breaking is difficult, but the sea ice breaks easily. What is the reason for that difference?

(Géza Tichy)

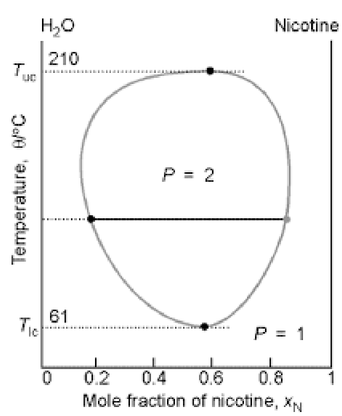
13. A balloon filled with carbon dioxide is not tied off but stretched over a test tube. A balloon filled with argon is also not tied off, but stretched over a second test tube. Both test tubes are submerged in liquid nitrogen and over time the balloons are seen to deflate. When the test tube with argon is raised from the liquid nitrogen, a neat plug of solid material is seen in the bottom of the tube. When the test tube with the carbon dioxide is raised, however, the solid is seen to be all over the test tube. The two are about the same color, but why are the shapes of the two solids so different looking?

(George Fischer)

14. Three identical bodies of constant heat capacity are at temperatures +19°C, +19°C, and −200°C. If no work or heat is supplied from the outside, is it possible to warm one of the bodies to +200°C by only operation of heat engines and refrigerators between these bodies?

(Gyula Radnai, based on the idea of M. W. Zemansky)

15. The phase diagram of the nicotine–water system is plotted on the figure. At low and high concentrations they solute each another but at middle concentrations there is phase separation. For simplicity let us assume that the two-phase region is an ellipse. In accordance with this approximation and the criterions of the thermodynamics give a possible formula for the free energy vs temperature and concentration, $F(T, x)$, leading to this phase diagram.



(Géza Tichy)

16. In industrial productions, it is often very important to be able to produce error-free thin films. Typical application is when we wish to grow a semiconductor thin film, on another, bulk semiconductor.

If the film is very thin, it will typically (altough not without exception) have the same crystal structure as the bulk material. It is easy to see that a sufficiently thick film will be structured according to the crystal structure associated with its own material, as it is energetically favourable. This means that in a thick film, dislocations have to appear, which will ruin the otherwise fair properties (e.g. electronic) of the film.

Give a safe upper bond for the thickness of an error-free silicon thin film, which is grown on a GaAs bulk.

(Ákos Gombkötő)

17. A cork is seen through a lens of dioptre 5 and diameter 4 cm. The cork is a cylinder of diameter 2 cm and length 4 cm. The lens is located 30 cm from our eyes, and the circular base of the cylinder is at a distance of 2 cm from the lens. The optical axis of the lens is the same as the axis of the cylinder. What do you see? Make a drawing, such that on the paper the diameter of the lens is 6 cm.

(Géza Tichy)

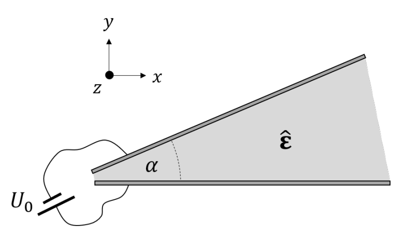
18. A summer experience... the Sun is shining, waves appear on the Lake Balaton (certainly with perfect sinusoidal plane waves). The sun rays are incident perpendicularly to the ridges of the waves, at a constant angle relative to the vertical direction. The reflected light can accumulate above the water along specific lines, creating high intensity caustic surfaces. (Due to the symmetry of the phenomenon, it is sufficient to make the studies below in two dimensions, in the plane perpendicular to the ridges of the waves).

Calculate the equations determining the caustics using the relevant geometrical parameters. Plot the rays reflected from the various points of the wave surface, and plot the analytically calculated caustic lines on the same figure—check the match! Make various figures changing the parameters (amplitude and wavelength, incident angle of sunlight).

Explain qualitatively (and also, possibly, quantitatively) the geometrical properties of the observed caustics. Where and why are there singular points and peaks on the caustic lines? Determine their positions.

(József Cserti, Zoltán Kaufmann, Gyula Dávid)

19. Two large sized metallic plates, with angle α between them, are used as electrodes of a capacitor. The volume between the plates is filled with an uniaxial birefringent dielectric material, with permittivity tensor $\boldsymbol{\varepsilon}$, and voltage U_0 is connected to it using a battery, according to the figure.



The principal axes of the birefringent material are x, y and z denoted on the figure, and $n_x > n_y = n_z$ is fulfilled for linearly polarized electromagnetic waves.

a) What is the value of the electric potential U and the electric field strength vector $\mathbf{E}$ between the plates in an arbitrary point?

b) What is the shape and structure of the electric field lines and the equipotential surfaces? Make an approximate drawing.

c) Give the electric energy density w_e between the plates as a function of position!

(Róbert Németh)

20. In vacuum two metallic spherical balls of the same radius $r = 1$ cm and mass $m = 1$ g are located at a distance $l = 1$ m from each other. The balls are set in motion towards each other along a straight path, both with an initial velocity $v = 10$ m/s. One of the balls is neutral, the other carries an electric charge $Q = 10^{-7}$ C. The collision is central, and perfectly elastic. Give the velocities of the balls at the moment when they are again $l = 1$ m apart.

(Ferenc Woynarovich, based on the idea of László Holics)

21. Let $\mathbf{x} \in \mathbb{R}^3$ be a fixed point. Suppose we put dipole moment density

$$\mathbf{d}(\boldsymbol{\xi}) = \frac{\mathbf{x} - \boldsymbol{\xi}}{|\mathbf{x} - \boldsymbol{\xi}|}$$

on some surface $\Sigma \subset \mathbb{R}^3$ with a given finite area. What choice of Σ makes the absolut value of the electric field $\mathbf{E}(\mathbf{x})$ maximal?

(Mihály Csirik, Gábor Helesfai, Gábor Homa)

22. A rocket moves along straight path with a steady speed $v = \beta c$ relative to an inertial system K. It emits a light beam, which is steady in the rest system K' of the rocket and is perpendicular to the direction of the relative velocity of inertial frames K and K'. The light is made 'visible' by a fine cosmic dust being at rest in K. What is seen by an observer resting in K located at a distance d from the path of the rocket, in a direction perpendicular to the plane swept along by the light beam?

(Ferenc Woynarovich, based on the idea of István Varga (1952-2007))

23. A free electron moves with such a minimal energy, which allows the following scenario to take place: The electron absorbs a photon moving towards it in the opposite direction. Then it emits a virtual photon, which subsequently decays into an electron-positron pair, the latter two moving in opposite directions with respect to each other, and their velocities are the same magnitude as the final velocity of the original electron.

a) What was the velocity of the original electron? How much times higher was the energy of the absorbed photon than the energy of the original electron? What is the (rest) mass of the 'fatted' electron after absorbing the photon? How high is the energy and momentum of the virtual photon? What is the relative velocity of the electron and positron created in the pair production process?

b) Explain why is there a minimal energy for the scenario to take place, what sort of 'geometrical' extremal property makes this energy value specific?

c) Change to the inertial system where the original electron is at rest, describe the complete process and answer again the questions above!

d) In the rest system of the original electron, certainly it does not make sense to consider the 'minimal energy of the electron', since the energy is the same as the rest mass. Which extremal property makes this process under study special among the many other similar ones?

During the derivation, do not use decimal fractions, but only fractional expressions and roots! *Suggestion:* use the units $c = 1$ and $m_e = 1$ (c is the speed of light, m_e is the electron mass).

(Gyula Dávid)

24. A rocket moves along a straight line, exhausting the propellant backwards at constant mass rate referred to its proper time. The speed of the exhaust gas is $u = c/n$ relative to the rocket, where c is the speed of light, n is a number larger than 1. If the rocket would consist of fuel only, then its mass would go to zero after time T.

To which point of spacetime can the accelerating rocket reach, before the fuel runs out? Give the answer as a function of the parameter n. Study also the limiting case of 'photon rocket' with $n = 1$.

(Gyula Dávid)

25. A large size, homogeneous, fully transparent glass block with dielectric constant ε =9/4 and magnetic permeability μ =1 moves along the direction of the negative axis x with a speed of v =2c/3, where c is the speed of light in vacuum. Inside the glass block, an electromagnetic planar wave is propagating into the positive direction x represented with wave number vector $\mathbf{k}$. Give the components of the vector fields $\mathbf{E}$, $\mathbf{D}$, $\mathbf{B}$ and $\mathbf{H}$ inside the glass brick as functions of position vector $\mathbf{r}$ and time t. (If there are multiple independent modes, study all of those.) Disregard the surface effects.

(Gyula Dávid)

26. Find the error in the following argument! Let us assume that there is a particle with mass m in an infinite potential well of width $2a$. The wavefunction is: $\Psi(x) = N(a^2 - x^2)$, if $|x| < a$ where N is a constant of normalization (calculate).

The Hamiltonian inside the well is $H = -\frac{\hbar}{2m}\frac{\partial^2}{\partial x^2}$, thus $H^2\Psi = 0$. It follows directly that its mean value is: $\langle H^2\rangle_\Psi = \langle \Psi, H^2\Psi\rangle = 0$. At the same time it holds that $\langle H^2\rangle_\Psi = \sum_n E_n^2 p_n > 0$. Based on this, we can conclude that the mathematical apparatus of quantum mechanics contains contradictions. :(

(Ákos Gombkötő)

27. Let us consider a point-like particle circling around the z-axis. Find a quantum state ψ for which the standard deviation of the z-component L_z of the angular momentum operator $\mathbf{L}$ satisfies $\Delta L_z < \hbar/4\pi$. Considering the uncertainty principle between the azimuthal angle φ and the angular momentum L_z, do not we find the existence of such states rather peculiar?

(Gergely Fejős)

28. It is known that the Jaynes-Cummings model, which describes the coupling of an electromagnetic mode and a two-level system, utilizing the rotating wave approximation, gives a useful framework to interpret some quantum electrodynamical processes.

In the rotating wave approximation, the ground state $|g\rangle|0\rangle$ is static – that is, disregarding some phase factors, the dynamics will not change it – which is not fulfilled in case of the exact dynamics, without assuming the rotating wave approximation.

Consider now the system when the energy difference between the two levels is zero, but there is a possibility of a dipole transition. This system can be described by the following Hamiltonian:

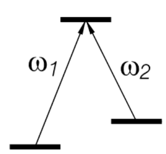
$$H = \hbar\omega\, a^+ a + \hbar\,\frac{\Omega}{2}\,\sigma_x(a + a^+)$$

Give the exact solution of the system, that is, the time evolution according to the Hamiltonian above, when the initial state is the ground state as quoted above.

Do not make any further approximations, and do not neglect any terms, during the calculation.

(Ákos Gombkötő)

29. Consider a medium of gas phase, which has two spectral line, generated by the transitions which can be schematically seen below.



Frequencies can be written as $\omega_{1,2} = \omega_0 \pm \Delta/2$. The spectral bandwidth is $\gamma \ll \Delta$. Optical transitions may be modelled with classical oscillators. Suppose that transition 2 is pumped by a laser with frequency ω_2. Estimate the group velocity of a pulse with mean frequency ω_0, if $\Delta \approx 10^7/s$, and the particle-number density is $N/V \approx 10^{14}$ atom/cm^3.

(Ákos Gombkötő)

30. Quantum dissipation of a damped harmonic oscillator with mass m, frequency ω and damping factor γ is described by the following master equation in Born-Markov approximation:

$$i\frac{\partial\hat{\rho}}{\partial t} = \left[\frac{\hat{p}^2}{2} + \frac{\omega^2\hat{x}^2}{2}, \hat{\rho}\right] - i\frac{2\gamma m k_B T}{\hbar^2}[\hat{x}, [\hat{x}, \hat{\rho}]] + \frac{\gamma}{\hbar}[\hat{x}, \{\hat{p}, \hat{\rho}\}],$$

where $\hat{\rho}$ is the density operator of the damped harmonic oscillator, $\hat{x}$ and $\hat{p}$ are the position and momentum operators, respectively, T is the temperature of the environment, k_B is the Boltzmann constant and $\hbar$ is the reduced Planck constant. Let us start the time evolution of the density operator from the pure state $\hat{\rho}_i = |\Psi\rangle\langle\Psi|$.

By examining the time evolution of quantity $\mathrm{Tr}\hat{\rho}^2$ which characterizes the purity of the quantum state, let us find out the minimum value of constant C from the required physical condition for σ_{xx} width of initial wave function Ψ:

$$\sigma_{xx} = \sqrt{\mathrm{Tr}(\hat{x}^2\hat{\rho}_i) - [\mathrm{Tr}(\hat{x}\hat{\rho}_i)]^2} > C \cdot \lambda_{th},$$

where $\lambda_{th} = \sqrt{2\pi\hbar^2/(mk_BT)}$ is the thermal de Broglie wavelength, so that physical condition $0 \leq \mathrm{Tr}\hat{\rho}^2 \leq 1$ is certainly fulfilled for a short time period after the beginning of the time evolution of the density operator $\hat{\rho}$.

(Gábor Homa, László Lisztes)

31. Let us attempt to define the concept of 'weight' in a covariant fashion in general relativity, with detailed study of the experimental situation below.

In a terrestial experiment, the whole Earth (assume that the idealized Earth is an insulating ball without its own magnetic field) is placed in a large homogeneous magnetic field, in which a particle is orbiting. The particle is of mass m, electric charge q, the angular velocity is ω according to an observer co-moving on the Earth surface. Besides the orbiting, the particle would evidently 'fall' towards Earth. Let us assume that we equilibrate the Earth's 'gravitational attraction' with a weak, radial electric field which points outwards from the Earth center, so that the particle would not fall. Determine the electric field needed to achieve this. *Remark*: it is allowed to use automated calculation (e.g. Maple). The linearized gravitational approximation can be used, but not necessary.

Based on the above situation, give a formal definition to the 'weight' of the relativistic, orbiting particle, and try to interpret it heuristically.

Supplementary information 1: An infinitely large solenoid, containing Earth (that is, the 'homogeneous' field) in the Schwarzschild spacetime takes the form

$$B^{\mathsf{a}}(t, r, \vartheta, \varphi) \sim \sqrt{1 - \frac{r_S}{r}}\left(0, \cos\vartheta, -\frac{1}{r}\sin\vartheta, 0\right)$$

in the usual Schwarzschild coordinates, according to an observer co-moving with Earth. This magnetic field keeps the particle orbiting on a circle. The derived electromagnetic field tensor is

$$F^B_{\mathsf{bc}} = -u_0{}^{\mathsf{a}}\sqrt{-\det(g)}\,\epsilon_{\mathsf{abcd}}\,B^{\mathsf{d}}.$$

Supplementary information 2: The radial electric field (that is, an imaginary, homogeneous spherical surface charge just below the Earth actual surface) in the Schwarzschild spacetime takes the form

$$E_R{}^{\mathsf{a}}(t, r, \vartheta, \varphi) \sim \frac{1}{r^2}\left(0, \sqrt{1 - \frac{r_S}{r}}, 0, 0\right)$$

according to an observer co-moving with Earth. The derived electromagnetic field strength tensor is

$$F^{E_R}_{ab} = u_0{}^c g_{ca} E_R{}^d g_{db} - u_0{}^c g_{cb} E_R{}^d g_{da}.$$

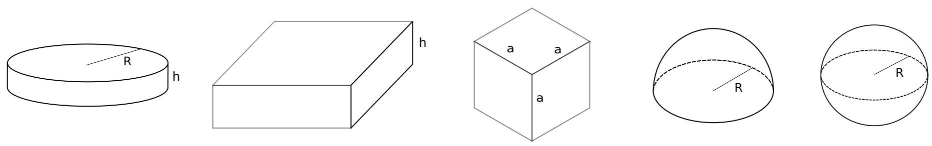
This electric field will hold the particle against gravitational 'falling'. (In the formulae above, u_0 denotes the velocity field of the observer co-moving with Earth.)

(András László)

32. Let us fill up a balloon with ideal gas of pressure P_0 and temperature T_0 and drop it in a black hole. Determine the pressure and temperature as a function of position inside the balloon when it reaches the horizon of the black hole. We can assume that the balloon is much smaller than the black hole and its mass and also the mass of the gas are negligible.

(Bence Kocsis)

33. There is a recent, very dangerous pseudo-scientific view spreading. Some people propose the totally absurd concept, that our Earth – which is known and liked to be a flat disc by all sober person since their childhood – is not actually a flat disc. The wild phantasies which appear in parallel include cubic, semi-spherical and spherical shapes. The figure below shows a few of these ridiculous imaginations.



The Geo-metrical and Geo-physical Departments of the Gummy Beach Academy of Sciences, named after Dr. Absoluto Zero, has decided to make absolutely precise series of experiments to disprove these unrealistic ideas. The method is as simple as a scientifically clean measurement can be. It is also possibly cheap, but not necessarily. During the experiment, a vertical hole is drilled through Earth, until the other side is reached. The borehole is placed (for symmetry reasons) close to the Middle of the World, which happens to be just by Gummy Beach. The borehole drilling will be covered by national funding.

Once the borehole is available, a probe mass (good quality standard gummy football) is dropped into it. The body starts accelerating and then decelerates as it approaches the other side, and it turns back and arrives into our hand after some time. (Certainly, in an absolutely ideal borehole, neither air drag, nor mechanical friction with the walls need to be considered).

The Earth Disk, as known for centuries from earlier measurements, has a diameter of 40 000 km, reaching out to the Terminal Ice Wall, at the circumference of the Disk. We will learn the thickness from the drilling. After that, an absolutely precise stopwatch will be used to measure the travelling time of the gummy ball. The calculation then provides the value of the density of Earth Disk: this latter can be assumed constant (disregarding a thin surface layer), as the unity of the People of Gummy Beach can not be weakened by any underground disturbances and unevenness.
Having the flight time value in hand, it can be compared to the ridiculous alternative scenarios (using the measured thickness and density data as input). Certainly, gross differences will be apparent, which will silence the proponents of folly forever.

The purpose of our present project call is to request from theoretical experts to calculate the return time of a free falling body for the proposed shapes, as shown on the figure above, before the actual measurements. The geometrical data and the density of Earth should be taken as parameters. The borehole is drilled at the Middle of the World, in the most symmetric way. Specifically to be compared: a) Flat disc (the actual shape of Earth), b) Infinitely Large Plate with finite thickness, c) Cube, d) Hemisphere, e) just to be even more ridiculous, Sphere.

Supplementary information: Newton's three laws of motion and the laws of gravity are (until any upcoming law amendment) are presently valid.

(József Cserti, Gyula Dávid)

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