THE 44th—16th INTERNATIONAL—RUDOLF ORTVAY PROBLEM SOLVING CONTEST IN PHYSICS
25 October—4 November 2013

1. Gain access to a microwave oven, in the family, or from a friend, if you do not have your own. (Let us exclude Panasonic ovens made in the past 5 years.) Heat 5 centiliter milk on maximal power setting so that it does not boil but becomes warn enough. Based on the time elapsed and the nominal output power of the oven we can determine how much nominal field energy was used.

   The task is to warm the same amount of milk with the same output energy, but now setting the microwave power to about one third of the maximum. Try to determine by experiments how long the milk needs to be warmed. Can you give a repeatable recipe?

   After simpler hypotheses you can take into account inhomogeneities in the field power density, the position of the cup, and the angular velocity of the plate.

   The answer may depend on the specific appliance. Give an account of your experiments and draw the conclusions about your oven. Intelligent reasoning and report are appreciated.

   Why did we exclude recent Panasonic ovens?

   Warning: Do not turn on an empty oven. Why?

   (Géza Györgyi and János Lendvai)

2. Felix Baumgartner has jumped out of a helium-filled balloon on 14th October 2012, from an altitude of approximately 39 kilometers, and as a first one in the world, was falling towards the Earth faster than the speed of sound. With this action he broke the record of his predecessor, Joseph Kittinger, who in 1960 jumped 'only' from an altitude of 31km, only slightly approaching the speed of 1000 km/h. It is to be noted however, that Baumgartner did not break the record of the longest time free fall, since the time of 4 minutes 19 seconds he took, is 17 seconds less than the earlier record. Is it actually possible, that starting from a higher altitude, and thus reaching higher speed, the jumper reach the surface earlier, assuming same mass and same atmospheric drag? Or can it be that this is impossible, and the time difference is actually due to the different conditions? (For the calculations, let us assume that the drag force is proportional to the square of the speed, and the air density follows the barometric formula.)

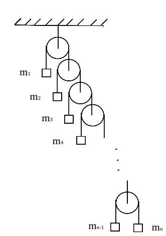
   (Béla Ráczkevi)

3. In case of an elastic, central collision the velocities after the collision are homogeneous linear functions of the initial velocities, that is, the scattering may be represented by a matrix.

   Calculate the eigenvalues and eigenvectors of the matrix. Give the physical interpretation of these eigenstates.

   (Géza Tichy)

4. Let us study the behaviour of the simple structure shown in the figure, in homogeneous gravitational field. There are $n-1$ ideal, massless, frictionless pulleys, with a massless, non-stretchable, very flexible rope over them. On one side a small body of mass m, and on the other side an additional pulley is attached. On both sides of the lowest pulley, two bodies of mass m are fixed. Determine the acceleration of each bodies and the forces of the ropes rolled over the corresponding pulleys. Give a closed formula for the acceleration of the uppermost body as a function of n. Study specifically the limiting case $n \to \infty$.

   (Gábor Homa and Attila Pásztor)

5. A planet orbits around its sun on an elliptic orbit, and loses mass slowly due to evaporation. How do the parameters of the orbital ellipse change as a function of time?

   (Gábor Széchenyi and József Cserti)

6. Riding a bicycle on hillocks up and down I often wondered how should I optimize my finite effort to be fastest on a given track. For simplicity, instead of attempting to understand the complicated details of a human being, consider an electric bike with a rechargeable battery capable to perform total work W and the motor is able to perform arbitrarily high torque if needed. How should we control the driving force and the velocity to complete a given varyingly steep monotonous uphill section (length l, total height h)? The given total energy W is well sufficient to reach the highest point. Assume that the drag force is $-\beta v^2$, where v is the velocity of the bicycle. How does the answer change if the drag force is proportional to first power of the velocity or any positive power of it? What is the optimal strategy if there are also downward slopes and we can or cannot feed back energy to the battery?

   (Gábor Cynolter)

7. As known from freshman mechanics courses, a mass point in a central potential performs an effectively one-dimensional motion in the radial coordinate. The effective potential can be derived from the energy, if we use the conservation of the angular momentum: the centrifugal potential should be added to the original one.

   The equation of motion can be obtained also from the Lagrangian. If we substitute, however, the conserved angular momentum herein then the centrifugal potential arises with opposite sign. That is, if we naïvely apply the Euler–Lagrange equation then the centrifugal force appears with the wrong sign in the equation of motion. Resolve the apparent contradiction.

   In the general case we consider a system with one cyclic coordinate, whose conserved momentum we resubstitute into the Lagrangian. How do we get from here the correct equations of motion?

   (Géza Györgyi)

8. Let us study the Fermat-principle of geometrical optics in the case that the refraction index depends not only on the position, but also on the direction of the light propagation: $n = n(\mathbf{r}, \mathbf{e})$, where $\mathbf{r}$ defines the position, and $\mathbf{e}$ is a unit vector which points in the direction of the light propagation.
   a) Write down the Euler–Lagrange equation, defining the path of the light, associated with the Fermat principle as a variational problem, choosing the path length as independent variable. (*Suggestion*: first introduce an arbitrary variable w which runs along the path monotonously, and in a later stage change to path length parametrization.)
   b) Study the special case when the refraction index takes the following form:
   $n = n(\mathbf{r}, \mathbf{e}) = 1 + (e^{\beta(\mathbf{r})} - 1)\,(1 + \mathbf{ek})$, where $\mathbf{k}$ is the unit vector pointing toward the z coordinate. Write down the equation defining the path in its simplest form.
   c) Let us assume now that the function $\beta(\mathbf{r})$ depends only on the absolute value r of the position vector $\mathbf{r}$. Show that in this case, the path lays in a plane, and write down the equation defining the path curve. How should one choose the function $\beta(\mathbf{r})$, if we wish the light beam to orbit around the center of the reference frame on an elliptical path?

   (Gyula Dávid)

9. Let a mass point move in a central potential $V_0(r)$ between the finite minimal and maximal radii, and assume the knowledge of the orbit during one oscillation by the form $r_0(\phi)$, depending on the energy E and the magnitude of the angular momentum N. Starting from the point closest to center, denote by Φ_0 the change of the polar angle for one radial oscillation (e.g. for Kepler orbits $\Phi_0 = 2\pi$, in an harmonic potential $\Phi_0 = \pi$, else in general Φ_0 and π are not commensurate).

   Show that upon the perturbation of the potential by $\delta V(r)$ the leading correction of the change in the polar angle is

$$\delta\Phi = -\frac{\partial}{\partial E}\int_0^{\Phi_0} \delta V(r_0(\varphi))\,\mathrm{d}\varphi,$$

   where the potential should be taken along the unperturbed orbit $r_0(\varphi)$. The partial derivative is understood with constant N.
   Consider a $\delta V(r) = \gamma/r^n$ perturbation to the gravitational potential $V_0(r) = -m\alpha/r$. Determine the perihelion deviation $\delta\Phi$ explicitly for positive integer n. For which n is the deviation independent of the eccentricity?

   (Géza Györgyi)

10. On a slope, inclined at angle α, a right cone of height h and opening angle of γ and with constant mass density is performing small amplitude oscillations, rolling around its equilibrium state. Determine the frequency of the oscillation.

    (Géza Tichy and József Cserti)

11. A flexible, rectangular, homogeneous steel beam of thickness d, width w (the density of steel is ϱ, its Young modulus is E) is embedded into the wall such that a part of length L is sticking out. (For the sake of simplicity, all this happens in weightlessness.) The beam is hit so that it starts to vibrate along its thickness.
    a) Find the oscillation frequencies of the beam. Based on realistic data design a beam that can be used as a tuning fork, i.e. its base frequency is 440 Hz.
    Now a point mass of M is fixed on the end of the beam which is hit now again.
    b) Write down equations which give the oscillation frequencies in this case. There is no need to solve them. (*Advice:* use the parameter $\mu = M/(M+m)$ where $m = dwL\varrho$ is the mass of the beam.)
    c) Find the detuning of the modes of the beam in the case $M \ll m$. How large mass M should be fixed on the previously designed 'tuning fork' in order to detune it by 5 Hz?
    d) Which would be the resonance frequencies of the system if M was infinite? Find the amount of detuning compared to this in case of $\infty > M \gg m$.
    e) How large mass M is needed to detune the base frequency by an octave (a quint, a quart)? How do the frequencies of other modes change then?

    (Attila Szabó)

12. Two very small pulleys are placed at distance d from each other, and a thin, weighty rope of total length L is laid on them. One can observe that the rope sags between the pulleys to h depth. Let us study the dependence of the sagging depth h on L and d. Under which conditions the equilibrium states of the rope are stable or unstable? What could be the minimal length of the rope in equilibrium? Study the limiting case as $L/d \to \infty$.

(Géza Tichy, József Cserti and Máté Vigh)

13. A droplet of mercury rests on a horizontal glass plate. It is half as high as wide. How much its mass may be? The contact angle of mercury to the glass is 138°.

(Gyula Radnai and Máté Vigh)

14. The ceiling of a steam cabin is made of a perfectly wetting material. Since the temperature is slightly below the dewpoint, water droplets are forming on the horizontal ceiling. What is holding these droplets up there? Determine the height h of the largest stable (just-not-dripping) droplet. Give this height h, that is, the distance between the lowest point of the droplet and the ceiling, as a function of the water density ϱ, surface tension α and gravitational acceleration g. Calculate h numerically.

(Máté Vigh)

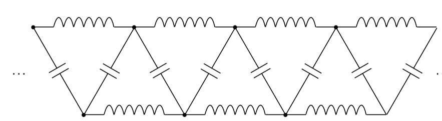
15. A small liquid sphere of surface tension σ and density ϱ, somewhere in a remote region of the Universe, is held together by the surface tension and its own gravitation. The liquid is incompressible, and one can neglect friction or viscosity. How does the shape of the droplet change, if it rotates slowly with angular velocity ω? Give also the proper meaning of 'small size' and 'slow rotation' in this context.

(Áron Kovács)

16. In homogeneous, isotropic air the sound propagates at a speed of u, and fulfills the usual homogeneous wave equation. Let us now change to an other inertial system, which moves with velocity V with respect to the rest system of air, in a direction defined by any unit vector $\mathbf{n}$. Transform the wave equation into the new reference system, and write down the dispersion relation of the plane waves. Let now the relative velocity of the two inertial system be equal to the sound velocity u. Write down the homogeneous wave equation in this specific reference system, determine the dispersion relation, and give the general solution of the equation. Study also the inhomogeneous wave equation (that is, the problem of irradiation of sound), and calculate the Green-function of the equation. Perform the calculations based both on classical physics and special relativity.

(Gyula Dávid)

17. The infinite triangular chain shown in the figure is made of coils of inductance L and capacitors of capacitance C. Find the total impedance between any two vertices of the chain operated at an angular frequency ω. Examine the behaviour of the chain against direct current. Does the system have resonance frequencies? What will happen if the capacitors and the coils are exchanged?



(Attila Szabó)

18. A very large square shaped conductive plate is on ground potential. A thin, very long, electrically charged wire runs parallel with one edge, at a given finite distance from that edge of the plate.

In which case does the force acting on the wire get larger
a) when the wire is in the plane defined by the plate
b) when the wire is in the plane which is perpendicular to the plate and contains one of the given edge?

What is the ratio of the size of the two forces?

(Péter Gnädig)

19. Let us study the motion of an infinitely long metal cylinder, of radius R, mass density ρ, and with electrical charge per unit length η. At a distance d from its axis, there is a fixed, grounded conductive plane. What will be the impact velocity, if the cylinder is released at zero speed, and radiation effects are negligible? Let us estimate how much time is taken until the impact, in case that $d \gg R$.

(Gábor Széchenyi)

20. A small dipole of magnetic moment $\mathbf{m}$ is placed at a distance d from a superconducting sphere of radius R. The dipole momentum vector is perpendicular to the line connecting the center of the sphere and the dipole. Determine the force acting between the sphere and the dipole. Sketch the force on a plot as a function of d. One can assume that the London penetration depth is zero.

(Áron Kovács)

21. Two point-like compasses of magnetic moment m, moment of inertia J and with vertical axis are placed in a distance d from each other in the magnetic field B_0 of the Earth which can be considered as horizontal and homogeneous. One compass is diverted by an angle $\alpha_0 \ll 1$ away from its equilibrium and the system is left alone. Describe the behaviour of the system if the compasses are placed
a) along a vertical line;
b) along a (magnetic) north–south line;
c) along a (magnetic) east–west line.
Assume that the magnetic field of the compasses is much weaker than that of the Earth. Does the oscillation of the first compass stop at some moment? If yes, when, if no, what is the minimal amplitude of its oscillation?

(Attila Szabó)

22. A small, vertically directed dipole of magnetic moment $\mathbf{m}_0$ and mass m is released above the center of a horizontal, thin conductive ring of resistance R and of radius a, from a height of h. Describe the motion of the magnetic dipole in the gravitational field. Assume that the self-inductance of the ring is negligible, and that the magnetic dipole moves along the vertical symmetry axis of the ring.

(József Cserti)

23. Classically behaving $\boldsymbol{m}_i$ magnetic moments of equal strength are put on every site of a honeycomb lattice. We assume that each moment feels the effect of its three neighbours only, and the energy of the system can be written as

$$E = J \sum_{\langle i,j \rangle} \boldsymbol{m}_i \cdot \boldsymbol{m}_j \,,$$

where $\langle i,j \rangle$ denotes that the summation goes over nearest-neighbour pairs.

For $J > 0$ the energy takes minimum value if the magnetic moments point in opposite directions, let us say in direction $+z$ or $-z$, on neighbouring sites. The lattice sites with magnetic moments pointing upwards or downwards form two interpenetrating sublattices.

This state can be visualized as follows: the magnetic moment at site i feels an effective magnetic field

$$\boldsymbol{B}_i^{\text{eff}} = -\frac{\partial E}{\partial \boldsymbol{m}_i}$$

arising from its neighbours, and this effective field orients the magnetic moments up or down on the two sublattices.

If the magnetic moments deviate from the full alignment and a small component appears in the xy plane, the moments start to precess, since the magnetic moment goes together with an angular momentum $\boldsymbol{I}_i = \boldsymbol{m}_i/\gamma$ (where γ is the giromagnetic coefficient), and the effective field gives rise to a torque

$$\boldsymbol{M}_i = \boldsymbol{m}_i \times \boldsymbol{B}_i^{\text{eff}} \,.$$

Owing to the coupling between neighbouring moments, they are not precessing independently. The precession propagates as a wave in space and time on both sublattices. This is the classical analogue of spin waves.

a) Assuming that the deviation of the magnetic moments from the fully aligned orientation is small, that is the m_i^x and m_i^y components of $\boldsymbol{m}_i$ are small compared to the z component, determine the frequency $\omega_{\boldsymbol{k}}$ of the wave propagating with wave vector $\boldsymbol{k}$.

b) Show that the magnetic energy belonging to such classical spin waves can be written as the sum of energies of two harmonic modes, both of frequency $\omega_{\boldsymbol{k}}$, in which the xy components of the magnetic moments of the two sublattices are mixed together.

c) These spin waves can be excited thermally at finite temperatures. Determine the amplitudes of the spin waves on both sublattices assuming that the system is in thermal equilibrium.

d) Assume that all waves with wave vector $\boldsymbol{k}$ allowed by the periodic boundary condition are present at finite temperatures. Determine the lowest-order correction to the reduction of the z component of the magnetic moment on the two sublattices owing to the thermally excited spin waves.

e) Show that this reduction is infinitely large in this approximation at arbitrary finite temperature in a large system, where the $\boldsymbol{k}$ vectors form a continuum, indicating that the disordering effect of thermally excited spin waves is so strong that the fully aligned ground state is completely destroyed at any finite temperature.

(Jenő Sólyom)

24. In the Nordström type (special) relativistic gravitational theory the equation of motion of a particle is the following: $d(Mu_k)/d\tau = M\,\partial_k\,\Phi$, where M is the rest mass of the particle, u_k is the four-velocity vector, τ is the proper time of the particle and Φ is the Nordström type gravitational potential.
a) Write down the formula determining to the four-acceleration vector of the particle.
b) Let us assume that (in a given inertial system) the gravitational potential Φ does not depend on time but only on the position. Find the first integral of the equations of motion, expressing the energy conservation.
c) Study the problem of free fall in the Nordström theory: let the gravitational potential Φ be simply $\Phi = gz$, where z is the vertical coordinate, g is a constant with the dimension of acceleration. Let the particle start from altitude of H with zero velocity. Calculate how long it takes to touch the ground and at which speed. How much is the proper time, measured by a clock moving with the particle?
d) Study the non-relativistic limiting case as well, and compare to the Newtonian solution. Under which conditions do the differences between the relativistic and the Newtonian solutions become considerable?

(Gyula Dávid)

25. Let us consider a large size, two dimensional optical transmission grid, with square structure. The grid constant is $d = (K + 1/2)\lambda$ in both directions, where K is an integer number, and λ is the wavelength of the illuminating monochromatic, perpendicularly incident light. In the Fraunhofer-limit of diffraction, the image which appears on the distant screen corresponds to the principal maxima, that is, sharp bright spots in closely squared pattern. The screen covers all possible directions, that is, for example, in case of $K = 1$ one observes 9, whereas for $K = 2$ there are 21 sharp spots. Naturally, if the grid was rotated around the light beam axis by an angle of α, the image also rotates the same.

a) Let us now place two identical square grids right behind each other: assume that they are very close, that is, the transmission of the combination in each point is given as the product of the individual transmissions. The two grids are rotated with respect to each other by an arbitrary angle α.

How does the diffraction pattern look like? Where can one observe spots, and how many? Specifically for $K = 2$, plot the total number of the visible spots as a function of α. Sketch the visible diffraction image in the limit of very small α values.

b) Let us again place the two grids close to each other, in this case in a parallel alignment, but assume that their grid constants are slightly different (as a result of production error, for example): one grid is a magnification of the other by a factor of $(1 + \beta)$. How does the diffraction pattern look like in this case? Is there any similarity with the case a), and if so, why?

(Dezső Varga)

26. One of the fundamental results of classical statistical physics involves the description of a system consisting of N linear harmonic oscillators in thermodynamic equilibrium. The Hamiltonian of a single particle bound this way can be written as

$$H = \frac{p^2}{2m} + \frac{1}{2}\,kx^2, \tag{1}$$

where x and p are the so-called normal co-ordinate of the problem and the associated momentum, respectively. Starting from this initial condition, one can proceed along the usual textbook lines and calculate, e.g., the internal energy U, free energy F, entropy S, specific heat c_v, etc. of a given number N of particles in a gas in equilibrium state. However, when confronted with 'real' systems — which happens more often than expected — the Hamiltonian in (1) cannot be put in the purely quadratic form shown above (and this does not even call for any of the more exotic cases mentioned, see for instance the relevant Wikipedia entry). Take one particular case (still far from a truly observable system but perhaps better approaching real gases or crystalline bodies) as some kind of reasonable correction in the form of the Hamiltonian

$$H = \frac{p^2}{2m} + \gamma\left(1 - \cos 2\pi\frac{x}{a}\right), \tag{2}$$

where the potential is periodic in x.
a) Take N particles moving under the influence of H in (2), select the value of the parameter γ such that it fits the spring constant k in (1) (to facilitate comparison), then employ the conventional tools of classical physics to calculate the temperature (T) dependence of the quantities U, F, S, c_v (and/or anything similar thought to be instructive) invoked above. Trace the graphs of these quantities against temperature, and try to interpret the deviations found with respect to the baseline case (in fact the equilibrium situation) at least intuitively, if not quantitatively.
Note: Do not expect such an oversimplified model neglecting all known quantum effects (zero point energy, tunneling, etc.) to be convincing, as it is, the rough description may in fact lead to some incorrect conclusions. Try to eliminate these. The skills to manipulate Bessel functions may come in handy.
b) For such (or a similar type of) oscillating potential the quantum mechanical treatment of the basic problem (i.e. energy levels) is also available (for want of a better source, you may want to consult the webpage
`www-personal.umich.edu/~jbourj/cm/homework%203.pdf`
– not trivial!). Do you see a way to improve (with a reasonable amount of work and time) the results of the previous section actually obtained with the aid of essentially purely *classical* means?

(Péter Magyar)

27. It is known that Heisenberg's commutation relations can not be fulfilled by finite matrices representing the quantum mechanical operators (or rather, if it is not generally known, let us actually prove the statement.) Why can still one use such finite matrices in nanophysics (e.g. to describe the properties of the graphene), where even 2 by 2 matrices appear? Is this not in contradiction with the basic assumptions of quantum theory?

(Gyula Dávid)

28. Let us consider a hypothetical square lattice with two basis atom per unit cell and with a lattice constant a_0. The energy dispersion of the conductance and valence band is: $\varepsilon(\mathbf{k}) = \pm\gamma\sqrt{2+\cos(k_x a_0)+\cos(k_y a_0)}$ (where γ is a constant, the states with energy below zero are occupied). Wrap up this lattice to form a cylinder so that a given point at $\mathbf{R}_{n,m} = a_0(n,m)$ is aligned with the origin. Neglect the effects of the curvature. How does the dispersion relation of the new system look like? Plot some of the possible dispersion relations, and study specifically the cases of $n = m$ or $m = 0$. In which cases is this system conductive?

(Gergő Kukucska)

29. Certain organic colouring agents (aka. pigments) comprise linear molecular chains that allow electrons to move freely along the nucleonic structure. Such ions can be produced by chemically removing one $(CH)^+$ group from a polyethylene molecule including an even number of carbon atoms. In this case, the bonds binding the ion in question are rearranged in a way such that eventually the following type of linear structure is formed:

$$(CH_2 \cdot CH \cdot CH \cdot CH \cdot CH_2),$$

which contains an *odd* number of C atoms placed uniformly at a distance of $d = 0.14$ nm from each other. Considering this setup, one may assume that from among the double bonds of the original molecule $n+1$ electrons (with n even) displace themselves independently and without obstacle within a '1D' confining potential with a characteristic length of $L_n = n\,d$.
a) Draw up a simple model for the potential described above, and determine the energy levels ϵ_k of an electron under the influence of the same. To be specific, proceed and give the eigenenergies E_0 and E_1 of the fundamental and first excited states of the whole multi-electron molecule (ensemble). Specify the wavelength, λ_n, of the photon absorbed during the transition from the ground state to the first excited state.
b) Experimental evidence revealed that the absorption lines of e.g. the ions with $n = 9$ ($n = 11$) or $n = 13$ fell into the blue ($\lambda_9 \approx 470$ nm), (orange) or red ($\lambda_{13} \approx 730$ nm) region of the visible spectrum. Can this be explained on the grounds of the rudimentary model used so far? Is there any need to refine this model?
c) Specify the integer indices n for which the ions prepared according to the method presented here are *coloured*. Think of a condition for this. Are there any general trends that emerge?

(Péter Magyar)

30. Two infinite plates, made from different materials but with the same width d, are attached together. In quantum mechanics the motion of the electron in three dimensions is described by the Hamiltonian $\hat{H} = \hat{\mathbf{p}}\frac{1}{2m(z)}\hat{\mathbf{p}}$, where $\hat{\mathbf{p}} = (\hat{p}_x, \hat{p}_y, \hat{p}_z)$ is the momentum operator of the electron, and the effective masses of the electron in the two regions are $m(z) = m_1$ if $z < 0$ and $m(z) = m_2$ if $z \geq 0$. The z axis is perpendicular to the plane of the plates. For simplicity, assume that the confining potential is $V(z) = 0$ if $|z| < d$ and $V(z) = \infty$ if $|z| \geq d$. Find the energy levels (Landau levels) of the system in homogeneous magnetic field pointing along the z axis!

(József Cserti and Gábor Széchenyi)

31. *The Stars and Beyond.* Rumour has it that dispensing with the alternative ways for interstellar travel (like wormholes, stargates, parallel universes, etc. *proposed by biased EU-based scientists*), in the near future the *Hungarian National Space Research Office* will publish a heretofore *classified, non-orthodox technological development* design effort not detailed here that will enable Mankind to construct a spaceship that can travel at velocities close to the speed of light, c, or at least comparable to it, sustained for a prolonged period of time. The location of the launch pad has been leaked out, too: allegedly a *small municipality in a Brave Pannon County of Hungary* has been singled out for the event, and the constituent parts of the vessel will be delivered to the site by *the newly constructed narrow gauge railway*. Unfortunately, the press has immediately swooped down on this fascinating and promising achievement scheduled for 2014, baptised the '*year of breakout*' by insiders, and attempted to discredit the campaign with some by now typical down-to-earth rhetoric citing researchers who 'wish to remain anonymous' who put forward the naïve argument that during such a perilous mission the spacecraft and its crew could be subjected to a decelerating force increasing with the cruise speed v, involving an interaction presumably producing an 'infinite' energy transfer due to head-on energetic photon collisions (the so-called photon barrier), besides not forgetting the successive scattering of particulate matter encountered along the path, which – alone and/or combined, one cannot say – would cause a loss of kinetic energy of the rocket that even with all other factors benevolent would question the success of reaching the destination. The heated and inspired response of the sponsored research team, hurt in their feelings, was soon to follow: they emphasised that *ever since the Red Star has been extinguished* no significant resistance or opposition force prevailed in the Galaxy. *Try to stem the tide of this emerging pointless debate*, and use your powers of deduction to decide whether or not the following statement is true or false: In a radiation field that is isotropic with respect to an observer at rest (i.e. in deep space), is it reasonable that the radiation pressure P_v exerted on a spaceship moving at velocity $v\,(\rightarrow c)$ can

seriously endanger the success of such an imaginary mission? Check your calculations: take the limit of $v \to 0$ and see if you recover the familiar formula. Give the resulting pressure due to incident photons for $v = 0.5c, 0.9c$ and $v = 0.99c$. Is there some definite limit (saturation) for $v \to c$? What can we say about the stream of microscopic particles hitting the hull during motion? How do these two compare? Can you name any other important obstacle? Support your case with an estimate where you plug in numbers from the literature.
Note: Some fragments in italics above refer to current funny or peculiar topics often discussed in the media in Hungary. Do not bother if you do not get the hint, the physics is the same.

(Péter Magyar)

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