A Tour of Fyziklani 2025 Problems

Karel Kolář, FYKOS
based on Solutions Fyziklani 2025[1]

Abstract

Fyziklani is Europe's largest team physics face-to-face competition, attracting nearly 1,200 upper secondary school students from more than ten countries to Prague each February. During a three-hour session of intense problem-solving, teams of up to five students tackle carefully crafted physics problems spanning classical mechanics, thermodynamics, waves, astrophysics, and modern physics. This article showcases five selected problems from the 19th edition held on 14 February 2025, demonstrating the breadth of topics and varying difficulty levels that characterise this unique competition.

Introduction

Fyziklani, organised annually by FYKOS[2], a student group from Charles University's Faculty of Mathematics and Physics, represents a remarkable celebration of physics education in Central Europe. The 2025 edition presented fifty-six problems ranging from everyday scenarios to exotic astrophysical situations.

Figure 1: Organisers of Fyziklani 2025

This article highlights five problems that demonstrate both the philosophy and the breadth of physics disciplines represented in the competition: thermodynamics, astrophysics, dimensional analysis, rotational mechanics, and electromagnetism. All the problems of the previous years of Fyziklani with their solutions can be found in the competition’s archive[3].

[1] https://fyziklani.org/download/2025/solutions.pdf
[2] Fyzikální korespondenční seminář, https://fykos.org
[3] https://fyziklani.org/archive

Problem AA ... quick pasta

Assignment: Honza is cooking pasta for dinner in his dorm room. He has at his disposal a cooker of power $P_1 = 1{,}200$ W and a kettle of power $P_2 = 2{,}200$ W. What is the shortest time in which he is able to heat half a litre of water from 20 °C to 100 °C?

Physics Insight: This is a relatively simple problem from thermodynamics. It was among the first seven problems for warm-up. It requires students to comprehend an essential principle of maximising power delivery for a fixed task. Rather than using the appliances sequentially, the optimal strategy involves employing both simultaneously. If they divide the water among both appliances with the optimal ratio, they can achieve the shortest time.

The effective heating power becomes $P = P_1 + P_2 = 3{,}400$ W. The energy required to raise 0.5 kg of water by 80 °C is $Q = mc_{\text{water}}\,\Delta T = V\rho_{\text{water}}c_{\text{water}}\,\Delta T \approx 167$ kJ. Using the fundamental relationship $t = Q/P$ yields the result, which is approximately 49 seconds. This problem elegantly demonstrates how adding independent power sources reduces completion time – a principle applicable from electrical circuits to industrial processes.

Problem BF ... an attempt at (not)shooting oneself

Assignment: How much time do you have to dodge a bullet you fire on a planet or moon with no atmosphere? You are shooting in such a way that the bullet remains at a constant (and negligible) height above the surface of a perfectly spherical body of radius R and mass M on which you are standing.

Physics Insight: This problem exemplifies the bridge between gravitational dynamics and circular motion. On a planet with sufficient spin or in idealised conditions, a projectile can achieve orbital velocity, also known as the first cosmic velocity.

At orbital velocity, gravitational force equals the required centripetal force

$$\frac{GMm}{R^2} = \frac{mv^2}{R}.$$

Solving for orbital velocity

$$v = \sqrt{\frac{GM}{R}}.$$

The circumnavigation distance is $2\pi R$, so the dodging time becomes

$$t = \frac{2\pi R}{v} = 2\pi\sqrt{\frac{R^3}{GM}}.$$

This formula reveals a profound astronomical principle: orbital period depends solely on orbital radius and central mass, independent of the object's mass. This also explains why the

Moon and a satellite orbit at predictable rates. For Earth-like planets or smaller bodies (asteroids, moons), this calculation provides a direct link between observables and planetary properties. This problem also shows that some of the problems might be a bit classical.

The accepted solution was the equation; nevertheless, for example, using Earth's values, we get approximately 1.4 hours. In the case of our Moon, we get 1.8 hours.

Problem AE … deeply they wave

Assignment: Pepa sailed his private yacht during the holidays to watch the waves. He noticed that far from the coast – in the so-called deep water – the effect of water depth is not significant. It can therefore be assumed that the angular frequency of the waves ω depends solely on the gravitational acceleration g and the wavelength λ. Deduce what this dependence should look like, i.e., find the real numbers α and β such that $\omega = C g^{\alpha} \lambda^{\beta}$, where C represents some dimensionless constant. The relation obtained is equivalent to the so-called dispersion relation for waves in deep water.

Physics Insight: This problem shows a powerful problem-solving tool independent of detailed physics knowledge – the dimensional analysis. The dimension of angular frequency is $[\omega] = \mathrm{s}^{-1}$. Assuming $\omega = C g^{\alpha} \lambda^{\beta}$ (where C is dimensionless), we require dimensional consistency

$$(\mathrm{s})^{-1} = (\mathrm{m} \cdot \mathrm{s}^{-2})^{\alpha} \cdot (\mathrm{m})^{\beta}$$

Matching exponents

- for seconds: $-1 = -2\alpha$, yielding $\alpha = 1/2$,
- for metres: $0 = \alpha + \beta$, yielding $\beta = -1/2$.

Therefore $\omega \propto \sqrt{\frac{g}{\lambda}}$.

This result explains why large ocean waves move faster than small ripples—a phenomenon sailors have exploited for millennia. The formal solution, including the dimensionless constant from linearised wave theory, becomes

$$\omega = C\sqrt{\frac{g}{\lambda}},$$

which describes the dispersion relation for gravity waves.

Problem FH … pencil on the edge

Assignment: A pencil of length l lies on a table with 3/5 of its length resting on the surface and 2/5 hanging in the air. What is the maximum distance $d_{\max}$ below the hanging end where one can strike the pencil with an upward impulse so that the entire pencil lifts off without tipping over its supported edge?

Physics Insight: This deceptively simple problem combines rotational dynamics, impulse mechanics, and geometric constraints. The key insight is that the pencil must acquire both translational and rotational motion from a single impulse, and the balance between these determines whether it lifts cleanly or merely rotates.

Let us denote the magnitude of the impulse of the force by I, the distance of the impulse from the centre of gravity of the pencil by x, and the mass of the pencil by m. Note that to actually apply the impulse in the air and not on the table, the following must hold: $x > l/10$.

The impulse gives the pencil both linear momentum p and angular momentum L with respect to the axis of rotation passing through its centre of gravity. From the impulse theorems

$$\Delta p = F\Delta t = I \quad \Rightarrow \quad p = I\,,$$

$$\Delta L = xF\Delta t = xI \quad \Rightarrow \quad L = Ix\,.$$

Now, let us examine the vertical displacement of the left end of the pencil $\mathrm{d}y_0$ at the first infinitesimal time interval $\mathrm{d}t$. For the vertical y-coordinate of the centre of gravity y, we have

$$p = m\frac{\mathrm{d}y}{\mathrm{d}t} \quad \Rightarrow \quad \mathrm{d}y = \frac{p\,\mathrm{d}t}{m} = \frac{I\,\mathrm{d}t}{m}\,.$$

At the same time, the pencil rotates around its centre of gravity by $\mathrm{d}\theta$, which satisfies

$$L = J\frac{\mathrm{d}\theta}{\mathrm{d}t} = \frac{1}{12}ml^2\frac{\mathrm{d}\theta}{\mathrm{d}t} \quad \Rightarrow \quad \mathrm{d}\theta = \frac{12L\,\mathrm{d}t}{ml^2} = \frac{12Ix\,\mathrm{d}t}{ml^2}\,,$$

where we have used the relation for the moment of inertia of a thin rod with respect to the axis through its centre of gravity: $J = (1/12)ml^2$.

From the geometry, we can see that the vertical displacement of the left end of the pencil $\mathrm{d}h$ caused by rotation by $\mathrm{d}\theta$ is

$$-\tan \mathrm{d}\theta = -\mathrm{d}\theta = \frac{2\mathrm{d}h}{l} \quad \Rightarrow \quad dh = -\frac{l\,\mathrm{d}\theta}{2} = -\frac{6Ix\,\mathrm{d}t}{ml}\,.$$

Therefore, we obtain

$$\mathrm{d}y_0 = \mathrm{d}y + \mathrm{d}h = \frac{I\,\mathrm{d}t}{m}\left(1 - \frac{6x}{l}\right).$$

The detachment from the table happens when $\mathrm{d}y_0 > 0$, which gives the condition

$$\left(1 - \frac{6x}{l}\right) > 0 \quad \Leftrightarrow \quad x < \frac{l}{6}\,.$$

The task was to find the maximum distance from the edge of the table

$$d_{\max} = x_{\max} - \frac{l}{10} = \frac{l}{6} - \frac{l}{10} = \frac{l}{15}\,.$$

Thus, we obtain the final result

$$d_{\max} = \frac{1}{15}\,l \approx 0.067\,l\,.$$

Remarkably, this answer is independent of gravitational acceleration. This is a reminder that gravity affects the pencil uniformly and thus does not influence whether it lifts.

Problem GH … a little restive dipole

Assignment: A little magnetic dipole with the magnetic moment $m = 1.0 \cdot 10^3\ \mathrm{A \cdot m^2}$ harmonically oscillates on the axis of a conductive circular loop with the radius $R = 1.0\ \mathrm{m}$, at a frequency $f = 1.0\ \mathrm{MHz}$ and with an amplitude of the deflection equal to $h_0 = 1.0\ \mathrm{mm}$. The direction of the magnetic moment is parallel to the axis of the loop and the equilibrium position of the little dipole is located in the geometric center of the loop (meaning the little dipole oscillates between the maximum distance h_0 below and h_0 above the loop). Determine the amplitude of the induced voltage in the loop, assuming the little dipole is sufficiently small, and therefore the vector potential it creates can be expressed as

$$\mathbf{A}(\mathbf{r}) = \frac{\mu_0}{4\pi}\frac{\mathbf{m} \times \mathbf{r}}{r^3}\,,$$

where $\mathbf{r}$ is the vector from the little dipole to any point in space, $r = |\mathbf{r}|$, and μ_0 is the vacuum permeability. Recall that the magnetic induction is given by $\mathbf{B} = \nabla \times \mathbf{A}$.

Physics Insight: This problem bridges magnetostatics, electromagnetic induction, and calculus – requiring students to find the magnetic flux through a loop generated by an oscillating dipole, then differentiate to find the induced voltage.

Let us calculate the magnetic induction flux Φ generated by the little dipole inside the loop. From the formula for magnetic induction in the assignment and from Stokes' integral theorem

$$\Phi = \int_S \mathbf{B} \cdot \mathrm{d}\mathbf{S} = \int_S (\nabla \times \mathbf{A}) \cdot \mathrm{d}\mathbf{S} = \oint_{\partial S} \mathbf{A} \cdot \mathrm{d}\mathbf{l}\ .$$

Let the equilibrium position of the dipole be located in the origin of a Cartesian coordinate system, and the magnetic moment points in the positive direction of the z-axis. Then $\mathbf{r} = \mathbf{R} + \mathbf{h}$, where $\mathbf{R}$ is the vector from the middle of the loop to the point on the loop and $\mathbf{h}$ is the vector from the little dipole to the middle of the loop. We determine

$$\Phi = \oint_{\partial S} \mathbf{A} \cdot \mathrm{d}\mathbf{l} = \frac{\mu_0}{4\pi r^3}\oint_{\partial S} \mathbf{m} \times (\mathbf{R} + \mathbf{h}) \cdot \mathrm{d}\mathbf{l}\,.$$

In front of the integral, we put the total distance r of the little dipole from the point on the loop, because it is approximately the same for every point of the loop. Since $\mathbf{m} \perp \mathbf{R}$ and $\mathbf{m} \parallel \mathbf{h}$, we receive

$$\Phi = \frac{\mu_0}{4\pi r^3} \oint_{\partial S} mR \,\mathrm{d}l = \frac{\mu_0}{4\pi r^3} \cdot 2\pi R \cdot mR = \frac{\mu_0 m R^2}{2r^3} = \frac{\mu_0 m R^2}{2(R^2 + h^2)^{\frac{3}{2}}}.$$

Now, let us consider time dependence $h = h_0 \cos(\omega t)$. For the induced voltage U, we receive

$$U = -\frac{\mathrm{d}\Phi}{\mathrm{d}t} = -\frac{\mu_0 m R^2}{2} \frac{\mathrm{d}}{\mathrm{d}t} (R^2 + h^2)^{-\frac{3}{2}}.$$

Taking the derivative

$$U = \frac{3\mu_0 m R^2}{4} (R^2 + h^2)^{-\frac{5}{2}} \cdot 2h \frac{\mathrm{d}h}{\mathrm{d}t}.$$

Substituting $h = h_0 \cos(\omega t)$ and $\frac{\mathrm{d}h}{\mathrm{d}t} = -h_0 \omega \sin(\omega t)$

$$U = -\frac{3\mu_0 m R^2}{2} (R^2 + h_0^2 \cos^2(\omega t))^{-\frac{5}{2}} h_0^2 \omega \cos(\omega t) \sin(\omega t).$$

Now we use the trigonometric identities $\cos(2x) = 2\cos^2 x - 1$ and $\sin(2x) = 2 \sin x \cos x$ to rewrite

$$U = -\frac{3\mu_0 m \omega R^2 h_0^2}{4} \left(R^2 + \frac{h_0^2}{2} (1 + \cos(2\omega t)) \right)^{-\frac{5}{2}} \sin(2\omega t).$$

From the assignment, it is evident that $h_0 \ll R$. So let us develop the result to a Taylor expansion for $\varepsilon = h_0/R$ and omit terms of ε^4 and higher

$$U \approx -\frac{3\mu_0 m \omega \varepsilon^2}{4R} \left(1 - \frac{5\varepsilon^2}{4} (1 + \cos(2\omega t)) \right) \sin(2\omega t).$$

Since h_0 is three orders of magnitude less than R, additional terms will have no effect on the solution given (in accordance with the assignment) with precision to two significant figures. For the amplitude of voltage U_0, we can get the final result

$$U_0 \approx \frac{3\mu_0 m \omega h_0^2}{4R^3} = \frac{3\pi \mu_0 m f h_0^2}{2R^3} \approx 5.9 \text{ mV}.$$

Conclusion

The Fyziklani 2025 had wide diversity within physics areas. From optimising household appliance use to calculating orbital mechanics and comparing energy sources of civilisational importance, these problems reveal physics as an interconnected discipline addressing real concerns.

Invitation to Fyziklani 2026

Upper secondary students are warmly invited to participate in **Fyziklani 2026**, the 20th edition of this celebrated competition, taking place on **13 February 2026 in Prague**. Teams of up to five secondary school students compete in a three-hour problem-solving marathon alongside a rich programme of lectures, excursions, and informal scientific discussions.

Registration is now open and remains available until **6 February 2026, 23:59 CET**. For detailed information, rules, and registration, visit https://fyziklani.org. Nearly 1,200 participants from more than ten countries competed in 2025; this year promises an even more vibrant gathering of young physicists.

Join the largest physics team competition in Europe held in one place, and discover why hundreds of students return year after year to celebrate their passion for understanding the natural world!