

## Physics Olympiad Errata

This file lists all the errors in Physics Olympiad solutions that I am aware of. Even at the international level, solutions files have more errors than one would think. People can spend a lot of time searching for a mistake in their work, when in fact it's the official solution that is wrong. My hope is that having all the errors in one place will make it easier for students to go through the problems by themselves.

All problems and solutions can be found in my [archives](#).

### IPhO

For reference, I still haven't checked the papers from 2019, 2008, 2005 and everything before that.

- (1) **2011 1.3** This part of the problem is wrong because the equilibrium about the Lagrange point in question is unstable. You can see this by considering the force on a stationary object displaced radially from the Lagrange point by a little bit (in the reference frame of the rotating objects). You will find that this force points away from the Lagrange point. The additional assumption of constant angular momentum is both false and redundant. See this [article](#) by Jaan Kalda for a detailed analysis.
- (2) **2014 2B.8** The value for the surface tension is  $\sigma = 0.12 \text{ N/m}$  (without the  $10^{-2}$ ).
- (3) **2017 2B.1** Depending on how you measure the arrival time, your answers in the next two parts may diverge significantly from those in the original solutions. So, to be explicit – assume the arrival of the P-wave corresponds to the instant when the seismometer reading becomes nonzero.
- (4) **2017 2B.2** Another comment – do not take any additional measurements for this part. Use only your results from **B1**.
- (5) **2017 2B.3** And yet another clarification – assume that the first signal to arrive at DNP is indeed due to the wave travelling through the mantle.
- (6) **2017 2B.4** The original solution is incomplete. We need to take the upper limit of the integral for  $X$ , and only then do we find  $X = \frac{2}{ap} \sqrt{1 - (pv_0)^2}$ .
- (7) **2017 2B.6** The result of this calculation is very sensitive to the denominators, and the original solution hasn't been careful with this. I get  $T = 184.1 \text{ s}$ .
- (8) **2017 2C.1** To make the problem statement less vague, you are being asked to find the potential energy of the slab of height  $h$  with respect to the ocean level.
- (9) **2017 3B.1/3B.2** These two parts of the problem are wrong, do not attempt them. They expect you to work with a nonzero  $k$  and make use of the scale factor's time dependence from **A4**. But that was obtained using  $k = 0$ !
- (10) **2017 3B.3** The “condition for inflation” you are expected to use is  $w = -1$ , not anything that comes later in the text.
- (11) **2017 3D.2** To be a bit more rigorous than the official solution, the observational constraints are  $-5.19 > n > -6.69$  and  $n > -1.81$ , and these cannot be satisfied simultaneously.
- (12) **2022 2C** The model used here isn't self-consistent (as discussed in the solutions), and I think it's impossible to figure out what you are supposed to do if you are attempting the problem on your own. The rest of the problem is really nice.

**EuPhO**

Nothing here yet!

**APhO**

- (13) **2003 2A** The solution is incorrect because it doesn't account for the relativistic correction on the speed of light in a moving medium, which is of order  $\Omega R/c$  too. This is the same correction as the one in Fizeau's experiment (for that, see [Wikipedia](#) or IZhO 2018.3). The final result should be  $\Delta t = \frac{4\pi R^2 \Omega}{c^2}$  as per this [paper](#) – the refractive index doesn't matter.
- (14) **2003 2B**  $\Delta L = c' \Delta t$  is not the correct expression for the optical path difference. The OPD is what you multiply by the wavevector in vacuum  $k$  to get the phase difference  $\Delta \phi$ , so

$$\Delta \phi = \omega \Delta t = k \Delta L \quad \Rightarrow \quad \Delta L = \frac{\omega}{k} \Delta t = c \Delta t.$$

Then in the next part we have  $\Delta L = 3.0 \times 10^{-12}$  m. After that we obtain

$$\Delta \theta = N \omega \Delta t = \frac{8\pi^2 R^2 N \Omega}{c \lambda}.$$

?

- (15) **2015 2C** The ratio of the magnetic fields is 0.3, not 1.0.
- (16) **2015 2D.ii** The inequality should go the other way,  $\theta_{\text{cr}} \leq \arcsin \left( \sqrt{\frac{B_0}{B_m}} \right)$ .

**IZhO**

I've done everything up to 2011 except for some tedious problems that I don't recommend. These are **2017 3**, **2016 3**, **2015 2**, **2013 3**, **2012 3**. There are also some problems where the graphs are missing, so these can't be worked through: **2012 1.2**, **2015 1**, **2017 1.3**.

- (17) **2010 3** There's a nasty typo in the data: the mass of the  $\Delta$  baryon is  $m_\Delta = 1232 \text{ MeV}/c^2$ . Also, note that the solution is available only in Russian.
- (18) **2010 3.3a** You're asked to find the energy of the proton, but the solution gives you the energy of the photon instead. For the proton, you should have

$$E_p = \left( \frac{m_p^2 + m_\Delta^2}{2m_\Delta} \right) c^2 = 973 \text{ MeV}.$$

- (19) **2010 3.4** The momentum of the  $\pi$  meson in the zero-momentum frame is  $q_\pi = 227 \text{ MeV}$  (there's no additional  $10^6$  factor).
- (20) **2010 3.4** The solution works interchangeably with  $E^{\text{max}} = 7 \times 10^{20} \text{ eV}$  and  $E_p^{\text{max}} = 10^{21} \text{ eV}$ . Don't do that, use only the former value! In that case, the momentum of the  $\pi$  meson is  $p_{\pi 1} = 3 \times 10^{20} \text{ eV}/c$  if it comes out parallel to the initial proton, and  $p_{\pi 2} = 2 \times 10^{19} \text{ eV}/c$  if it comes out antiparallel. The changes in the magnitude of the proton's momentum are then  $\Delta p_{p1} = -p_{\pi 1}$  and  $\Delta p_{p2} = +p_{\pi 2}$ .

?

- (21) **2010 3.6** The solution is wrong, there is no lower bound on the momentum of the photon, given that high-energy protons can allow for any reaction (the optimal case is  $E_p \rightarrow \infty$ , not  $E_p = m_p$  as they say).
- (22) **2011 1.1** When solving this, you are supposed to take it for granted that it's easiest for the cube to jump up when the puck is at its highest point. However, proving this seems quite difficult.

- (23) **2012 2.2** I don't recommend this problem since its assumptions are shaky. To clarify, the problem statement implies that the change in the internal energy of the gas under the piston is one half of the sum of the gravitational potential energy decrease and the work done by the atmosphere.
- (24) **2012 2.9** I believe that the solution is wrong here. Either the molecular flux statement or the energy conservation statement needs to have the right hand side reversed. This is because the flux equation assumes that the piston is descending with speed  $u$ , while the energy equation assumes it's ascending with speed  $u$ . Following the correction, I get  $T_3 = 44$  K (suspicious). ?
- (25) **2013 1.3.1** All the calculations are wrong after a certain point. The correct values are  $\beta = 30.7^\circ$ ,  $\alpha - \beta = 24.1^\circ$ ,  $|AO| = 0.82$  mm,  $|OF| = 0.37$  mm,  $|DF| = 0.79$  mm,  $|EO| = 0.58$  mm. Their drawing is qualitatively correct, but the dimensions will need changing.
- (26) **2013 1.3.2** In spite of the above, their value for the exit angle  $\gamma$  is still correct. However, the small triangles projected on the screen should point outwards rather than inwards.
- (27) **2014 1.1** The numerical value for the efficiency is  $\eta = 0.53\%$ .
- (28) **2014 1.2** There's a typo in the final answer for  $Q$  in the second solution. The answer in the first solution is fine.
- (29) **2014 2.6** Note that the maximum height includes the ascent following the exhaustion of the fuel. I don't think that the answer is obvious like they claim in the solution. It's better to get a general answer for  $H$  in terms of  $\mu$ , and then analyse.
- (30) **2014 2.9** The answer is  $m_0 = 10^{14.317}$  kg.
- (31) **2016 2.3.3** The equation should be written down only in terms of  $h_0$ ,  $\alpha$ , and  $R$ .
- (32) **2016 2.3.4** To make the problem statement more concrete, assume that the height of the tube is almost equal to  $R/\tan\alpha$ . This will guarantee the existence of equilibrium configurations (for appropriate values of  $\alpha$ ).
- (33) **2017 1.2** Their equations are correct, but the final answer for the charge should be

$$q = 32\pi\sqrt{\frac{6}{11}\sigma\epsilon_0 R_1^3}.$$

- (34) **2018 3.2.4** The numerical answer in the marking scheme is wrong. The one in the solution is correct.
- (35) **2018 3.3.2** Using the same approach (switching to the rest frame of the flow, using Snell's law there, and then switching back), I find

$$\sin\beta = \frac{\sin\alpha}{n} + \frac{v}{c} \left( \frac{n^2 - 1}{n} \right),$$

implying a constant offset  $B_1 = \frac{n^2-1}{cn}$ . I got the same result using the formulae on this [site](#). Then **3.3.3** would be wrong as well. The final two tasks are fine. ?

- (36) **2020 1.1** I don't think it's allowed to use noninertial frames the way they do. My answer is

$$\varepsilon = +\frac{\omega_1^2 r_2}{g_0} \left( \frac{r_1}{r_2} \right)^2 = 1.5 \times 10^{-7}.$$

I found this by comparing the tension forces on a pendulum in equilibrium at midday and at midnight. The tension, summed with the Earth's and the Sun's gravitational forces, should equal the centripetal force for the pendulum bob's trajectory around the Sun. I made use of  $\frac{r_1}{r_2} \ll \frac{\omega_1 r_1}{\omega_2 r_2} \ll 1$ . I'm not sure about my answer, but certainly one should get something that depends on  $\omega_1$ . ?

- (37) **2020 1.3.1** The thickness of the border of the triangle should be  $\Delta r = 2r_1 = 2 \text{ mm}$ .
- (38) **2020 1.3.2** The thickness of the border of the star should be  $\Delta r = 3r_2 = 0.3 \text{ mm}$ .
- (39) **2021 1.1** The formulae for the frequencies are correct, but the values should be  $\omega_1 = 6.14 \text{ rad/s}$  and  $\omega_2 = 10.20 \text{ rad/s}$ .
- (40) **2022 1.3** The final answer should be

$$Q = \frac{8\sqrt{2}\varepsilon_0 mg}{\sigma}.$$

In going from equation 5 to equation 6, they've missed an extra factor of  $\cos \beta$ . This means you will need to find  $\int_{-\pi/2}^{\pi/2} \cos^2 \beta \, d\beta$  rather than  $\int_{-\pi/2}^{\pi/2} \cos \beta \, d\beta$ .

- (41) **2022 2.9** The answer for  $\alpha$  in the marking scheme is wrong. The solution has the right one,  $\alpha = 0.014 \text{ K}^{-1}$ .
- (42) **2022 3.6** The calculation is off by a hundred; The time is  $\tau = 1.27 \times 10^{10} \text{ s}$ .
- (43) **2023 3.9** There is a typo in the formula for  $T$ . We should have  $T \ll \frac{eV_0}{k_B} = 8.70 \times 10^5 \text{ K}$ .
- (44) **2024 2** The radius of the Earth's orbit is missing its units,  $R_0 = 1.5 \times 10^8 \text{ km}$ .

## USAPhO

I'm only collecting errors from before 2007. The solutions of the papers from 2008 and onwards are still maintained, and their most recent versions can be found [here](#). If you spot an error in those, email [Kevin Zhou](#).

- (45) **1997 B1** In part E, the assumption that there's no induced field on the axis of symmetry is unphysical. The electrons rotating at any given radius are like the current in a solenoid, meaning that a layer of plasma at  $r_0$  produces a homogeneous field for  $r < r_0$ , whilst its contribution for  $r > r_0$  is zero. To obtain  $\mathbf{B}(r)$ , you should use Ampère's law for a rectangular loop between  $r$  and  $R$ , and the answer is  $\mathbf{B}(r) = -\mu_0 en_0 \omega \frac{R^2 - r^2}{2} \hat{\mathbf{k}}$ . For part F, it follows that  $\frac{F_{\text{mag}}}{F_{\text{el}}} = \frac{v^2(R) - v^2(r)}{c^2}$ .
- (46) **1998 B2** In part A, the number of protons is  $Z = 56$ . In the original solution they plug in  $r_1 = r_{\text{max}}$ , but in reality  $r_1 = r_{\text{max}}/\beta$ . This error propagates to part B, where I get  $\lambda = 5.8 \times 10^{-9} \text{ m}$ .
- (47) **2006 B1** In part B(ii), the equation for  $y(t)$  should be

$$y(t) = \frac{mgL}{(BX)^2} \left( 1 - \cos \left( \frac{BX}{\sqrt{mL}} t \right) \right).$$

The height  $D$  doesn't have anything to do with it.

- (48) **2006 B1** There are multiple answers for part B(v):

$$t = (2n + 1) \frac{\pi \sqrt{mL}}{BX}, \quad n \geq 0.$$

- (49) **2007 B2** To clarify, in part A(iii) you're being asked to find the time-averaged magnetic field. The instantaneous magnetic field has a different form, which can be obtained using the Biot-Savart law for a single charge  $-e$  moving with speed  $\omega_0 R$ . This would correspond to a magnitude  $B_e = \frac{\mu_0 e \omega_0 R}{4\pi(R^2 + z^2)}$ , akin to a monopole rather than a dipole.
- (50) **2007 B2** Parts B(iii) and B(iv) are wrong, because the EMF must depend on the time interval  $\Delta t$  when switching on the magnetic field. If this is done at a constant rate, we have  $\mathcal{E} = -\frac{B_0}{\Delta t} \pi R^2$ , but then the next part of the problem wouldn't make any sense. The original solution follows the unfounded assumption that  $\Delta t$  equals exactly one orbital period of the electron.

**NBPhO**

- (51) **2024 6D** In Solution 4, the radial component of the normal force is not  $\frac{mv_{\perp}^2}{r}$ . The normal force  $N$  balances the normal component of the centrifugal force, so  $N = \frac{mv_{\perp}^2}{r} \cos \theta$ . We plug this into  $N \sin \theta = m\dot{v}_{\parallel} \cos \theta$  (from Solution 3) to find  $\dot{v}_{\parallel} = \frac{v_{\perp}^2}{r} \sin \theta$ . You can follow the official solution after that, but note that the final integral doesn't have anything to do with the area of a circle. That would be  $\int_0^1 \sqrt{1-u^2} du$ , which evaluates to  $\pi/4$ , not  $\pi/2$ .

**InPhO**

- (52) **2014 7E** One of the terms in  $\beta$  has an extra factor of  $5/3$ :

$$\beta = \frac{1 + f^{1/3} + (5/3)f + f^2 + f^{5/3}}{(1 + f)^{5/3}(1 + f^{1/3})}.$$

**Contributing to the list**

There are many errors missing from this file, and a single person can't hunt all of them down. This is where I ask for your help! If you have found an error, please [email](#) me so that I can add it to the list. Borrowing [Donald Knuth's](#) idea, I will award physics money (i.e. Joules) for your troubles, as follows:

- **Clarifications.** Worth 5 J. If you think that a problem statement is too ambiguous for someone to get the problem right the first time around, I can try to tidy it up here. Be explicit in what it was that had you confused.
- **Verifications.** Worth 10 J. There are some errors here that I am not certain about. I've marked them with a ?. I'd like someone else to double-check those. Message me with the number of the error (e.g. (17)) and attach some working which supports or disproves what's written down in the list. It doesn't have to be neat, just legible.
- **Wrong solutions.** Worth 10 J. Some problems are correctly stated, but there are major issues with their solutions. What I count as an error is something which leads to a wrong final answer, either in the formula or in the numerical value. For example, a minus which disappears in one line of the solution but reappears in the next is fine with me – this sort of typo is quite common and not too harsh on the reader. Should you notice a significant error, please:
  1. Explain why the official solution is wrong.
  2. Show me what the correct answer is.
- **Wrong problems.** Worth 15 J. Occasionally there are problems which are so wrong that one cannot patch up the solution and call it a day. One way this can happen is when a problem author forgets about a key physical effect, and the setup actually does things which are completely different from what the problem statement hints at (e.g. instability instead of oscillations). If you think a problem is wrong, please outline why. There should be enough detail so as to convince a fellow student aiming for IPhO.

Keep in mind that I am only tracking the competitions listed above, that is, IPhO, EuPhO, APhO, IZhO, USAPhO, NBPhO, and InPhO. If maintaining the file proves easy enough, I might include a few more in the future.

**Energy balance**

Additions to the list are tracked and credited. If you want to stay anonymous, that's alright too!

Teo Kai Wen .....	30 J
▷ ( <a href="#">45</a> ), ( <a href="#">49</a> ), ( <a href="#">50</a> )	
Atanas Gochev .....	10 J
▷ ( <a href="#">47</a> )	
Eppu Leinonen .....	10 J
▷ ( <a href="#">51</a> )	
Alex Prodanov .....	5 J
▷ ( <a href="#">36</a> )	