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 have checked all the papers up to 1991, except for 2019.

(1) 1971 1B Equation (13) should be corrected to

$$-m_2 a \sin\alpha_2 = T\sin\alpha_2 + R_2\cos\alpha_2 - m_2 g.$$

Everything that follows is alright, though they've missed a g in the answer for a_0.

(2) 1991 2A Equation (4) in the solution should read $a_{\mathrm{AB}} = \frac{\sqrt{1-(v/c)^2}}{1+(uv/c^2)}a$.

(3) 1992 1 This is an instructive problem on tidal forces, but its wording is a bit too vague. I suggest that you use the following improved versions of the problem statement and the solution, edited by Teo Kai Wen. You'll still need the original solution for reference though. I've uploaded it here.

(4) 1993 1.4 This is a real-world problem for which I don't think the assumptions are made clear enough. Firstly, you'll need to assume that the field right above the quadrants always remains equal to E_0 (say, due to continuity, as derived from $\oint \mathbf{E}\cdot \mathrm{d}\mathbf{l} = 0$). This should come above all other considerations.

(5) 1993 1.5 The crux of the problem is what happens to the charge on q_l the lower surface of the insulated quadrants – after all, the total charge on the quadrants that accumulates through the capacitor and the resistor is actually $q + q_l$. To resolve this issue more easily, you can assume that the ground is quite close to the quadrants, at a distance $l \ll r_2$. See below for more details. Spoiler warning.

Consider a line integral of the electric field $\mathbf{E}$ in the air, starting from the lower surface and ending at the ground. This gives us $V = \int_{\text{lower}}^{\text{ground}} \mathbf{E}\cdot \mathrm{d}\mathbf{l}$. As you can see from the diagram, the ground is in close proximity (it's the ring around the rod), so from Gauss's law $E \approx q_l/(\varepsilon_0 S_{\text{quadr}})$ and $V \approx El$, where l is some characteristic distance. Notice that $\varepsilon_0 S_{\text{quadr}}/l$ can be used as an order-of-magnitude estimate for the capacitance of the quadrant system C_{s} when you take out R and C and all that. Therefore $V = q_l/C_{\mathrm{s}}$, and since we're told that C_{s} is small, we can conclude that $q_l \approx 0$. ?

(6) 1994 3.1 The minus sign on the right hand side of Equation (5) in the solution should be a plus. No errors after that.

(7) 1995 1C.2 They've made an error when converting the units for the rest mass. The numerical answer ought to be $\Delta f/f_0 = 5.44 \times 10^{-9}$.

(8) 1998 3F Referring to the notation of Figure 3.2, the correct formula to use for the Doppler shift is $\lambda = \lambda_0\gamma(1+\beta\cos\phi)$. But this doesn't change the final answer.

(9) 2000 3B I think this warrants a clarification; here ω is the lowest permitted angular frequency of a longitudinal standing wave in the rod, given the boundary conditions.

(10) 2000 3D For this part and the next, assume that Δg is directed along one of the rods.

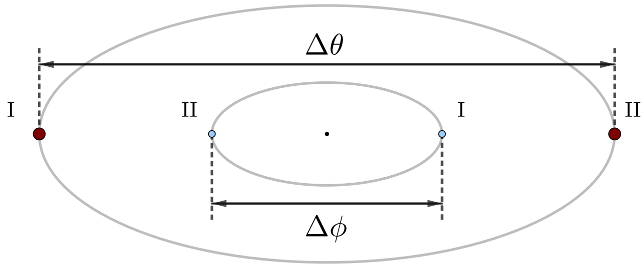
(11) 2000 3E I believe they mean that the minimum detectable optical path difference is 10^{-4} of the laser's wavelength. In that case, a displacement Δl in one rod brings about an OPD of $2\Delta l$ because the light goes back and forth. The answer should therefore be twice as large. $\boxed{?}$

(12) 2000 3F There's no official solution. My answer is $\sqrt{300/0.1} = 55$, which I got through some handwaving with energy scales, as in $kA^2 \sim mv^2 \sim k_B T$. $\boxed{?}$

(13) 2000 3G No official solution again. The answer should be, hopefully in clear enough notation,

$$\tau = \frac{m s_i T_i}{4P}\left(1 - \left(\frac{T_f}{T_i}\right)^4\right) = 25\,\mathrm{h}.$$

(14) 2001 2A You'll also need to assume that the orbits are circular and tilted with respect to the line of sight. A better diagram for how the orbits are projected on the night sky would be as follows:



(15) 2001 2A To put it another way, they're telling you that the time interval between betweeen configurations I and II is equal to τ.

(16) 2001 2B Both the problem statement and the solution are incoherent. Here's a rewrite...

> In what follows, assume that $M \gg m_0$ and denote the radius of the ordinary star's orbit with respect to the neutron star by r_0. The ordinary star ejects a blob of gas. In the reference frame of the ordinary star, the velocity of the gas outflow is directed towards the neutron star and is equal to v_0. Find the distance of closest approach r_f between the gas blob and the neutron star. Neglect the gravitational influence of the ordinary star.

The answer that I get is $r_f = \frac{r_0}{1+v_0\sqrt{r_0/GM}}$.

(17) 2003 1C The answer for α_c in the marking scheme should be to the power of -1, just like in the solution.

(18) 2004 3A There is a minor typo in the expression for $\tan\phi$ in the answers section. The correct answer is $\tan\phi = \frac{b\omega}{m(\omega_0^2-\omega^2)}$, as derived in the detailed solutions.

(19) 2005 2.7 Read Footnote 2 as "When you're calculating the force on the coils, you can neglect the misalignment between their axes."

(20) 2008 1.3.1 Note that in this subpart you are allowed to approximate. In particular, when you're computing the moment of inertia of the water, you should consider it as a point mass.

(21) 2009 2.3D The expression for $\varepsilon_{\mathrm{at}}$ is incorrect, you should instead find that $\varepsilon_{\mathrm{at}} = \frac{mv^2}{2}\left(1 - 4\frac{\hbar q}{mv}\right)$. This error propagates throughout the rest of the problem. Here are the rest of the answers that need corrections. In **4C**, $\varepsilon_{\mathrm{at}}^- = \frac{mv^2}{2}\left(1 - 2\frac{\hbar q}{mv}\right)$. In **5A**, $\Delta\varepsilon = -\hbar\omega_L\frac{v}{c}$. In **6A**, $\Delta\varepsilon = +\hbar\omega_L'\frac{v}{c}$.

(22) **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.

(23) **2014 2B.8** The value for the surface tension is $\sigma = 0.12\,\mathrm{N/m}$ (without the 10^{-2}).

(24) **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.

(25) **2017 2B.2** Another comment – do not take any additional measurements for this part. Use only your results from **B1**.

(26) **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.

(27) **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 $X = \frac{2}{ap}\sqrt{1-(pv_0)^2}$.

(28) **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 $T = 184.1\,\mathrm{s}$.

(29) **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.

(30) **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 $k = 0$!

(31) **2017 3B.3** The "condition for inflation" you are expected to use is $w = -1$, not anything that comes later in the text.

(32) **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.

(33) **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

(34) **2024 3B** There are a few typos in the intermediate calculations in Solution 1. It should read:

$$(|r|^2 + |t|^2)^2 = |r|^4 + |t|^4 + 2|r|^2|t|^2 = 1$$

$$\implies -2|r|^2|t|^2 = r^2t^{*2} + r^{*2}t^2.$$

And "This is equivalent to $(rt^* + r^*t)^2 = 0$". The rest is fine.

(35) **2024 3B** Solution 4 is alright conceptually, but the energy fluxes I_{in} and I_{out} have not been computed correctly – after all, we want to obtain $\sin(\pi + 2(\theta - \psi)) = 0$ instead of $\cos(\pi + 2(\theta - \psi)) = 0$. Unfortunately, the calculations turn out to be quite tedious.

APhO

(36) 2001 2.1 We aren't told anything about the plane of rotation in this part of the problem, so for now you should stay agnostic about the expression for the angular momentum about the CM – just write $\mathbf{L}_{\text{rot}}$ instead of $I\omega$.

(37) 2002 1 There's a typesetting error in the solution. Any time you see a "_" there, keep in mind that it stands for $\frac{1}{2}$.

(38) 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.

(39) 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

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

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

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

(40) 2003 3E You need to assume that the plasma slab is a cylinder coaxial with the electron beam. You'll also have to take it on trust that after a long time, all the electrons in the plasma get blown out, while the ions stay in place (this isn't immediately obvious, but it's an experimental fact). Note that most of the solution is redundant, you only care about the expression for the force on an ion.

(41) 2010 1Ab.i I think that the phrase 'only vibrational and rotational motions can be excited' should be disregarded because it hints at an elastic collision, which is not what happens in the original solution. In fact, I don't think that an elastic collision can even occur within this toy model, because the immediate response of the pivoted spring is inevitably associated with some heat losses (imagine the same situation if there was a rigid rod instead of a spring).

(42) 2010 1Ab.i In order for your solution to match that of the problem author, you need to think of Q as the energy stored in the oscillator after the collision. Note that this Q doesn't have that much in common with the Q of part (a).

(43) 2011 2G There's a factor-of-two error when substituting κ right at the end. The correct formula for Ω doesn't have a 2 in the numerator. It should evaluate to $5.61 \times 10^{-3}\,\text{s}^{-1}$.

(44) 2015 2C The ratio of the magnetic fields is 0.3, not 1.0.

(45) 2015 2D.ii The inequality should go the other way, $\theta_{\text{cr}} \leq \arcsin\left(\sqrt{\frac{B_0}{B_m}}\right)$.

(46) 2019 2A.8 They haven't evaluated the integral correctly. I get $F_{\text{Pr}} = 7.55 \times 10^{26}\,\text{N}$. Then, the answer to A.9 is 152 %.

(47) 2019 2C.1 The $\sin\phi$ factor in the cross product is redundant, and thus $\Omega = \frac{eB}{\gamma m}$.

(48) 2019 2C.2 The beam makes an angle ϕ to the rotation axis, so it doesn't just sweep a great circle on the celestial sphere. The beam will subtend an angle of $\frac{2}{\gamma \sin\phi}$ as seen from the rotation axis (not the origin!), and so $\Delta t = \frac{2}{\gamma\Omega\sin\phi}$. The rest of the solution is fine.

(49) 2019 2D.2 The original solution is flawed because the power law distribution isn't actually unbounded (i.e. from 0 to ∞). Instead, we should consider the following. The particles that end up in $[\varepsilon,\, \varepsilon+\mathrm{d}\varepsilon]$ after the expansion originate from the range $\left[\varepsilon\left(\frac{V}{V_0}\right)^{1/3},\, (\varepsilon+\mathrm{d}\varepsilon)\left(\frac{V}{V_0}\right)^{1/3}\right]$. The number of particles there is

$$V_0 f_0\left(\varepsilon\left(\frac{V}{V_0}\right)^{1/3}\right)\mathrm{d}\varepsilon\left(\frac{V}{V_0}\right)^{1/3}.$$

We can obtain $f(\varepsilon)\mathrm{d}\varepsilon$ through dividing this by V. The result is

$$f(\varepsilon)=\left(\frac{V}{V_0}\right)^{-\frac{2+p}{3}}\kappa_0\varepsilon^{-p}.$$

(50) **2024 2B.2** The unofficial Russian solution that I've linked in my archives doesn't cover this part correctly. The moments of occultation for A and B in the right panel of the figure differ by $\Delta t = 25\,\mathrm{s}$. We also measure that, upon touching A, the lunar limb needs to shift by an extra 8 mm horizontally to reach B. That distance corresponds to $\omega_{\mathrm{M}}\Delta t = 14'$. Meanwhile, the two sources are separated by 19 mm, so the angular distance between them should be about $33'$.

IZhO

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

(51) **2010 3** There's a nasty typo in the data: the mass of the Δ baryon is $m_\Delta = 1232\,\mathrm{MeV/c^2}$. Also, note that the solution is available only in Russian.

(52) **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

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

(53) **2010 3.4** The momentum of the π meson in the zero-momentum frame is $q_\pi = 227\,\mathrm{MeV}$ (there's no additional 10^6 factor).

(54) **2010 3.4** The solution works interchangeably with $E^{\max} = 7\times 10^{20}\,\mathrm{eV}$ and $E_p^{\max} = 10^{21}\,\mathrm{eV}$. Don't do that, use only the former value! In that case, the momentum of the π meson is $p_{\pi 1} = 3\times 10^{20}\,\mathrm{eV/c}$ if it comes out parallel to the initial proton, and $p_{\pi 2} = 2\times 10^{19}\,\mathrm{eV/c}$ if it comes out antiparallel. The changes in the magnitude of the proton's momentum are then $\Delta p_{p1} = -p_{\pi 1}$ and $\Delta p_{p_2} = +p_{\pi 2}$. ?

(55) **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 $E_p \to \infty$, not $E_p = m_p$ as they say).

(56) **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.

(57) **2011 1.1** There shouldn't be a w^2 term when applying energy conservation, only the $(u-w)^2$ is relevant. The equations following this are fine.

(58) **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.

(59) **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 $T_3 = 44\,\mathrm{K}$ (suspicious). $\boxed{?}$

(60) **2013 1.3.1** All the calculations are wrong after a certain point. The correct values are $\beta = 30.7°$, $\alpha - \beta = 24.1°$, $|AO| = 0.82\,\mathrm{mm}$, $|OF| = 0.37\,\mathrm{mm}$, $|DF| = 0.79\,\mathrm{mm}$, $|EO| = 0.58\,\mathrm{mm}$. Their drawing is qualitatively correct, but the dimensions will need changing.

(61) **2013 1.3.2** In spite of the above, their value for the exit angle γ is still correct. However, the small triangles projected on the screen should point outwards rather than inwards.

(62) **2014 1.1** The numerical value for the efficiency is $\eta = 0.53\,\%$.

(63) **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.

(64) **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 μ, and then analyse.

(65) **2014 2.9** The answer is $m_0 = 10^{14\,317}\,\mathrm{kg}$.

(66) **2016 2.3.3** The equation should be written down only in terms of h_0, α, and R.

(67) **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 α).

(68) **2016 3.7** Just as a warning, the solution here involves drawing a tangent, which can possibly lead to large deviations in your numerical values.

(69) **2017 1.2** Their equations are correct, but the final answer for the charge should be

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

(70) **2018 3.2.4** The numerical answer in the marking scheme is wrong. The one in the solution is correct.

(71) **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. $\boxed{?}$

(72) **2020 1.1** The main idea here is to compare the tension forces in equilibrium at midday and midnight. It is precisely these forces that determine the period of the pendulum. The original solution is correct, but it's also incomprehensible. Noninertial frames are tricky, and they haven't talked about the Coriolis force at all. I'd advise you to instead work in an inertial frame and follow the approach in IPhO 1992.1. However, in this problem you need to write down the expression for the tidal force to second order, because the first order terms will cancel out, implying $\varepsilon = 0$.

(73) **2020 1.3.1** The thickness of the border of the triangle should be $\Delta r = 2r_1 = 2\,\mathrm{mm}$.

(74) 2020 1.3.2 The thickness of the border of the star should be $\Delta r = 3r_2 = 0.3\,\mathrm{mm}$.

(75) 2021 1.1 The formulae for the frequencies are correct, but the values should be $\omega_1 = 6.14\,\mathrm{rad/s}$ and $\omega_2 = 10.20\,\mathrm{rad/s}$.

(76) 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 $\int_{-\pi/2}^{\pi/2}\cos^2\beta\,\mathrm{d}\beta$ rather than $\int_{-\pi/2}^{\pi/2}\cos\beta\,\mathrm{d}\beta$.

(77) 2022 2.9 The answer for α in the marking scheme is wrong. The solution has the right one, $\alpha = 0.014\,\mathrm{K}^{-1}$.

(78) 2022 3.6 The calculation is off by a hundred; The time is $\tau = 1.27\times10^{10}\,\mathrm{s}$.

(79) 2023 3.9 There is a typo in the formula for T. We should have $T \ll \frac{eV_0}{k_B} = 8.70\times10^5\,\mathrm{K}$.

(80) 2024 2 The radius of the Earth's orbit is missing its units, $R_0 = 1.5\times10^8\,\mathrm{km}$.

(81) 2025 1.1 The problem statement is too vague. You're supposed to work in an approximation where the Moon is on a circular orbit around a static Earth. Treat the approach to the Moon in two stages. Initially you're only under the gravitational influence of the Earth. And when you're about to cross the lunar orbit, you're only influenced by the Moon.

(82) 2025 1.1 The solution is wrong because it doesn't account for conservation of angular momentum, which makes it impossible to approach the Moon exactly head-on. Instead, the maximum velocity will be obtained when we launch the spacecraft such that it grazes the Earth. The tangential velocity of the spacecraft near the lunar orbit is $v_\tau = v_{2E}(R_E/r)$, while the normal velocity is $(u^2 - v_\tau^2)^{1/2}$. Hence, it approaches the Moon with a velocity of

$$V_{\max} = \sqrt{(v_M + v_\tau)^2 + (u^2 - v_\tau^2)} = \sqrt{3v_M^2 + 2v_M v_\tau}.$$

This leads to $v_{\max} = \left(V_{\max}^2 + v_{2M}^2\right)^{1/2} = 3.05\,\mathrm{km/s}$. The minimum velocity can be obtained the same way, but this time the tangential velocity of the spacecraft is collinear with that of the Moon:

$$V_{\min} = \sqrt{(v_M - v_\tau)^2 + (u^2 - v_\tau^2)} = \sqrt{3v_M^2 - 2v_M v_\tau}.$$

The final answer is $v_{\min} = \left(V_{\min}^2 + v_{2M}^2\right)^{1/2} = 2.93\,\mathrm{km/s}$.

(83) 2025 2.7 Provided that the heat loss mechanism is related to heat condution, I believe that the expression for the power should be $P \propto R^1$. This is because $P \propto \kappa S\left(\frac{\mathrm{d}T}{\mathrm{d}r}\right)$, where S scales as R^2, but also $\mathrm{d}r$ scales as R. In that case, $\tau = \tau_0\left(\frac{R_E}{r_0}\right)^2 = 1.25\times10^{12}\,\mathrm{yr}$.

(84) 2025 2.10 There's a factor of $\frac{3}{4}$ missing from the final answer, and the corrected numerical value is $\Delta T = 2.36\times10^{-2}\,\mathrm{K}$.

(85) 2025 3.8 One subtle point that the solution glosses over is what happens when $z = 0$. There, the flux from the monopole changes sign, but the current in the loop stays the same nonetheless. This is because of a modification in Ampère's law in the presence of magnetic charges. See this note for more details.

(86) 2025 3.9 This is a bit unclear. They're asking you to find the current when $z = -\infty$.

(87) 2025 3.16 There's an $\hbar^2$ omitted from the final answer.

USAPhO

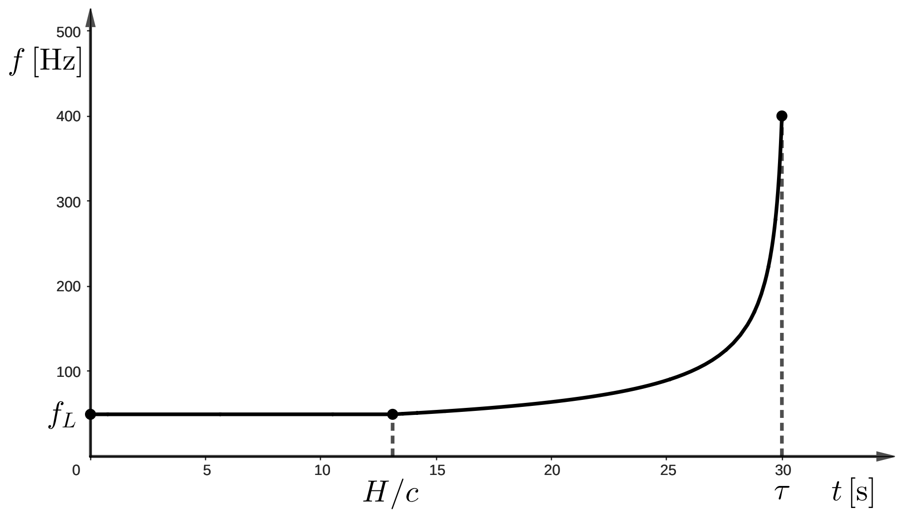
I'm only collecting errors from before 2007. The solutions of the papers from 2008 and onwards are still maintained, and their most recent versions can be found here. If you spot an error in those, email AAPT.

(88) **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 $\mathbf{B}(r) = -\mu_0 e n_0 \omega \frac{R^2 - r^2}{2}\hat{\mathbf{k}}$. For part F, it follows that $\frac{F_{\text{mag}}}{F_{\text{el}}} = \frac{v^2(R) - v^2(r)}{c^2}$.

(89) **1998 B1** The original solution to part **E** doesn't account for the finite travel time of sound. First, note that the height of the helicopter is $H = \frac{g\tau^2}{2} = 4500\,\text{m}$. Then, following the same approach as in 2008 A4, we should find that $f = f_L$ for $t < \frac{H}{c}$, and

$$f = \frac{f_L}{\sqrt{1 - \frac{2g}{c}\left(t - \frac{H}{c}\right)}} \qquad \text{for} \quad \tau \geq t \geq \frac{H}{c}.$$

The graph of the frequency should look like this:



(90) **1998 B2** In part **A**, the number of protons is $Z = 56$. In the original solution they plug in $r_1 = r_{\max}$, but in reality $r_1 = r_{\max}/\beta$. This error propagates to part **B**, where I get $\lambda = 5.8 \times 10^{-9}\,\text{m}$.

(91) **2004 B2** The answer in part **F** needs a sign change: $\Delta\mathbf{L}_{\text{EM}} = +\frac{1}{2}Q\mu_0 n I(b^2 - a^2)\hat{\mathbf{z}}$. Only then does it become apparent that the total angular momentum of the system is conserved.

(92) **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.

(93) **2006 B1** There are multiple answers for part **B(v)**:

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

(94) **2007 A2** There's a minor typo in the final answer for part **A(ii)**. The exponent is 3/5, not 5/3.

(95) **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. But note this is inaccurate anyway, because a single electron does not constitute a steady current, and so technically you're not allowed to use Biot-Savart. See the chapter on magnetostatics in Griffiths for more details.

(96) **2007 B2** Parts **B(iii)** and **B(iv)** are wrong, because the EMF must depend on the time interval Δt 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 Δt equals exactly one orbital period of the electron.

NBPhO

(97) **2005 5.3** There's a calculation error, you should get $\nu' \approx (5000 \pm 50)\,\text{kHz}$.

(98) **2007 3.1** The diagram is misleading, you'll need to change the $U(t)$ there to $-U(t)$. You can then interpret $U_B(t)$ and $U_C(t)$ from the problem statement as the voltage changes at B and C, respectively. The essence of the setup here is that the velocity of the electrons changes instantaneously at B and C. The segments BC and CD are covered with constant speed because time-dependent potentials can change without implying any force.

(99) **2007 3.4** Here you're given T, but you don't know explicitly what U_m is. Also assume that the period of the signal is $T > a\sqrt{\frac{m}{2eU_0}}$.

(100) **2007 3** The original solution is very terse and therefore difficult to understand. For part **3**, I also think it's wrong. I've rewritten the whole solution from scratch, see here.

(101) **2010 2** While the problem is nice and the solution is correct, I found it very, very difficult to understand. I've given the solution a complete rewrite here, which should hopefully make things easier. I've also fixed a minor typo in the answer to the second subpart.

(102) **2015 2.1** All that really matters is that the transparent rings give you constructive interference, so for an arbitrary offset α any answer along the lines of

$$r_m = \sqrt{((f+\alpha)+m\lambda)^2 - f^2}$$

is technically fine. If you want to follow the original solution, the first transparent ring there has an optical path difference of $\lambda/2$ with the centre. Label this ring with $m = 0$.

(103) **2015 2.3** The total duration of the pulse is

$$\tau = \frac{1}{c}\left(\sqrt{\left(\frac{d}{2}\right)^2 + f^2} - f\right) = 3.9 \times 10^{-11}\,\text{s}.$$

(104) **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

(105) 2014 7E One of the terms in β has an extra factor of 5/3:

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

GPhO

(106) 2019 2C When solving this, assume that the entropy change due to the ionisation is negligible. Then, all the work done by the external pressure goes towards raising the internal energy of an ideal gas.

(107) 2019 2C.3 The correct answer is $d = R$.

(108) 2019 2D.3 They've missed the factor of $\frac{3}{2}$ in the final answer, you should get $T_m = \frac{p_e}{6p_0}T_0$.

(109) 2019 2D.3 The procedure they use for finding r_m seems dubious to me. The process might be adiabatic, but it's still far from quasistatic, so $TV^{\gamma-1} = \text{const}$ is inappropriate here.

(110) 2022 2.2 You should assume that that the solar panels are evenly distributed across the surface of the Earth. Note that the solutions file compares the total area of the panels with the Persian Gulf rather than the Empty Quarter, but this is a minor inconvenience.

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 $\boxed{?}$. 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.

Keep in mind that I am only tracking the competitions listed above, that is, IPhO, EuPhO, APhO, IZhO, USAPhO, NBPhO, InPhO, and GPhO. I'm generally rather slow to reply, but still, you could send me a reminder if I haven't addressed your query within a month.

Energy balance

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

Teo Kai Wen .... 130 J
▷ (2), (3), (18), (21), (40), (41), (42), (43), (88), (95), (96), (102), (103), (106), (107), (108)
Smbat Poghosyan .... 20 J
▷ (34), (35), (37)
Feodor Yevtushenko .... 20 J
▷ (47), (49)
Murad Bashirov .... 15 J
▷ (57), (101)
5929 .... 10 J
▷ (91)
Atanas Gochev .... 10 J
▷ (92)
Alan Wang .... 10 J
▷ (94)
Eppu Leinonen .... 10 J
▷ (104)
Mohammed Alsawafi .... 5 J
▷ (1)
David Hayrapetyan .... 5 J
▷ (6)
Alex Prodanov .... 5 J
▷ (72)

...and other anonymous contributors.