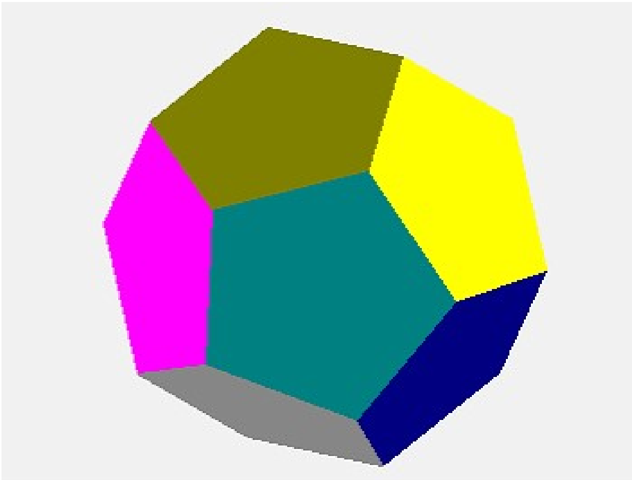
20 questions to the Engineer’s letterbox



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1. Introducing the background for this article

In June 2018 I received a request from an employee at the magazine "The engineer", who was concerned with the letterbox having technical questions from the readers.

She wrote, that they among others, had received a letter about bicycles, and as she wrote, she had seen that I had made a "physics-rapport" on bicycles

(I must explain that a "physics-rapport" in Denmark is the name of the 1 – 4 pages, where the students in the 9-12 grade high school explain and analyze the result of a small experiment)

The article that she referred to on my homepage is, however, not a "physics rapport", that I made in high school, but a processed version of an elective subject that I made with my students in their last year in high school in the year of 2009, where the students had the highest level in physics.

As I tried to explain to the editor of the letter box, as gently as possible, a theoretical physicist is hardly the right person to give answer to "boys ass questions" in a popular magazine for engineers and their students. Questions, which most of all reflect a fatal lack of understanding of theoretical physics.

It showed up that the bicycle question was, whether it was a fast or a slow braking, which slid most on the braking pads.
This question does not really belong to the category of interesting issues in theoretical physics, and the only thing I could contribute, was that the same energy must be absorbed (but at a different rate) in the brake pads, and that the only person that might answer the question (but hardly) would be the manufacturer of brake pads.

The editor of the letter box, however, was not entirely satisfied with this explanation, since she did not think it answered the question of the inquirer.

The same happened more or less with the rest of the questions, I received from the editor of the letter box, but I shall only deal with five of them.

1. Relativistic rotation

The next one was the following, where the inquirer writes:

1. I have wondered whether there is a theoretical limit for rotational velocity. Is it possible under ideal circumstances that an engine could drive a swing disc having a radius ca. 16 cm with a frequency of 299,792,458 rounds per sec? And an added question. Why will the centrifugal force not tear the disc apart?

The question does not really make sense, since the frequency stated is the velocity of the speed of light in meters per second. But I thought that an elucidation of the forces that affects a rotating body perhaps would make the inquirer to contemplate in a more constructive way. (I was wrong)

But at least to give a possible path to an understanding of why neither of the two question may be answered, I shall sketch the most elementary about uniform circular motion

If a body having mass *m*, e.g. a loot in a string, moves in a uniform circular motion with radius *r* and having frequency ν, then the angular frequency becomes $\omega = 2\pi\nu$, the velocity $v = \omega r$, and the centripetal force necessary to hold it in its orbit is $F_c = m\omega^2 r$. The centripetal force is directed towards the centre of the circular motion, and is delivered by the string, which holds the loot.

Although the notion often appears in popular articles on circular motion, the *centrifugal force* does not exits. There is no outward directed force on a body performing a circular motion.
The reaction force to the centripetal force is certainly is directed outward, but the reaction force is acting on the string, not on the body which performs the circular motion.

The centrifugal force is a so called fictional force, which compensates for a lack of a centripetal force. If the string breaks the loot will continue in a uniform linear motion with its instantaneous velocity.
But to approach an answer to the questions of rotational speed and tensile strength, let us assume that we have a mass 0.50 *kg*, which we sling around in a circular motion with radius 2.0 *m*.
The string which holds the loot is assumed to have a tensile strength of *F*= 1000 *N*, which roughly corresponds to the weight of 100 *kg*. The string will break, when the centripetal force exceeds the tensile strength.

$$F_c = m\omega^2 r > F \quad \Leftrightarrow \quad 0.50\omega^2 2.0 > 1000 \;\Rightarrow\; \omega > 31.6\, s^{-1} \quad \Leftrightarrow \quad \nu > 5.0\, Hz$$

It is implied in the question, whether it is possible to rotate with relativistic velocities.

Firstly: It is not possible to accelerate macroscopic bodies to relativistic velocities. For example: If one should accelerate a mass of 1 *kg* to 90% of the speed of light, it would require the energy:

$$E_{kin} = \frac{m_0 c^2}{\sqrt{1 - v^2/c^2}} - m_0 c^2 = (\frac{1}{\sqrt{1 - 0.081}} - 1)c^2 = 3.810^{15}\, J$$

A power plant of 1 *GW* can supply energy to a larger city. And to supply the energy needed, it should therefore be active in 3.8 10^6 s, which corresponds to 45 days.

The machines, which have been built, for example at CERN in Geneva, to accelerate atomic particles to near the speed of light are gigantic.

Secondly: When a massive body approaches the speed of light, its mass will become infinitely heavy according to Einstein's formula: $m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$, so speculations about rotation with relativistic speed are really not so interesting.

The dynamics above, with a mass held by a cord performing a uniform circular motion may immediately be transferred to a massive rotating disc, having radius 16 *cm* and mass *M* = 20 *kg*. Let us determine the centripetal force, which acts on the outer centimetre of the disc, at a rotation with frequency ν. The mass per unit area of the disc is $d = \frac{M}{\pi r^2}$, and the mass of the outer centimetre $\Delta r = 1\, cm$ is therefore: $m = 2\pi r \Delta r d$.

The centripetal force, which must be delivered hold the outer of the disc in a circular motion is $F_c = m\omega^2 r$. Inserting the numerical values together with a (extreme) high rotational frequency 100 *hz*, that is, $\omega = 200\pi$, we find:

$$d = \frac{M}{\pi r^2} = 249\ kg/m^2 \text{ and } m = 2.50\ kg\ .$$
$$F_c = m\omega^2 r = 2.50(200\pi)^2 r = 1.58\,10^5\ N \approx\ 1.6\,10^4\ kg\ .$$

Whether it should be enough to tear the metal apart, I do not know, but I doubt it.

It is of course straightforward to use an even higher frequency (until the absurd is reached), but it really serves no purpose.

Neither this answer satisfied the editor, since a straight answer free from the confusing formulas was not given. As she wrote, it was far from all the readers of the popular magazine "The Engineer", who understood mathematical formulas.
Could I not give a theoretical answer, which was not accompanied by formulas?
Regrettably, I replied, this was not possible, if the answer should contain an explanation.

2. Black holes in the laboratory?

Differences in forces, which are sufficient to tear a massive body apart does only exist when the body falls into a black hole, where it splinters in atoms.

Black holes are evidently not something you can produce in laboratories, but yet, by the same token as the myth of cold fusion there appeared conjectures in the more rambling and not scientific medias that "The Large Hadron Collider" LHC, which were taken in operation in 2008, would be able to create micro black holes, that would grow and shallow the laboratory and ultimately the earth!

But as it was the case with the myth of cold fission these speculations can be rejected by a rather simple theoretical analysis, which however, contains formulas that are not suitable for the common press or the more rambling social media.

The calculations below show that the notion creating a black hole by the collision of two highly relativistic protons is not entirely sane. Below are the data we have used:

Mass of proton: $m_p = 1.67\ 10^{-27}$ *kg*.
Speed of light: c =3.0 10^8 *m/s*
Gravitational constant: G =6.67 10^{-11} SI
Radius of the proton: 1.4 10^{-15} *m*.
1 *eV* = 1.60 10^{-19} J.
The CM energy for the two colliding protons at LHC in CERN: 8 *TeV* = 8.0 10^{12} *eV*.

We start by evaluating the equivalent mass, corresponding to the CM-energy 8 TeV

E = 8.0 *TeV* = 8.0 10^{12} 1.60 10^{-19} J = 1.28 10^{-6} *J*, which corresponds to a mass:
$m = E/c^2$ = 1.42 10^{-23} *kg*.

Subsequently, we shall evaluate the mass of a black hole, which we (somewhat arbitrary have set to 10 proton radii. The radius of a black hole is (according to the general theory of relativity) given by the formula.

$$R = \frac{2GM}{c^2} \quad \Leftrightarrow \quad M = \frac{Rc^2}{2G} \quad => \quad M = \frac{14.0\,10^{-15}(3.0\,10^8)^2}{2 \cdot 6.67\,10^{-11}} = 9.45\,10^{12}\ kg = 945 \text{ billion ton}$$

There is consequently a factor 10^{35} between the mass of a black hole and the mass of the CM-energy in a collision in the LHC.
However, the calculation above will hardly influence the conviction of the readers of the rambling media.

3. Air balloons with vacuum

Another question I received with the request of giving a theoretical answer was not less weird.

2. Why do one not use vacuum instead of hot air in a balloon to keep balloons and air ships floating. One could for example buckle plastic around a rigid frame, and subsequently pump the air out. By a suitable construction would the air ship theoretically not be floating without consuming energy.

Again, it is hardly possible to present an answer to such (idiotic) questions, without sketching the theoretical foundation.

Firstly: It is not the pressure that makes the balloon rise, it is the buoyancy, which comes about because of the difference of the density of the gas inside and outside the balloon.
The pressure is (almost) the same inside and outside the balloon. Otherwise the balloon would be compressed or expand.
But if there was vacuum in the balloon, there would be an (atmospheric) pressure of $1\ atm = 1.013\ 10^5\ N/m^2$ on the outside of the balloon, corresponding to $1.013\ 10^4\ kg$, that is, 10,013 *kg* (10 tons) *per.* m^2.
There shall probably be more than 1 *cm* of steel to resist such a pressure, as we shall deal with later. But what is it then that keeps the balloon floating?

The buoyancy on a body is according to Archimedes law equal to $F_{up} = (\rho_1 - \rho_2)Vg$,
where $(\rho_1 - \rho_2)$ is the difference in density of the balloon and the surroundings. V is the volume of the balloon and g is the gravity.

We shall then proceed to investigate how big the buoyancy is on a hot air balloon, under some simplified assumptions.
We assume that the balloon has the shape of a sphere with radius 5.0 *m*.
The volume of a sphere is given by the formula: $V_{sphere} = \frac{4}{3}\pi r^3 = 524\ m^3$.
Outside the balloon the temperature is 20^0 *C*, while the gas in the balloon is supposed to beheated to 60^0 C.
When a gas is heated under constant pressure, we have according to Gay-Lussacs 2. law :

$$\frac{V_1}{T_1} = \frac{V_2}{T_2},$$

where *T*, is the Kelvin temperature. We then find for the volume after the heating.

$$\frac{V_2}{V_1} = \frac{T_2}{T_1} = \frac{273+60}{273+20} = 1.14$$

This is the factor, by which the volume is increased after the heating.
Since the density is defined as the mass per unit volume: $\rho = \frac{m}{V}$, the density of the gas will be decreased with the same factor. The density of atmospheric air at 20^0 *C* is 1.29 *g/l* = 1.29 *kg/m*^{3}, and the density for the heated gas therefore becomes: $\frac{1.29}{1.14}\, kg/m^3 = 1.13\, kg/m^3$
Hereafter the buoyancy becomes:

$$F_{up} = (\rho_1 - \rho_2)Vg = (1.29 - 1.14)524 \cdot 9.82\ N = 772\ N,$$

which corresponds to the gravity of 78.6 *kg*.

If the diameter of the balloon is increased to 15 *m*, the buoyancy is increased by a factor 1.5^3 =3,38.

To satisfy the inquirer, it is straightforward to calculate the buoyancy if the balloon is a steel container with vacuum.

$$F_{up} = \rho_{air} Vg = (1.29)524 \cdot 9.82\ N = 6638\ N \approx 676\ kg$$

Before you raise your arms on this marvellous improvement, you should rather estimate the weight of the steal container, say 1 *cm* steal, which is necessary to hold the vacuum against the outer pressure.

The surface of a sphere with radius r = 5.0 *m* becomes: $O = 4\pi r^2 = 314\ m^2$, which corresponds to a sphere of steal having thickness 1 *cm*. $\rho_{steel} = 7874\ kg/m^3$, so

$$m_{steel} = 0.1 \cdot 314 \cdot 7874\ kg = 24{,}724\ kg$$

Which is about six times the buoyancy, so the idea of replacing hot air with vacuum is hardly sustainable, so to speak

4. Moving with a speed higher than the speed of light (1)

Being a theoretical physicist, I can get immensely tiered of listening to ”results of experiments”, which are in conflict with the special theory of relativity, although they have appeared from time to time in more than hundred years.
The question below from the engineers letterbox, is an notorious example.

3. I perceive the speed of light as an absolute max, and nothing, not even communication moves faster than the 300,000 km/s, but I have recently experimented an article from the scientific magazine Nature, already in 2008 that Swiss scientists in the university of Geneva, lead by Nicolas Gisin, have succeeded in having two photons communicate with a speed of 100.000 times the speed of light.

What happened to Einstein's theory of relativity? And quantum physics as a whole.

My strenuous response was:

I have no specific recollection of the experiment mentioned, but either it is a reference to an experiment sending neutrinos from Italy to Geneva, the results of which were falsified shortly after, or it is a misinterpretation of Apect's experiment, conducted by the Frenchman Alain Aspect in the 80'ties (I think)

Aspect's experiment has nothing to do with communication between photons or the speed of light for that matter, but it is a consequence of some deep and incomprehensible cohesion in quantum physics. A description, which requires several years of studying in a physics department at a university.

Quantum physics cannot be understood from everyday experiences, but it offers a precise mathematical description of the atomic world.

5. Moving with a speed higher than the speed of light (2)

The fourth question was of the same intellectual calibre, namely to cast doubt on validity of the theory of relativity. (As it has been tried for the last hundred years)

4. I have once been told from Einstein's theory of relativity, that no one can reach a velocity greater than the speed of light, but now I read that astrophysicists have observed stellar objects, which move away from us with a speed far beyond. The speed of light.
How can that be? Is Einstein gone out of fashion, like many other things in this volatile world?

My laconic answer was this:
You cannot measure the speed of very distant objects. What you measure is the red-shift, that is the change of the wavelength of radiation emitted from a moving body, according to the Doppler effect. From the Doppler effect one has:

$$z = \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

Where v is the velocity of the moving body relative to a inertial system emitting the light, and c is the speed of light.
As far as I recall, I have heard of quasars having $z = 0.7$, (70% of the speed of light), but I am sure that I have never heard of stellar objects with $z > 1$.
But I have many times in my career encountered popular "scientific" articles, with the purpose of undermining one of the best experimentally consolidated theories, namely the special theory of relativity.
However, they have never been able to discriminate Einstein's theory.

Additional note: If two body move relative to each other with velocities v_1 and v_2, then the relative speed (which by the way is an invariant) may be greater than the speed of light, but neither will be able to measure the others speed as greater than c. But I shall let it hang.

6. Cold fusion. Another phantom assertion

Concerning rambling assertion, one of the most notorious was the claim of cold fusion, from the eighties, which first appeared in the media (but not in scientific publications).

The result of the falsified experiment was published in the press before it had been tested in a physical scientific magazine, which is highly uncommonly and quite risky, since the editors of the newspaper do not have the scrutiny to evaluate the validity of claim.

At that time I was teaching physics andmathematics in the Danish 9-12 grade high school. Especially the humanists, who never lost a chance to demean the cocksure an arrogant physicist, (who thought they were more cleaver than anybody else) (and often they are), grasped the news of cold fission.
However, I went to a lesson with my 3. year class in physics, and demonstrated for them that it could not be done. The experiment was a fake. The humanists scowled: Why do you pretend that you are more cleaver than anybody else. Certainly I do not in general, but in that case I was.

The fake experiment ended by the exclusion forever of the two Italian physicists from all universities (in Europe?), and from all the physical magazines. But of course they had about two months of world fame.

The cold fusion is impossible is, however quite elementary to demonstrate, as it could be done in the Danish high school in the eighties. (But no longer after the reforms in 1988 and 2005)

To initiate fusion it is necessary that two protons collide to create deuterium.
To do so they must, however, overcome the electrical Coulomb repulsion in a distance of two proton radii. We therefore calculate the electrical potential energy at that distance.

$$E_{pot} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r_p} = 9.0\,10^9\,\frac{(1.60\,10^{-19})^2}{2\cdot 1.4\,10^{-15}} = 8.23\,10^{-14}\,J = 514\,KeV.$$

To overcome the potential barrier, the protons must have a similar kinetic energy.
However by a cold fusion the protons are thermal, having energies about 1 eV.
But to induce a head on collision between two protons it requires about 500,000 times the energy of a thermal proton.
No babbling about the tunnel effect can overturn this fact.

The editor was clearly not satisfied with my way of answering the questions, because as she wrote:

“That I did not answer the questions, but rather wrote a lot of formulas”

“Would it not be possible to give an answer in a few sentences?”

And hereby ended a relatively short corporation between me and the engineers letterbox.

From my point of view, I thought I had given a qualified theoretical explanation, so I have chosen to publish them, although the physics is rather elementary.