Fundamental Flaws of Equivalence Principle – the Violation of Energy Conservation

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Abstract: This paper is dedicated to demonstrating the intrinsic flaws in the equivalence principle, which is considered as the foundation of general relativity theory. Einstein's relativity theories hypothesized the warping of spacetime to support the equivalence principle and the consequent universal freefall acceleration but failed to comprehensively address other physical consequences and overlooked many other essential physics including the variation of inertial mass through nuclear binding energy. Inevitably, the equivalence principle will theoretically lead to the violation of energy conservation, leaving a loophole that can be used to create infinite amount of energy. Multiple gravitational experiments also challenge the equivalence principle by showing different accelerations for different atoms and neutrons. Although Einstein's equivalence principle and relativity theories can explain some classical and relativistic phenomena, the fundamental flaws and the gravitational experiments outrightly threatens their validity. If left unresolved, the credibility of the concepts and logics behind these theories will remain questionable and many of the theoretical predictions based on these theories will become unreliable.

1. Introduction

Einstein's relativity theories are quite unique in that they were developed in prominent isolation from other physics principles. They focus intensively and inclusively on the perplexing properties of time and space. For example, the special relativity introduces a lot of concepts that involve the stretch and contraction of time and space in order to explain the fact that speed of light remains constant to any moving or still observer and acceleration of objects becomes more and more difficult when they approach the speed of light. The general relativity theory takes a step further to theorize that spacetime is warped in the presence of a mass and describes spacetime in the very abstract mathematical formulism in the form of Einstein's field equations. The very simple physics of gravitational acceleration is transformed into a mind-bending consequence of the twisted spacetime, which is by no means straightforward because space and time are by themselves fluid and closely corelated, changing any one of them will inevitably affect the other. All these spacetime manipulations are the hallmark of Einstein's relativity theories, other fundamental physical observables such as energy, mass and interactions play very no active rules in the manipulations. In sharp contrast, no other physical theories require the manipulation of spacetime, but rather use time and space as simple input parameters to describe physical processes and observables. The distinctive difference makes Einstein's theories very incompatible with other theories because of the fundamentally different world view of physics. For example, quantum physics and general relativity theory can hardly find any common physical language to make them work coherently. The reason why the relativity theories are still practically used regardless of the unusual manipulations is that the free parameters in relativity theories are mathematically adjusted to match real world physical observations. For example, the special relativity stretches space and time to match the Lorentz factor, and general relativity select coefficients and constants so that the resultant freefall acceleration matches that of the Newtonian gravitational accelerations. In essence, the special and general relativity theories are all mathematical curve fittings of existing Lorentzian and Newtonian physics, respectively. These theories can be viewed as the deliberate mathematical manipulation of spacetime which serves to interpret observed relativistic phenomena and the underlying equivalent principle, which is no different from Newtonian gravitational theory. They do offer some practical predictions such as the gravitational effects on atomic clocks and gravitational effects on resonant light emissions and absorptions. However, they should be viewed as the result of the curve fitting where physics are smooth and analytical in a narrow range. The mathematical spacetime nature of the relativity theories do not put the fundamental physical principles including mass and energy at the center of its perspectives, therefore there exists no logical reason to believe that these relativity theories are well-rounded and compatible with other physics principles. In other words, there is no theoretical mechanism to guarantee that these mathematical fittings represent true physics and their predictions are valid beyond the range where the curve fitting is performed. Moreover, stretching spacetime with an innocent and targeted intention to explain some physical phenomena without addressing others is theoretically dangerous because space and time are the integral fabric of physics, almost any physical observables are directly or indirectly related to space and/or time. Manipulation of space time will inadvertently change physics in an undesired manner. For examples, stretching spacetime might lead to the change of speed of light, if speed of light is conserved then any contraction of space will lead to dilation of time and vise versa, and any change of spacetime will change energy around it including photons whose energies might be proportional or inversely proportional to space and time as well as kinetic energies which are proportional to the square or inverse square of space and time. Warping space will immediately change all potential energies including electric, nuclear and gravitational energies because they are all function of space.

The equivalence principle that considers gravitational acceleration as the result of the warped spacetime or gravity is equivalent to acceleration is therefore potentially inconsiderate given the fact that there are no follow-up theories to address the consequent physics after spacetime manipulation, the equivalence principle is therefore also probably incomplete. This paper will specifically investigate the equivalence principle and related implications and demonstrate its fundamental flaws that eventually lead to the violation of energy conservation.

2. The theoretical and experimental background of equivalence principle

About 400 years ago, Galileo and Newton realized that all objects should accelerate at the same gravitational acceleration and all objects are subject to gravitational pull that make them accelerate toward each other. For example, all objects on Earth will fall to the ground at the same acceleration regardless of their weights and atomic compositions if air friction is negligible. This was a historic breakthrough that liberated human from the misleading commonsense that light objects fall slower than heavy objects and revolutionized the understanding of gravitational nature, which is ultimately summarized as the Newtonian gravitational potential energy expressed as $V = -Gm_1m_2/r$ where m_1 and m_2 are the masses of interacting objects, r is the distance between them and G is a constant that relate masses to gravity. The universal constant G implicitly implies that the amount of gravity is proportional to the product of involved masses regardless of their compositions. However, the expression is only an accumulative empirical expression, namely m_1 and m_2 represent tremendous amounts of different types of elementary particles. No one knows which parts of the masses contribute to gravity. No one knows if gravity is proportional to the products of numbers of protons and/or neutrons and/or electrons or actual masses of them. There exists no theoretical or experimental knowledge at all whether gravity is truly proportional to the masses of electrons, protons, neutrons and so on individually. We have clear understanding that electrons have much smaller masses than protons and neutrons, but does it mean electrons have proportionally smaller gravity than protons and neutrons? In other words, do electrons, protons and neutrons have the same G factor? Obviously, there is no confident answer to this question except unfounded assumptions, and no experiments have ever been performed to study the amounts of gravity generated by electrons alone, or neutrons or protons alone, even accumulatively. The reason is very simple, there do not exist large accumulations of pure electrons, or pure neutrons or protons because they are not stable, they will not stick together unmixed with other types of particles for experimental investigations. All available accumulative objects are all made of atoms consisting of electrons, neutrons and protons, and what we know about gravity is based on the gravitational observations of large amounts of atoms except for the gravitation and quantum interference of free neutrons in the Colella, Overhauser and Werner (COW) experiment. No matter how modern gravity theories appear to be so sophisticated and advanced mathematically or conceptually, they are essentially no different from the Newtonian gravity theory in the sense that they are all linked back to the Newtonian gravity. To be more specific, there is no existing specific knowledge whether the G constant is the same for electrons, neutrons and protons or even different elementary atoms. In the case G constant is the same for all particles, then gravitational mass is the same as inertial mass and can be used interchangeably, namely gravitational mass and inertial mass are equivalent regardless where they come from only if G is universal.

We might not know very much about gravitational masses of elementary particles such as electrons, protons and neutrons, but we do know a lot about their inertial masses. In fact, these masses have been carefully measured through their kinetic properties by way of electromagnetic interactions and have achieved accuracies better than 1 part in a billion. Most common methods include the mass-to-charge ratio in electric and magnetic field or the periodic motion of charged particles in a magnetic field. It must be emphasized again that these precisely measured masses are all inertial masses, they are all directly or indirectly related to motion and energy, and none of them are related to gravitational mass. In other words, there should be no wrong impression that we know gravitational mass accurately. We literally know nothing about gravitational mass except that gravitational force is empirically found to be proportional to the product of the amounts of materials expressed as weights, which might be and appear to be proportional to inertial masses, as is accumulatively formularized by the Newtonian gravitational constant G. That is all we know and there is no theoretical foundation to extrapolate that gravitational mass can be equivalent or even proportional to inertial mass. Experimentally, G constant has been measured by many groups with very high precisions, but no matter how carefully and precisely the experiments were performed, the results always seems to differ by a fraction of a thousandth among them, more importantly the difference is much greater than their experimental uncertainties. For example, the most accurate measurements ever made in 2018 was published to have a standard uncertainty of 12 ppm using the time-of-swing (TOS) and the angular-acceleration-feedback (AAF) methods. However, the G values measured with these two different methods differ by 45 ppm, or 3.7 standard uncertainty, and the authors suggests that there may be undiscovered systematic errors in the measurements. There is one unnoticed detail that might contribute to the difference in G between the two independent methods: TOS and AAF used gold/copper coating and aluminum coating respectively on the fused silica block torque pendulums. This suggests that different atoms might have slightly different gravitational accelerations when both inertial and gravitational processes are involved in the measurements. This seems to contradict the equivalence principle that gravitational constants should be the same for any types of masses.

If equivalence principle were right, then all materials should have the same gravitational acceleration. However, Bessel in 1827 found that pendulum made of water seemed to have abnormal acceleration than other materials. Furthermore, precise COW experiments performed by various research groups indicate that free neutrons might experience a slower gravitational acceleration than expected because all their measured values of $q_{grav} = 2\pi\lambda m_n^2 g A_0/h^2/(1+\epsilon)$ are always about 0.8% lower than the theoretical expectation using the acceleration of gravity g based on regular atomic materials. Szász in 2004 performed a freefall experiment in a vacuum drop tower and found that lithium, carbon and lead blocks experienced slower accelerations than other materials such as aluminum and iron as evident in the recorded video (https://www.youtube.com/watch?v=jkNjvCmsWOU). Szász proposed that the mass defect will lead to differences in gravitational accelerations among different atoms. Unaware of these experimental efforts directly or indirectly related to the gravitational accelerations of different atoms or neutrons, Du in 2022 independently took ground-based gravitational measurements using a pendulum bob made of a spherical steel shell, as motivated by his grand unification theory which equally treats gravity as a true conservative force and extends the concept of mass deficit to all conservative forces including nuclear force, electric force and gravity. The measurements showed that the pendulum bob filled with wax accelerates slower than the empty steel bob (https://hong22183488.files.wordpress.com/2022/04/pendulum.pdf) by a fraction of a thousandth as expected from his theory, which is compatible with Szász's theory. These pendulum measurements, the G factor measurements, the drop tower freefall experiment along with the neutron COW experiments all indicate different types of atoms and particles likely have different gravitational accelerations on the order of a thousandth or more.

But equivalence principle in the general relativity theory clearly contradicts these measurements. It conceptually hypothesized that inertial mass is equivalent to gravitational mass without supporting logical reasons and theoretical details, arguing that all objects should have the same gravitational constant, and all objects regardless of atomic or particular compositions will have the same gravitational acceleration, and treating gravity not as a force but the result of warped spacetime or geodesics of spacetime. The equivalence principle is supported by claims of various Eötvös experiments that demonstrated equivalence of inertial mass and gravitational mass up to the precisions of one part in a quadrillion. These claims sharply contrast the reality that gravity is the weakest force. The fact that the measured gravitational constant G couldn't even have confident uncertainty lower than tens of millionths implies that these claimed high precisions through indirect measurements might be faulty at its design.

Without going further into the details in order to identify issues related to the Eötvös experiments, the following simple and straightforward theoretical analyses can easily shake the foundation of the equivalence principle.

3. The limit of the equivalence principle – a classical empirical hypothesis in essence

First of all, the equivalence principle is not a physics principle or theory, there exists no physical theories that can imply or deduce that gravitational mass must be strictly equal or proportional to inertial mass. The equivalence principle is a summary of the gravitational observations that all objects appear to free fall at the same acceleration as pointed out by Galileo and Newton, who pioneered and empowered the classical physics. In this sense, the equivalence is as accurate as the gravitational observations and it essentially deals with a classical physics phenomenon that is more than 300 years old. However, this classical observation alone cannot represent and/or reveal all underlying physics principles, and theoretical interpretations can easily get misguided by a faulty theory, just like sunrise and sunset observations could be explained by both heliocentric and geocentric theories. The classical physics about freefall is by no means complete because it was developed when mass was considered a physical observable that cannot change, a faulty assumption after relativistic effects were discovered near the end of the twentieth century.

Equivalence principle doesn't address the situation when mass can be changed. It takes the easy route to make inertial mass and gravitational mass equivalent so that it can explain objects with arbitrary amount of masses with different compositions appear to gravitationally accelerate at the same rate. Inertial mass is theoretically related to motion or kinetic energy, it has nothing to do with gravity, which is a conservative force. In parallel, it is well understood that electric force is a conservative force, it has nothing to do with inertial mass except that acceleration is codetermined by the electric force and the inertial mass. Because the dissociation of inertial mass and electric force, different particles or objects under the influence electric force can have wide ranges of accelerations. If gravity is also a true conservative force, then it should have nothing to do with inertial mass except that acceleration is codetermined by the gravity and the inertial mass and should have wide ranges of accelerations. But why do all objects appear to have the same gravitational acceleration making inertial mass and gravitational mass appear equivalent? Why gravitational acceleration behaves dramatically different than electric accelerations in this sense? The short answer is that for gravitational interactions, all involved objects are composed of large amounts of atoms, which are always composed of very similar underlying particles – a bunch of proton-electron pairs plus neutrons which can also be viewed as composite proton-electron pairs, so that the gravity-to-mass ratio is almost always the same in terms of proton-electron pairs. Consider the gravity of an object in terms of the number of proton-electron pairs, then gravity will be proportional to the number of proton-electron pairs, at the same time, its mass is also approximately proportional to the number of proton-electron pairs if mass deficit is not considered. This situation gives the wrong impression that gravity is proportional to mass, therefore gravitational acceleration is fixed for all objects regardless of atomic composition. While for electric interactions, involved objects can have drastically different charge-to-mass ratio, for example, positron and proton can carry the same amount of electric force but their masses can vary by more than a thousand times.

But will gravity evaluated by number of proton-electron pairs make the gravity-to-mass ratio the same for any atoms and any amounts of atoms so that it can validate the equivalent principle? This would be true in classical physics because the gravity will be strictly proportional to the number of proton-electron pairs and mass is also strictly proportional to the number of proton-electron pairs, therefore the gravitational acceleration is strictly the same regardless the total number of proton-electron pairs and the atomic compositions. So the principle equivalence is good enough for classical physics. At this point, there is no difference in gravitational mass and inertial mass because none of these masses will be changed for different atoms, they are all proportional to the number of proton-electron pairs.

But as mentioned above, equivalence principle is a theory rooted in the classical physics domain, it is based on classical observations and it has no mechanism to offer guidance for relativistic physics. All it offers is a reason for the curve fitting of warped spacetime in order to match Newtonian gravity.

In relativistic domain, the mass of atoms will no longer be strictly proportional to the number of proton-electron pairs. The reason is very simple. When the proton-electron pairs settle down into stable forms of atoms, they have many choices, namely they could form very different atoms, and different atoms will have very different mass deficits, therefore the resulting inertial mass will not be the same for different atomic compositions given the same number of proton-electron pairs. Notice that the mass deficit is named as a relativistic effect, because the binding energy strength is compatible to the rest mass energy of nucleons, similar to the relativistic kinetic energy when it becomes compatible to rest mass energy. So in relativistic domain, the mass of an object is not strictly proportional to the number of proton-electron pairs. At the same time, the gravity is likely still strictly proportional to the number of proton-electron pairs. If not, gravity would no longer a conservative force, and it would require a lot of theories to explain why gravity should not be conservative. If gravity is still conservative and is strictly proportional to the number of proton-electron pairs, then the equivalence principle is broken in relativistic domain. The theoretical foundation of Einstein's general relativity is no longer valid.

How much does the equivalence principle fail? The strongest binding energy known so far is the nuclear binding energy, and the maximum is approximately 8.8 MeV per nucleon. Each nucleon has a rest mass energy on the order of 931.5 MeV, so the mass deficit can cause a deviation from the equivalence principle by approximately 0.9%. This is the maximum deviation between iron atoms and hydrogen atoms or free neutrons, and equivalence principle can still be considered approximately acceptable. But from the perspective of extreme binding energy cause by gravity near neutron stars, the maximum binding energy can reach 900 MeV or more, making the equivalence principle completely fail more drastically in extreme relativistic domain.

4. Relativistic phenomena undermine the foundation of equivalence principle

Equivalence principle is promoted by Einstein in order to explain relativistic effects. But ironically, it is exactly the relativistic effects that undermines the equivalence principle.

In late 1800s, it was observed that photons always travel at the speed of light and it appears to be the upper limit of all possible speeds, and the observations were described by the Lorentz transformation which was developed by Woldemar Voigt and Hendrik Lorentz, characterized by the Lorentz factor $\gamma = 1/\sqrt{1 - v^2/c^2}$, which is no less than 1. Walter Kaufmann further found through the Kaufmann-Bucherer-Neumann experiments that electrons exhibited increased mass when moving at high speeds. This is now well known as the relativistic mass equal to the rest mass multiplied by γ, namely rest mass m becomes γm. Then the question is, what type of mass is this increased mass of γm? Is it inertial mass or gravitational mass? Experimentally, when electrons are accelerated to high speeds, it is very hard to further accelerate them with the same amount of electric force, which means the inertial mass must have increased at high speeds, namely γm is reasonably inertial mass, and it has nothing to do with gravity. To reinforce this conclusion, think about a fast electron circulating in a magnetic field, its inertial mass is γm based on the observation of its orbiting radius $r = \gamma mv/(qB)$ and frequency, and this method is known to rely on the charge-to-mass ratio. Meanwhile, this inertial mass is related to the total energy, which is known as $E = \gamma mc^2$. Of course, classical physics cannot foresee such effects and think mass cannot be changed, it is ignorant of this relativistic variation of inertial mass. But how about equivalence principle's view on this increased inertial mass? Unfortunately, equivalent principle doesn't have a clear and direct answer whether gravitational mass should also increase when relativistic inertial mass is increased, the reason is that it is based on classical physics and classical observation of equivalent freefall, it can only specify that the circulating electron should fall equivalently as any other non-circulating electrons following the geodesics of the warped spacetime. This doesn't sound very relativistic because when the electron is circling the magnetic field at near speed of light, it simply cannot fall equivalently with other non-circulating electrons because this will make it exceed the speed of light. The only hope to save equivalence principle is that gravitational mass would also undergo a relativistic increase to catch up with the increased inertial mass. Unfortunately, this will not only make gravity nonconservative meaning gravitational energy would be dependent on the history of the electron's motion, but will also undermine the concept of geodesics of the warped spacetime because gravity is no longer solely determined by warped spacetime but also by the motion of the electron.

Later in 1919, Francis William Aston was able to build mass spectrometers with high enough precisions and identified another type of relativistic effects that varied masses of particles: when particles such as neutrons and protons combine, their total mass is no longer conserved as classical physics thought, the final total mass is less than the sum of individual masses. Then what type mass is varied in this case? Sure enough, the mass has nothing to do with gravity, so it cannot be gravitational mass. The final mass again should be inertial mass exactly like the Lorentzian relativistic mass as in the case of γm because it was also measured by way of charge-to-mass ratio, which is related to the motion in magnetic field. Assuming the initial total mass before the combination is m, then the final total inertial mass can be expressed as ζm where ζ is a number no greater than 1, and $\zeta = 1 + V/(mc^2)$ where V is the negative binding energy, the most well-known example of which is the nuclear binding energy. In this process, the initial mass suffered a mass a loss or deficit equal to $\Delta m = \zeta m - m = V/c^2$. Meanwhile, similar as the relativistic inertial mass γm, this final inertial mass ζm is again related to the total energy $E = \zeta mc^2$. Einstein was also aware of this relativistic effect and he is known for writing down the famous mass-energy equivalence equation as $\Delta E = \Delta mc^2 = |V|$. Classical physics definitely has no mechanism to process this new type of relativistic effect. How about the equivalent principle's view on this mass deficit? Probably the equivalence principle doesn't explicitly address this kind of fundamental physics issues such as the mass deficit. It can only be inferred that following the equivalence principle, gravitational mass might follow the variation of inertial mass, meaning that gravity would also suffer a loss when particles combine with binding energy in order to achieve the theoretical claim that gravitational acceleration is the consequence of warped spacetime instead of the gravitational force. This will have a direct theoretical conflict with the classical concept that gravity is a conservative force that only depends on the involved objects and their relative geometric configurations. Therefore, on the surface, the equivalence principle appears like a classical theory because it doesn't have any mechanism to address the issues caused by the variation of inertial mass through relativistic motion or binding energy, but when examined more carefully, equivalence principle even is incompatible with classical gravitational theories that gravity should be a conservative force that doesn't depend on the motion or binding energy of the interacting masses.

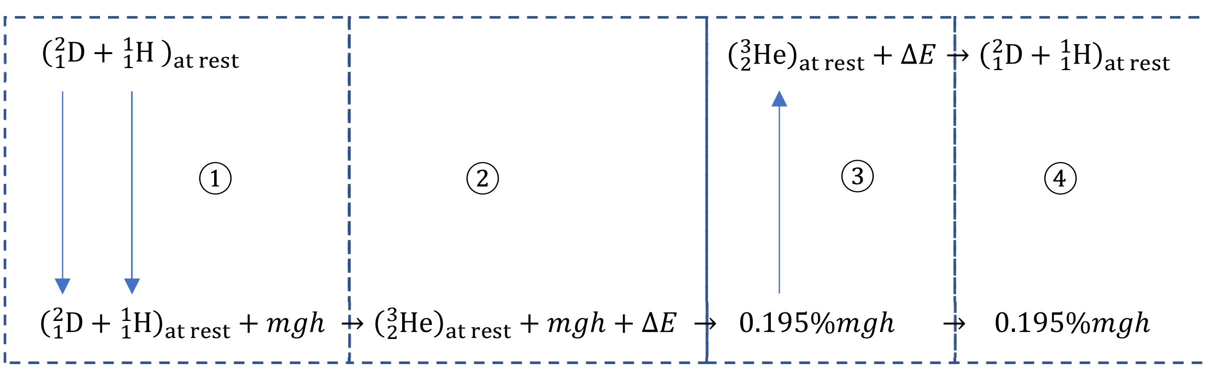
Based on the above analyses, it can be reasonably concluded that the equivalence principle is an immature hypothesis that originated from classical freefall observation but aimed at explaining relativistic physics from the perspective of classical physics. The equivalence principle fails to theoretically address two fundamental relativistic physics (1) the increase of inertial mass through relativistic motion in the form of γm and (2) the loss of inertial mass resulting in ζm through mass deficit owing to relativistic binding energy such as nuclear binding energy. These two relativistic physical phenomena effectively reveal the incompleteness of the equivalence principle and undermine its credibility. The following paragraphs will be dedicated to demonstrating that equivalent principle will inevitably violate energy conservation.

5. Equivalence principle violates energy conservation

The equivalence principle bypasses the necessary theoretical investigations related to the variation of mass due to nuclear binding energy and insists that all objects should have the same gravitational acceleration in gravity regardless of atomic composition. This will lead to an obvious theoretical loophole that leads to the violation of energy conservation.

Considering a deuterium atom ${}_1^2\mathrm{D}$ with mass $m_\mathrm{D} = 2.0141u$ and a hydrogen atom ${}_1^1\mathrm{H}$ with mass $m_\mathrm{H} = 1.0078u$, where u is the unified atomic mass unit, approximately 931.49 MeV/c^2. The total mass of the two atoms is $m = m_\mathrm{H} + m_\mathrm{D} = 3.0219u$. When these atoms are combined through nuclear fusion ${}_1^2\mathrm{D} + {}_1^1\mathrm{H} \rightarrow {}_2^3\mathrm{He} + \Delta E$, the resulting helium atom ${}_2^3\mathrm{He}$ has a mass equal to $m_{3\mathrm{He}} = 3.0160u = \zeta m$ where $\zeta = 1 - 5.496\ \mathrm{MeV}/mc^2 = 0.99805$ and the binding energy from ${}_1^1\mathrm{H}$ and ${}_1^2\mathrm{D}$ to $m_{3\mathrm{He}}$ is $V = -5.496$ MeV, the mass deficit for this fusion is $|\Delta m| = |(\zeta - 1)m| = 5.496\mathrm{MeV}/c^2$ with released energy of $\Delta E = |\Delta mc^2| = 5.496$ MeV. The reversed nuclear fission reaction would be ${}_2^3\mathrm{He} + \Delta E \rightarrow {}_1^2\mathrm{D} + {}_1^1\mathrm{H}$ where energy of $\Delta E = 5.496$ MeV can break a ${}_2^3\mathrm{He}$ atom into ${}_1^2\mathrm{D}$ and ${}_1^1\mathrm{H}$ atoms, turning energy of 5.496 MeV into equivalent mass.

In summary, the mass of a ${}_2^3\mathrm{He}$ atom is $\zeta m = 0.99805m$ and is 0.195% less than the total mass m of a ${}_1^2\mathrm{D}$ and a ${}_1^1\mathrm{H}$ atom. The equivalent energy ΔE corresponding to the difference between m and ζm can be used to break a ${}_2^3\mathrm{He}$ atom into a ${}_1^2\mathrm{D}$ atom and a ${}_1^1\mathrm{H}$ atom; reversely when a ${}_1^2\mathrm{D}$ atom combines with a ${}_1^1\mathrm{H}$ atom to form a ${}_2^3\mathrm{He}$ atom, energy ΔE is released. Now consider the physical processes depicted in the following figure. Beginning with box ①, let the ${}_1^2\mathrm{D} + {}_1^1\mathrm{H}$ atoms at rest at height of h fall to the ground to reach a speed of v where the kinetic energy becomes $mgh = mv^2/2$ following the universal gravitational acceleration g. Then bring ${}_1^2\mathrm{D} + {}_1^1\mathrm{H}$ to rest and harvest the kinetic energy and store it in a rechargeable battery. In box ②, fuse ${}_1^2\mathrm{D} + {}_1^1\mathrm{H}$ to form a ${}_2^3\mathrm{He}$ atom and harvest the fusion energy ΔE and store the energy in the battery so that the battery carries a total energy of $mgh + \Delta E$. In box ③, use 99.805% of the stored energy mgh, namely $\zeta mgh = 0.99805mgh$ and leave some extra energy $(1-\zeta)mgh = 0.195\%mgh$ in the battery, to accelerate the ${}_2^3\mathrm{He}$ atom to velocity of v because $\zeta mgh = \zeta mv^2/2$, and then let the atom overcome the gravity with the upright velocity to reach the original location and rest at the height of h



because the gravitational acceleration is the same regardless of atomic compositions per equivalence principle. The battery stores a total energy of $0.195\% mgh + \Delta E$ at this moment. In box ④, spend the stored energy ΔE in the battery to break down the ${}_{2}^{3}\mathrm{He}$ atom into ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$ atoms. Now compare the beginning status in box ① and the final status in box ④, the ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$ atoms return to the original status, but the rechargeable battery gained some energy in the amount of $0.195\% mgh$. If the processes from boxes ① to ④ are repeated infinite times, infinite amount of energy can be created, and the creation will be very efficient when gravity is strong, for example near a black hole where g can be very large and the violent environment can make nuclear reactions happen frequently.

The violation of energy conservation obviously comes from the equivalence principle which assumes that the ${}_{2}^{3}\mathrm{He}$ atom can reach the height of h at the velocity of v atoms ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$ gained after freefalling the same height h. The violation can be avoided if the universal freefall acceleration is invalidated and the conservative gravitational energy only depends on the height h and the number of proton-electron pairs including neutrons (3 pairs in this case) instead of the inertial mass ($3.0219u$ and $3.0160u$ in this case) which is variable depending on binding energies, then the amount of gravitational energy becomes true conservative, namely when the ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$ atoms fall down and when the ${}_{2}^{3}\mathrm{He}$ atom moves up the involved gravity and gravitational energy will be the same regardless of nuclear binding energy these atoms have. Consequently, the gravitational acceleration may vary due to different inertial masses as a function of nuclear binding energy, since the gravitational force and energy are unaffected, they only depend on the height h and the number of proton-electron pairs (including neutrons) which is conserved regardless of nuclear binding energy. If the involved gravitational energy is the same, then the speeds of falling or rising objects for the same height will be dependent on the inertial masses as a function of nuclear binding energy. In the above case, ${}_{2}^{3}\mathrm{He}$ at speed of v cannot rise to height of h because its freefall acceleration is larger than that of ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$, so it needs higher speed to do so. This will require all the kinetic energy gained by freefall of ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$, leaving no energy in the battery so that the energy can be rightfully conserved from boxes ① to ④. As indicated by the experiments performed by Du and Szász, objects whose atoms suffered less mass deficit will gravitationally accelerate slower, in this case the ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$ atoms should accelerate slower than the ${}_{2}^{3}\mathrm{He}$ atom, therefore, the speed v reached by the freefall of ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$ is unable to raise the ${}_{2}^{3}\mathrm{He}$ atom to the height of h, all of the kinetic energy $mgh = mv^2/2$ gained by the ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$ freefall must be used to accelerate the ${}_{2}^{3}\mathrm{He}$ atom to a speed $v_{3He} = \sqrt{2gh/\zeta} = v/\sqrt{\zeta}$, namely $\zeta m v_{3He}^2/2 = mgh$, so that ${}_{2}^{3}\mathrm{He}$ can reach the height of h because it accelerates faster in gravity. In other words, assuming the gravitational acceleration for ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$ is g, then the gravitational acceleration for ${}_{2}^{3}\mathrm{He}$ should be g/ζ instead of g. To be more generic, all atoms, including ${}_{1}^{2}\mathrm{D} + {}_{1}^{1}\mathrm{H}$, should take their own ζ factor into account to evaluate their gravitational accelerations as g_0/ζ where g_0 is the lowest hypothetical gravitational acceleration experienced by the simplest proton-electron pair whose binding energy is zero. From this perspective, all atoms will have different gravitational accelerations depending on their ζ values, which are dependent on their nuclear mass deficit values. This is also evident for the gravitational observation of free neutrons in the COW experiment by way of quantum interference. As the precision of the COW experiments is improved, the theoretical expected value of the factor $q_{grav} = 2\pi\lambda m_n^2 g/h^2/(1+\epsilon)$ were found to be always about 0.8% larger than the experimental values, and no satisfactory explanations were able to interpret this difference and no one suspected the freefall acceleration constant g can contribute to the difference. But when considering the effects of nuclear mass deficit on inertial mass and gravitational acceleration, this difference is actually theoretically expected: existing theories take for granted to use g measured from average atoms for free neutrons. The acceleration for average atoms should be $g = g_0/\zeta_{avg}$ where ζ_{avg} is based on average binding energy of approximately 8 MeV per nucleon with a value of $\zeta_{avg} \approx 1 - 8/931.49 = 0.9914$, while the free neutron must have a relatively low binding energy which leaves a ζ_n close to 1 (details of the binding energy of neutron modeled as a proton-electron composite is another topic and will be addressed in separate papers), namely $g_n \approx g_0 = g\zeta_{avg}$. So the faster freefall acceleration $g = g_0/\zeta_{avg} \approx 1.0086 g_0$ for average atoms was mistakenly used for the slower free neutrons whose acceleration is $g_n \approx g_0$, making the theoretical value of q_{grav} appear to be 0.86% larger than actual measurement. The correct theoretical factor should then be $q_{grav,n} = 2\pi\lambda m_n^2 g_n/h^2/(1+\epsilon) \approx q_{grav}\zeta_{avg}$. This equation will make the COW experiments agree better with the correct theoretical expected value. In this case, the equivalence principle offers no help because it has no idea that different particles should have different gravitational accelerations depending on the internal binding energy.

6. Discussion about the flaws of equivalence principle

So much has been said about the various flaws associated with equivalent principle, especially the fatal one leading to the violation of energy conservation. But why the flaws of equivalence principle weren't noticed by generations of physicists and why equivalence principle has been claimed to be experimentally validated over and over up to 1 part in a quadrillion? There are many possible reasons. (a) The fact that Einstein's relativity theories have been so successful in explaining many relativistic effects along with the absence of comparable alternative theories makes the underlying equivalence principle appear validated automatically, even though relativity theories are not directly derived from equivalence principle. For this reason, no one would doubt that the underlying equivalence principle might have issues, therefore any experiments threatening the equivalence principle would simply be overlooked or disapproved or even prohibited as in the case of Szász's freefall experiment performed in the ZARM drop tower. Any theories that doubt or deviate from the equivalence principle will not be peer reviewed and published, resources will only be dedicated to researches supporting the equivalence principle, there is no financial or theoretical motivations to do otherwise. (b) The tremendous success and breakthrough of classical physics began with the observation that all objects should fall at the same acceleration regardless of weights and compositions. It enlightened humankind to break away from the faulty mindset that heavier objects fall faster than light objects. Trying to differentiate gravitational accelerations for different atomic compositions will appear unwise and ignorant of the achievement of physics and will be considered erroneous. (c) As analyzed previously, freefall acceleration is dependent on the ζ factor, the so called inertial-to-gravitational mass ratio. The ζ factors are approximately the same for most common atomic compositions, the difference is mostly on the order of one thousandth or less. So all objects will fall at approximately the same acceleration, giving the illusion that the ratio of inertial-to-gravitational mass is always the same, leading to the impression that inertial mass is equivalent to gravitational mass. The minute difference caused by different ζ factors can be easily overlooked or overwhelmed by other factors such as air friction without appropriate theoretical guidance. There are practical obstacles to measure freefall acceleration in high precisions. Perfect freefall condition is very difficult to establish. It requires expensive vacuum. The freefall cannot last very long because the required height grows unachievable parabolically with time. The freefall is also very damaging and not easy to repeat promptly. Without a good theoretical purpose, all these hurdles make precise measurements difficult. (d) High precision experiments that claim to prove the equivalence principle up to 1 part in a quadrillion further make high precise gravitational acceleration measurement appear unnecessary. Unfortunately, those experiments never directly measured freefall, typically through indirect effects of gravitational accelerations involving sensors set up in very complicated feedbacks and calibration processes. Without these feedbacks and calibrations, there is no way to reach the claimed high level of precisions for the very weak gravitational interaction. But the feedbacks and calibrations could have inadvertently canceled out the true inequivalence signals due to the lack of thorough understanding of inertial and gravitational masses, thereby invalidating the high precision claims. It is very hard to determine if the claimed equivalence is actually the nulling consequence of the feedback cancelation. For example, the MICROSCOPE satellite experiment used the feedback from the accelerometer to drive thrusters so that the satellite could achieve a drag-free orbit, but this could accidentally cancel out the sought-after non-equivalent effect. (e) It should be understood that the relativity theories are indirectly related to equivalence principle: if one is wrong, then the others are probably wrong, if one is faulty, the others are also susceptible. Vice versa, in order to prove one of them is correct, the others must also need to be correct. Same thing for equivalence principle and relativity theories. Because some predictions made by equivalence principle look approximately right such as the universal freefall acceleration, it gives the wrong impression that itself and other related theories must also be right. Einstein's special and general relativity theories essentially manipulate space and time mathematically to fit relativity effects in the classical physics framework where the Newtonian gravitational theory works perfectly without worrying about the inertial mass being varied by near speed of light or by large nuclear binding energies. Because physics is continuous and differentiable mathematically, the mathematical fitting of Newtonian physics will be approximately correct even it violates the conservation of energy or other physics. This means that even equivalence principle and the relativity theories are faulty, but it doesn't mean all the predictions based on the mathematical fitting are not approximate more or less. Some of the predictions are actually quite reasonable. For example, the gravitational time-dilation observed with atomic clocks at different heights clearly match the experimental observations. However, the right prediction of a theory shall not be considered as the ultimate validation of the theory. If there is fault in the theory, the theory remains faulty regardless of the correct prediction. The gravitational time-dilation can well be viewed as the result of variation of inertial mass of electrons, to whom the atomic clock's frequency is proportional, owing to the gravitational binding energy just like the variation of inertial mass of atoms owing to the nuclear binding energy. This unified view of variable inertial mass can not only perfectly explain the time-dilation effect without the perplexing manipulation of spacetime which inadvertently disturbs other physics such as energy, but also unifies gravity as a true conservative force that can affect inertial mass through binding energy similar to nuclear force and electric force. Moreover, it works coherently with quantum mechanics which specifies that atomic clock frequency is proportional to electron's inertial mass.

7. Conclusion

The equivalence principle has a very fundamental flaw in that it will lead to the violation of energy conservation. Making inertial mass equivalent to gravitational mass and the concept of universal gravitational acceleration is essentially no different from classical physics developed more than 300 years ago, which doesn't differentiate gravitational mass and inertial mass and doesn't foresee the variation of inertial mass through motion and binding energy. Equivalence principle fails to theoretically investigate the relativistic effects of varied inertial mass by nuclear binding energy when nucleons combine. Equivalence principle deviates from classical physics by making gravity a non-conservative force. This leaves a theoretical loophole where energy can be created by the difference in gravitational potential energy when atoms fall before nuclear fusion and rise back after nuclear fusion if the gravitational acceleration were universal. Regardless of some of the successes of Einstein's relativity theories, the equivalence principle is fundamentally faulty. Various experiments indicate that gravitational accelerations are different for different atomic and particular compositions, including the pendulum measurements using water and wax by Bessel and Du, the freefall experiment using different elements by Szász's and the quantum interference of free neutrons by COW.

8. References

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