NATURE OF INERTIAL MASS
AND ITS INFLUENCE ON PHYSICS

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Abstract

The inertial phenomenon whose characteristic quantity is that the inertial mass is one of the natural phenomena known soonest but its nature has so far still been a big scientific enigma. On the basis of analyzing trends of cognizing the definition of inertial mass from the past up to present, the author has found another approach to the nature of this phenomenon, that is the limited time of all processes of energy exchange. In the mechanics, the finiteness of the time of energy exchange leads to the motion of the body with the limited acceleration. It does prove the portion between the potential field force and the motion acceleration of the body in the potential force field, that is a constant entity for each body, not depending on its motion; that is the inertial mass that has been hiding for a long term. Thanks to that, it is also to accurate the law of freely falling body and the principle of equivalence is also a long term enigma up to date. In addition, it has developed the general laws of dynamics for all frames of reference, not only for the inertial frame of reference.

Keyword*: Inertial mass, gravitational mass, principle of equivalence, the Galileo's law of freely falling body, Newton's laws.*

I. Introduction

The inertia, one hand, is the phenomenon against the motion of an body when it is acted upon a certain external force and, on the other hand, it is the maintenance status of uniform motion in a straight line of that body – it is one of the natural phenomena known soonest (from the time of Aristotle [1]), but its nature is also one of the most secrets, and although it has gone up and down; so far it has left open. Somewhere and somehow, research works at the end of the XX century and at the beginning of the XXI century, have been conducted endlessly [2-11]. However, so far, to characterize this phenomenon, people are still satisfied with the concept – "inertia by oneself" is characterized by the "inertial mass" $\tilde{M}$ under the Newton's second law:

$$\mathbf{F} = \tilde{M}\mathbf{a}_F \qquad (1)$$

here $\mathbf{a}_F$ – it is the acceleration that the body has when it is acted upon the force $\mathbf{F}$. It is said that when there is a force of outside impact on the body, in "the inner" body there shall appear a bearing force called "the force of inertia":

$$\mathbf{F}_q = -\tilde{M}\mathbf{a}_F. \qquad (2)$$

The symbol "–" in the Eq. (2) shows that the direction of the inertial force is opposite to the direction of the motion acceleration of the body, and $\tilde{M}$ is the characteristic quantity for the *inertness* of the body and it is the same as the gravitational mass – characterizing its gravity. Therefore, the concept "force of inertia" itself is hereby insufficiently shown. The simple reason is, in the nature it is accepted to become existence and there are only four types of fundamental interacting force: gravitational,

electromagnetic, strong and weak. Other forces include such as friction force, interfacial tension, centripetal force,…in fact those are different exhibits of the gravity or electromagnetic force; it is put into the mechanics only with the convenient reason and not having a different nature. While the inertial force seems to have a "closed" relation with the gravity, but it does seem from the electromagnetic force. Mentioning that "closed relation" is because it is not known why the inertial mass is always as same as the gravitational mass *M* – the characteristic quantity features the gravity of all bodies in the Newton's law of universal gravitation:

$$F_h = \gamma \frac{M_A M_B}{r^2}. \tag{3}$$

And Einstein used this equality (it is also called the principle of equivalence) as postulate to build the general relativity. Mentioning "it does seem" is because according to the calculation of many authors the electromagnetic force itself causes the phenomenon of inertia, but the electromagnetic force complies with the 3 law of the mechanical dynamics, but the inertial force does not comply with. Furthermore, the electrical charge of different particles remains same but they may have totally different inertial masses. That does not mention up to assumptions on independent existence of the inertial force that Kant critically opposed or saw the inertial force as "virtual force" under the d'Alambert's principle causing much debate…

In brief, although the mechanics (including classical and relative) is wholly constructed on the base of inertial phenomenon (with the assistance of inertial frame of reference), but the nature of that phenomenon is still vague. Whether it makes the physics acknowledge "metaphysics" as the only end? If the nature of the "enigma" is shown, there shall be likely many physical surprises?

II. Nature of inertial phenomenon

1. Brief analysis of recognition tendencies of inertial phenomenon

Thoroughly studying the inertial phenomenon from the past up to present, there are obviously 3 tendencies as follows:

a/ The first tendency is believed that the inertia of the entity has the inner cause inside the object – "inertia by oneself" as mentioned. This tendency is at present absolutely prevailing for two different branches:

+ Inertial mass is the measurer of material quantity contained in the object, leading to the inertial phenomenon – the more the quantity of material is the harder the object changes the status of motion. Almost famous scientists from the ancient time to the present agreed to this viewpoint such as: Aristotle, Galileo, Newton, Maxwell, Einstein, Hawking…

+ Inertial mass is the measurer of inertia or attractiveness of the object.

Although the approach is different, in fact, they are all in the form of visual recognition: in daily life, the heavier an body is, the harder it does move. However, herein, in this form or that form, the equivalence is already recognized between

"inertial mass" and "gravitational mass", and whether the cogency is visualized as "the Sun goes around the Earth" in a certain time or not?

b/ The second tendency is said that the inertia of an body does originate from the outside of the body. Under this tendency, there is ever a Mach's principle rather famous for a period – The inertia of a body is caused by the interaction of that body with remote stars in the universe; thanks to that it is possible to explain the phenomenon "Foucault's pendulum" – its flat surface of oscillation is independent from the rotation of the Earth. Though it is said "there is a cause from the outside" but Mach did secretly attach that cause with "remote stars" and forgot that their interaction of attractiveness with entities on the Earth is so small compared with the gravity of the Earth that it can be abandoned. For example, a star such as Alpha star most near the Earth has the same mass as the one of the Sun and it does only cause a gravitational force as one tenths thousand billion times compared with the gravity of any object on the Earth. At that time whether it is decisive or not?

Furthermore, there is also a concept that the inertia is caused by the interaction of the substance with the ether – one kind "special substance" filling up the vacancy between bodies in the cosmos with legendary natures, even in the recent time, it does also re-make a new interaction – interaction with ether. Whether this is the fifth interaction of the matter? And from here, the unification of interactions becomes further.

c/ The third tendency made by Sain-venant is believed that the inertia does not have the independent origin and it is only the characteristic of kinematics – defined through the variation of speed or motion acceleration of the body – that is from simply subjective factors of motion acceleration. But doing that is only a way of avoiding the actuality – what has made the motion speed of the body only change at a certain rate, that is causing the limited acceleration? From the above analyses, we can draw some significant comments.

Although the tendency is said that the inertia has the inner cause in every body – that is the measurer of contained material quantity – supported by almost scientists but the nature does show the most ambiguity.

The development of the awareness process is from the lively visualization to the discrete thought, from the discrete thought to the awareness. In the daily life, the inertia is recognized through the phenomenon of trip and fall when running, swinging when sitting in a vehicle, moving a heavy body…people ask what happens if not "trip", if the vehicle steadily runs on the plain road without friction, if the object does not resist the motion? From here, people come to the Galileo's principle of inertia or Newton's first law states that an object will remain at rest or in uniform motion in a straight line unless acted upon by an external force. The motion like that is also called "the inertial motion". According to this awareness, the mechanical state of a material point can be defined with 3 space coordinates (x, y, z), 1 time coordinate (t) and its inertial mass (m_q). From here, it is to allow the existence of a isolating material point – not interacting with any other body.

In fact, closely speaking, if there is no interacting force on a body (non-attractive, nonmagnetic, non-strong and non-weak) and the body does not impact any

other body, it is expressly nothing to say - whether the body is stationary or moves with the endless speed - for the "body", the surrounding world does not exist and for the world, the "body" does not exist. Even the "direct collision" cannot happen whether "that body" hits another body! And finally, that so-called "entity by itself" cannot exist.

In the fact daily seen, all motion phenomena of the body are in the interaction range of gravitational force - at first it is of the Earth, and then it is of the Sun and other bodies in the universe. An ideal condition as mentioned above cannot be realized. How can people believe the inertia is only from the internal cause (as there is an available "inertial mass") and that is not the result of interaction process of attracting other space bodies in the relatively deep universe as proposed by Mach? However, Mach highlighted the cause - active force from the outside of the body, but only expecting remote stars in the universe with the very small active force and it is possible to make omission compared with the gravitational force of the Earth - so whether the active force Mach mentions has a different nature?

So the result is all the awareness of inertia phenomenon and so far it is separated from the inner cause and the objective cause, isolating the "specific" and the "general" - a method of non-dialectic awareness.

2. Another approach to the nature of inertia

a/ Remarks

At first, we can try to use the method of counter evidence, specifically the existence of an body is assumed without inertial mass or exactly speaking that there is no phenomenon of inertia and what happens? But what is the non-inertial phenomenon? it means that if impacting that body, the motion speed can suddenly change from this value to that value - equivalent to the unlimited acceleration? But the influence means that it is the exchange of energy and like that the time of energy exchange is zero? This is impossible! Therefore, the deep nature of the inertial phenomenon is mainly *the finiteness of energy exchange time* between all bodies in the nature. This time shall mainly depend on type of energy required to exchange. For example, the exchange of mechanical energy often occurs later than the exchange of electric energy. Therefore, it is possible to say that each kind of different energy shall be equivalent to the different capacity of exchange, that meant it is faster or slower. The change of mechanical motion speed is step by step and not suddenly happening because of one of the consequences of the above energy exchange process and for that mechanical motion it is the "acceleration" of motion. On the other hand, equivalent to each kind of interaction there shall be the definite speed of energy exchange and specific for kind of interaction we call the "acceleration". With 4 basic interactions of the nature, we have 4 kinds of motion acceleration. However, it is seen that with the same body in the same kind of certain interaction can move with different accelerations, while different objects can move with the same acceleration so the acceleration cannot expose the feature for itself in this aspect. In brief, we need to find a quantitive whether it is the constant during the motion process to feature that body in motion under the action of fundamental interacting force as considered.

From observing the phenomenon of freely falling body in the gravitational field of the Earth, we see that when the higher the gravitational force **F** is, the higher the acceleration of free fall **g** is. This makes us think of a capacity whether it is the ratio of 2 covariance values:

$$\frac{\mathbf{F}}{\mathbf{g}} = \frac{F}{g} \tag{4}$$

that can meet the above requirement? Here the ratio (4) in principle can be called as *"inertia coefficient"* or a certain same name like that; it is not really the *inertial mass* although it is of the same dimensionality as the dimensionality of the mass. To avoid the complication, we still call this ratio as *the inertial mass* and denoted as *m* but it is noted that it is not an "available entity" inside the body as same as the gravitational mass. We shall check whether it is. At first, because hereby it is related to the so called "motion" so it is necessary to know the motion compared with "what", or speaking under the language of mechanics it is compared with what frame of reference? The mechanics so far (leisurely mentioning the general theory of relativity) can be only studied on motion when considering them in what called "inertial frame of reference", that meant the frame of reference of uniform motion in a straight line in another "inertial frame of reference"! - a concept that carries the intuition but it is very vague on the aspect of form logics - getting the concept required to be defined (inertia) to explain it for that concept! We shall try not to go on the way. To set up the frame of reference, we have 2 options: or it is to place on bodies that relatively move compared with each other, or it is to place on their general center of inertia. Selecting this frame of reference, in principle, does not impact basic interacting forces (so it is called "fundamental" to distinguish it with other forces) - that bodies expressly exchange the energy with each other does not depend on what we are observing or not, being aware of it or not. However, because the acceleration is the variation speed of the motion speed that the motion speed of the body, of course, depends on the frame of reference that we observe that motion so the "acceleration" also have to depend on the selected frame of reference. We shall consider the movement in both frames of reference with the interaction that is the gravitational force defined under the law of gravitation (3).

b/ In case the frame of reference placed on moving bodies

It is assumed that there is the reference frame with the origin of grid located in the center of the body *A* with the axis *0X* coinciding with the central connecting line of 2 body shown in Figure 1a. At that time, it is to calculate the dimension of mentioned vectors, we rewrite the Eq. (3) in the form of vector:
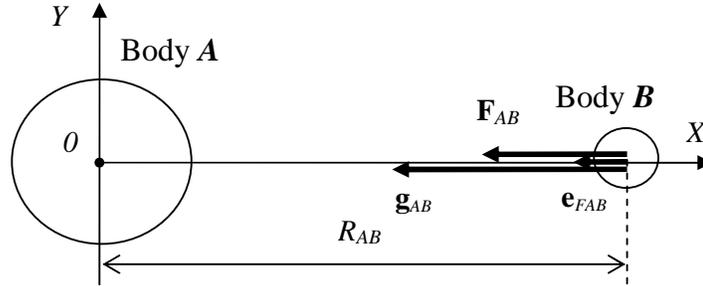
$$\mathbf{F}_{AB} = \gamma \frac{M_A M_B}{R_{AB}^2} \mathbf{e}_{FAB}, \tag{5}$$

here $\mathbf{e}_{FBA}$ is the unit vector with the direction in coincidence with the vector of active force $\mathbf{F}_{AB}$. If counting the relative motion acceleration of the body *B* equal to:
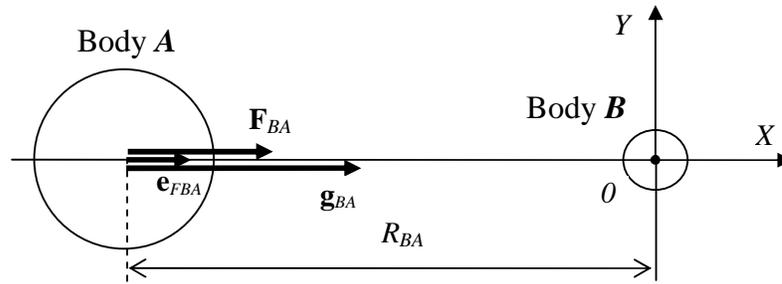
$$\mathbf{g}_{AB} = \frac{d^2 R_{AB}}{dt^2} \mathbf{e}_{FAB} \tag{6}$$

we can define the inertial mass of the body **B** (as shown in Figure 1b) in the gravitational field of the body **A** under the formula (5), specifically it is:

$$m_{AB} = \frac{F_{AB}}{g_{AB}} . \qquad (7)$$

a) Frame of reference placed on the body **A**.

b) Frame of reference is placed on the body **B**.

Figure 1. In case the frame of reference is placed on moving bodies.

Similarly like that, when the frame of reference is placed at the gravity center of the body **B**, we can write the same expressions as (5) - (7), only changing the order of the subscript "$_{AB}$" into "$_{BA}$":

$$\mathbf{F}_{BA} = \gamma \frac{M_A M_B}{R_{BA}^2} \mathbf{e}_{FBA} , \qquad (8)$$

$$\mathbf{g}_{BA} = \frac{d^2 R_{BA}}{dt^2} \mathbf{e}_{FBA} , \qquad (9)$$

$$m_{BA} = \frac{F_{BA}}{g_{BA}} . \qquad (10)$$

Comparing the Eq. (5) and Eq. (6) with the Eq. (8) and Eq. (9), we remark that although 2 different bodies at the gravitational mass ($M_A \neq M_B$) but the force of this body impacts on that body or the acceleration of relative motion between them are still equal in value and only different in direction:

$$\mathbf{F}_{AB} = -\mathbf{F}_{BA} , \qquad (11)$$

$$\mathbf{g}_{AB} = -\mathbf{g}_{BA} \qquad (12)$$

and this shall lead to the consequence that their inertial mass defined under the Eq. (7) and Eq. (10) is also equal:

$$m_{AB} \equiv m_{BA} = m \; . \tag{13}$$

Therefore, we shall call these quantitives as the general inertial mass of 2 bodies moving in the gravitational field. The question put forth is how this inertial mass has correlation with gravitational masses of 2 bodies? And whether they can ensure the constant in the motion of bodies as mentioned or not? To do this, we shall use the frame of reference of inertial center as said.

c/ The frame of reference is put at the general inertia center of 2 bodies.

We shall consider the case the frame of reference is put at the center of inertia or the general mass center of 2 bodies shown in Figure 2. When it is, the active force is put on each body, as known, it does not change and therefore, it is still defined under the Eq. (5) and Eq. (8), however, their motion acceleration in this frame of reference shall be different and marked as g_B and g_A and called as the absolute acceleration. But for the acceleration of relative motion between them, in principle, it is not possible to depend on the frame of reference so we must have:

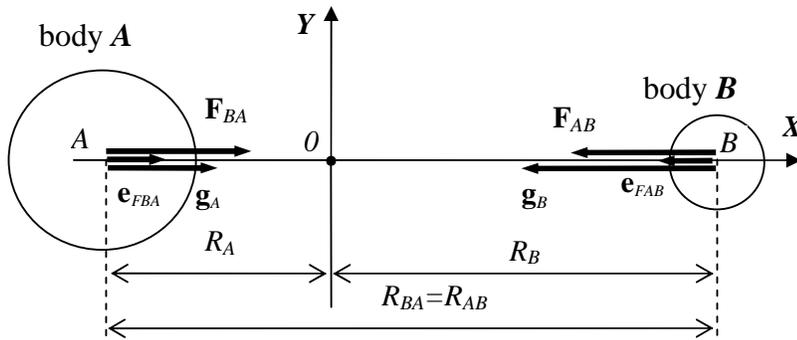$$g_A + g_B = g_{AB} = g_{BA}. \tag{14}$$

Figure 2. The frame of reference is put at the general mass center of 2 bodies

When it is, for the inertial mass of bodies A and B in the mass center frame of reference, we can write the same as the Eq. (7) and Eq. (10) and it is only to change the relative acceleration with the absolute acceleration:

$$m_A = \frac{\mathbf{F}_{BA}}{\mathbf{g}_A} \; ; \quad m_B = \frac{\mathbf{F}_{AB}}{\mathbf{g}_B} \tag{15}$$

and called as the *special inertial mass* of each body. It is possible to rewrite Eq. (15) in the indirection form as vector quantities hereby only lie on the same straight line and the notation of acceleration is already calculated in the Eq. (14):

$$g_A = \frac{F_h}{m_A}, \quad g_B = \frac{F_h}{m_B}, \tag{16}$$

herein $$F_h = F_{AB} = F_{BA} . \tag{17}$$

On the other hand, from the concept of inertial center, we have:

$$m_A V_A = m_B V_B . \tag{18}$$

We can rewrite in the derivation form of the path:

$$m_A \frac{dR_A}{dt} = m_B \frac{dR_B}{dt} . \qquad (19)$$

After reduce *dt*, we integrate both members of Eq. (19),

$$m_A \int dR_A = m_B \int dR_B$$

we shall collect:

$$m_A R_A = m_B R_B . \qquad (20)$$

Furthermore, from the general mass center concept of the two bodies system we have:

$$M_A R_A = M_B R_B \qquad (21)$$

as the general mass center of 2 bodies can also coincide with their inertial center. We divide both members of Eq. (21) in 2 correspond members of Eq. (20), we have:

$$\frac{M_A}{m_A} = \frac{M_B}{m_B} = k . \qquad (22)$$

The coefficient *k* features the difference between the gravitational mass and special inertial mass that we shall still mention hereafter. Besides, we can rewrite Eq. (7) and Eq. (10) in form:

$$\mathbf{F}_{AB} = M_B (\gamma \frac{M_A}{R_{AB}^2} \mathbf{e}_{FAB}) = M_B \mathbf{g}_{\gamma A} , \qquad (23)$$

$$\mathbf{F}_{BA} = M_A (\gamma \frac{M_B}{R_{BA}^2} \mathbf{e}_{FBA}) = M_A \mathbf{g}_{\gamma B} , \qquad (24)$$

herein we mark

$$\mathbf{g}_{\gamma B} = \gamma \frac{M_B}{R_{AB}^2} \mathbf{e}_{FAB} , \quad \mathbf{g}_{\gamma A} = \gamma \frac{M_A}{R_{BA}^2} \mathbf{e}_{FBA} , \qquad (25)$$

and calling as *absolute intensity* of the gravitational field of the correspond body. As γ is the feature of the gravitational field so we use this sign as the subscript of the field intensity – $\mathbf{g_y}$ to distinguish with the motion acceleration of the body in the potential force field $\mathbf{g}$, and the subscript "*A*" or "*B*" are adherent and directly relate to the body causing the correspond gravitational field. After replace Eq. (23) and Eq. (24) respectively in Eq. (16) then making the change, we have:

$$\mathbf{g}_A = (\frac{M_A}{m_A}) \mathbf{g}_{\gamma B} = k \mathbf{g}_{\gamma B} , \qquad (26)$$

$$\mathbf{g}_B = (\frac{M_B}{m_B}) \mathbf{g}_{\gamma A} = k \mathbf{g}_{\gamma A} , \qquad (27)$$

The Eq. (26) and Eq. (27) include the relation between the motion acceleration of the body under the interaction of the gravitational force in the mass center frame of

reference, that meant the absolute acceleration with the absolute intensity of the gravitational field.

d/ Definition of general inertial mass

Replace Eq. (16) into Eq. (14) and make the change we have:

$$g_{AB} = g_{BA} = F_h \left(\frac{m_A + m_B}{m_A m_B} \right). \tag{28}$$

Replace the Eq. (28) into the Eq. (5) or Eq. (10), we receive:

$$m_{AB} = m_{BA} = \frac{m_A m_B}{m_A + m_B}. \tag{29}$$

The formula (29) provides us a relation between the general inertial mass defined in the frame of reference is put on one of two bodies with separate inertial masses defined in the mass center frame of reference or their inertia center. Replace these expressions, after omitting the feature of vector, into Eq. (14), we have:

$$g_{AB} = g_A + g_B = k g_{\gamma AB} = k g_{\gamma BA}, \tag{30}$$

with:
$$g_{\gamma AB} = g_{\gamma BA} = g_{\gamma B} + g_{\gamma A} \tag{31}$$

and called as *relative intensity* of the general field of 2 bodies. Change correspond values from Eq. (25) into Eq. (31) and next change in Eq. (30), reduce it, we have the expression to define the relative acceleration depending on the gravitational mass of entities:

$$g_{AB} = g_{AB} = \frac{k\gamma(M_A + M_B)}{R_{AB}^2}. \tag{32}$$

When it is, change Eq. (32) in Eq. (7) and Eq. (10), we have:

$$m_{AB} = m_{BA} = \frac{M_A M_B}{k(M_A + M_B)}. \tag{33}$$

From the Eq. (33) we can see bodies with different gravitational masses shall fall differently. However, in the earth condition, the difference is very small and specifically if M_B is considered as the gravitational mass of the object and M_A is the gravitational mass of the earth:

$$\delta g_{BA} = \frac{g_{BA} - g_B}{g_{BA}} \approx \frac{M_B}{M_A}. \tag{34}$$

In fact, with the deviation 10^{-24} cannot be found in the experiment "freely falling body" of Galileo (see Figure 3a). This is also equivalent to the acceptance *k=1* as the frame of reference put on the earth can be also regarded as the coincidence with the general mass center frame of reference of the falling body (**B**) and the Earth (**A**), therefore, with the deviation 10^{-24}, it is also possible to say Galileo "measured" the special inertial mass m_B and the absolute acceleration g_B, that is not the general inertial mass m_{BA} and the absolute acceleration g_{BA}. It meant that by testing, it is possible to

confirm *k=1* with the smaller deviation than 10^{-24}. The matter is different if in the "test" it is possible to use an body with the same gravitational mass as the gravitational mass of the Earth (see Figure 3b), when it is, the acceleration that Galileo measured is likely two times as high as the acceleration of the freely falling body in the experiment that he tested on Pisa tower, exactly speaking that he would measure the relative acceleration calculated under the formula (27). And the matter shall be expressly reversed if "the test body" of Galileo has the same gravitational mass as the Sun for example (see Figure 3c), at that time, the free fall acceleration that Galileo measured is likely to be multiplicative compared with the acceleration that he measured with iron balls. It meant that *the law of freely falling body* made by Galileo is only accurate when testing objects have the much smaller gravitational mass than the gravitational mass of the Earth, which meant when all objects can be regarded as only falling with *their absolute acceleration* themselves; and *the principle of equivalence* – the inertial mass is equivalent to the gravitational mass and it is only accurate in the mass center frame of reference (the virtual frame of reference imaged by us), which meant that it is only accurate to the special inertial mass while all processes of dynamics including the exchange of energy among objects only related to the frame of reference actually is put on moving bodies, that meant to the general inertial mass.
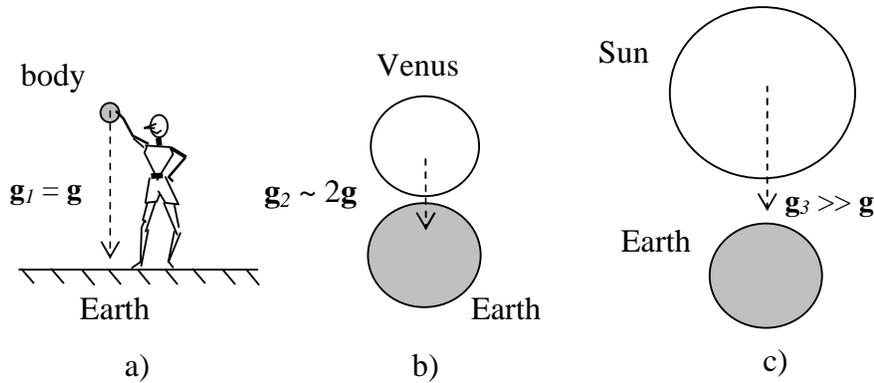

Figure 4. Different bodies shall have different falls

In brief, then for accurate calculations, it is required to change *the inertial mass* defined under Eq. (7) and Eq. (10) with *the general inertial mass* Eq. (33) with *k=1* and omit the subscript for both cases, specifically it is:

$$m = \frac{M_A M_B}{M_A + M_B} \tag{35}$$

and the equivalence is to distinguish *the absolute acceleration* defined under Eq. (28) and Eq. (29) with *the relative acceleration* defined under Eq. (32), also delete the subscript:

$$g = \frac{\gamma(M_A + M_B)}{R_{AB}^2} \quad . \tag{36}$$

Therefore, it is possible to rewrite the equation (30):

$$g = g_{\gamma AB}, \tag{37}$$

that meant *the relative acceleration* of the body moving in the gravitational field is equal to *the relative intensity* of that field. Because this movement does not have any intervention of a third physical object so it is called as *free fall* and the Eq. (36) can be also called *the law of freely falling body* in the gravitational field instead of this Galileo's law of freely falling body and in fact it is defined under the expressions (28) or Eq. (29). Similarly like that, we can also rewrite the Eq. (7) and Eq. (10) in an only expression:

$$m = \frac{F_h}{g}. \qquad (38)$$

Therefore, the inertial mass can be seen to be defined under Eq. (4) or Eq. (38) although in the virtual frame of reference (see the Eq. (24)) or in the real frame of reference (see the Eq. (33)) for a definite kind of potential force field, specifically herein that is the gravitational field and it is always the definite quantity and only depending on constants of the potential force field (herein they are γ and gravitational masses M_A and M_B) although masses to define include the force and acceleration that all vary under the motion of bodies. Speaking otherwise, using the concept of definite inertial mass under Eq. (4) is expressly appropriate.

On the other hand, the expressions from Eq. (8) to Eq. (10) all written in the actual frame of reference put on any body of 2 bodies that interact each other, so in principle, it is possible to use to check test measurement results and furthermore, all processes of interaction between bodies can only occur on those bodies without dependence on wherever you are sitting to observe them, so it is only that *the general inertial mass* defined under Eq. (35) is really significant in physics, but the *special inertial mass* is only referred in calculation.

III. GENERAL LAWS OF DYNAMICS

1. The general second law of dynamics

From all above speaking, can see that to settle the inertial phenomenon, the factor "interacting force" between bodies must be prioritized – it is "common child" of bodies and it is also the factor to confirm the existence of all bodies in the universe and the factor "inertial mass" is only the derived quantity. On the other hand, we can see that the concept "inertia" of a body we still use to point out the phenomenon against the motion of that body when it is not directly blocked by others (because of the friction, the direct collision…), on the other hand, the inertia hereafter only relates to indirect interacting forces through the (general) space between bodies, those are 4 types of interacting forces as known, to distinguish with those direct forces that we call them *the potential field force*.

For the mechanical motion, the change of energy state under the influence of an interacting force **F** always exceeds the potential field force keeping the energy state of the body and the result is there is a phenomenon of inertia – body moving with the limited acceleration. The motion acceleration of the body shall therefore depend on these quantities. We can express *the general second law of dynamics* in form:

The motion acceleration of the body has the direct proportion with the composition of forces acting upon that body and it has the inverse proportion with the potential field force already binding it to the energy state; direction of the acceleration coincides with the direction of general active force. We have:

$$\mathbf{a} = k_f \frac{\mathbf{F}_\Sigma}{F_{tt}} = k_f \frac{\mathbf{F} + \mathbf{F}_{tt}}{F_{tt}}, \tag{39}$$

herein $\mathbf{F}_\Sigma$ - net active force of other bodies on the tested body; k_f – proportional coefficient. If the direct active force of other bodies is made on the body $\mathbf{F} = 0$, from Eq. (39) we can see that the motion acceleration of the body is only the motion acceleration of the body in the potential force field $\mathbf{g}$:

$$\mathbf{a} = \mathbf{g} = k_f \frac{\mathbf{F}_{tt}}{F_{tt}} = k_f \mathbf{e}_{Ftt}. \tag{40}$$

herein $\mathbf{e}_{Ftt}$ is the unit vector with the same direction as the one of the potential force field. It is possible to rewrite Eq. (40) in form:

$$\mathbf{g} = g\mathbf{e}_g = k_f \mathbf{e}_{Ftt} \tag{41}$$

with $\mathbf{e}_g$ is the unit vector with the same direction as the one of the acceleration $\mathbf{g}$. As $\mathbf{e}_g = \mathbf{e}_{Ftt}$ so it derives $k_f = g$, hence we rewrite Eq. (40) in form:

$$\mathbf{a} = g \frac{\mathbf{F}_\Sigma}{F_{tt}} = g \frac{\mathbf{F} + \mathbf{F}_{tt}}{F_{tt}}. \tag{42}$$

If note the Eq. (38), we can rewrite Eq. (40) in the similar form:

$$\mathbf{a} = \frac{\mathbf{F}_\Sigma}{m} = \frac{\mathbf{F}}{m} + \frac{\mathbf{F}_{tt}}{m} = \mathbf{a}_F + \mathbf{g}, \tag{43}$$

herein we mark:

$$\frac{\mathbf{F}}{m} = \mathbf{a}_F \tag{44}$$

as the element of motion acceleration of the body under the influence of the active force $\mathbf{F}$. From Eq. (44) we can derive the familiar expression:

$$m\mathbf{a}_F = \mathbf{F}. \tag{45}$$

However, it is notable that the Eq. (45) now is accurate to all frames of reference not like the Newton's second law (1) that is only accurate in the inertial frame of reference. The reason is because the inertial mass herein is defined under Eq. (4) and it is not "available" in each body, not including the "itself" cause so it does not relate to the concept "the motion is according to the inertia when there is no active force" and, on the contrary, it only exists when there is an active force – hereafter it is the potential field force and furthermore, it must be in the state of motion. In addition, based on the Eq. (2), we also can define the inertial mass m in a potential force of field through the net active force $\mathbf{F}_\Sigma$ and the general acceleration a. Equipment to 4 interactions of 4 potential field force as known, we can calculate under Eq. (4) and we have 4 types of inertial mass coded as follows:

m- inertial mass in the gravitational field;

m_d- inertial mass in the electrical field;

m_M, m_Y – inertial mass in the strong and weak nuclear fields.

In some cases the object does have the gravitational mass and the electric charge that all exist at the same time with the object and they are not separated so in principle we must say *the combined inertial mass* in the electrostatic – gravitational potential force field.
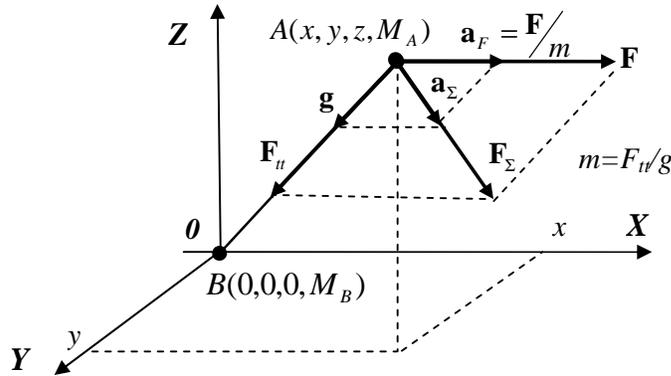

Figure 4. Express the general 2 law of the dynamics

Therefore, under the expression of the general 2 law of the dynamics Eq. (42), in lieu of the inertial mass of the body A, it is necessary to point out the potential force field of another body (B), creating its interacting force, for example if it is the gravitational field, it is required to provide the gravitational masses M_A and M_B as shown in Figure 4; if it is the electrostatic field, it shall provide the electric charges q_A and q_B.
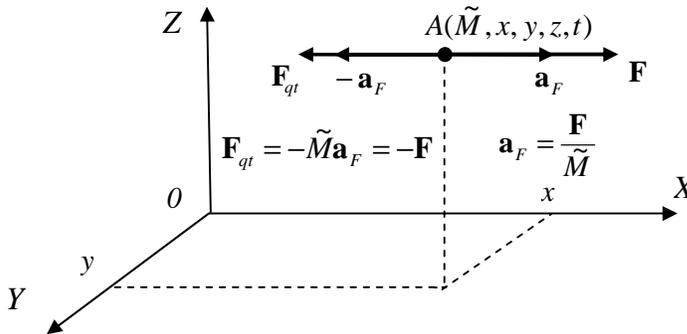

Figure 5. Express the Newton's 2 law and the d'Alambert's principle

While in the classical mechanics as well as the relative mechanics, they allow the existence of isolating object. The state of this object is regarded as totally definite if space coordinates (x,y,z) and the time (t) in a certain frame of reference with the same inertial mass ("oneself") $\tilde{M}$ is defined (see Figure 5). At that time, if the bodies is acted by the force **F**, we can write its equation of motion under the Newton's second law (1). The sign "=" in (1) must be understood as "equilibrium"; not "equal" because: two members of the equation belong to 2 independent objects – the right

member is the active force from the outside on the object; the left member contains kinetics parameters of the object itself.

But the force must be equal to the force not with any other quantity, we therefore have to put forth a concept that make many generations of physicists headache, that is the "inertial force" defined under the Eq. (2), herein the sign "=" can be understood with the exact meaning because two members of Eq. (2) belong to the same object, that is the object we are considering.

2. General law of inertia.

As remark to be made in head of the chapter II.2a: "...the deep nature of inertial phenomenon is mainly *the finiteness of energy exchange time* between all bodies in the nature", we may possibly find out that if energy exchange not be happened, then energy state of physical object will not change. On the other hand, in accordance with the general second law of dynamics (Eq. (42)), if net force on the body is equal zero, it's motion acceleration in the potential force field is equal zero, too. By combining those two remarks we can see that the state of zero net active force on the body similarly with non change energy state of the body, that is, in nature, for possiblity changing body energy state in some potential force field, necessitate a non zero net force on the body. From here, we have the new concept above as called the inertial motion: "*the inertial motion is the motion of the body in potential force field with a unchanged energy state*", and therefore, we can formulate general inertial law of dynamics is that:

"***The body remain at rest or in inertial motion in some potential force field if it is acted by an zero net force in this field***".

So, the renouncement of motion form into the body energy state rejected a demand of as called "inertial frame of reference" that is very indenfinite, brings about serious inconvenient as Einsstein had remarked: "We have the laws, but don't know what frame of reference the laws necessitate to convert into? and our physical castle seems to build in the air"[13]. Now, with the general inertial law of dynamics we can work in any frame of reference, and it is will generate a larger "corridor" for further development of physics. Obviously, our approach with purpose to reject inertial frame of reference is stricter than Einsteinian when he still taked maintenance of principle of equivalence "inertial mass is equivalence with a gravitational mass" for build of General Relativity, because that principle is only still consequence of the inertial frame of reference, and as we saw when this frame of reference is reject absolutely, principle of equivalence will not true no more.

III. Conclusion

1. The inertial mass does is not available feature, an "availability" inside any body or also called "inertial mass by oneself" but that is a property of dynamics defined thanks to the interaction of the body in the potential force field and the motion acceleration in that potential force field.

2. Totally there is no equivalence between the inertial mass and the gravitational mass and the principle of equivalence is only true in the mass center frame of reference of bodies systems and, in fact, it is the virtual frame of reference

because hereafter it is only a simply geometric point without any physical objects so that it is possible to place the frame of reference.

3. The Galileo's law of freely falling body is only true to bodies that have the small mass when they fall in the gravitational field of the body with the much more gravitational mass. For example in the range of tests on the Earth, the difference is only 10^{-24}. In the general case, different bodies shall fall differently.

4. For any frame of reference, it is not necessary to be the inertial frame of reference; it is required to apply the general laws of dynamics and when it is, the Newton's second law becomes a separate case when it is possible to omit the interaction of potential field force on that body compared with the force directly acting upon it. Herein it is noted to bypass the potential field force like that and the inertial mass that is the proportion between that potential field force and the motion acceleration still remained unchanged.

5. The concept of "inertial motion" is not understand as the form of motion (that is at rest or uniform motion in a straight line) but with the mean of an unchanged energy state, and therefore, Newton's law of inertia will be change by general inertia law of dynamics.

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