A Special-Case Test of Newton's Second Law of Motion*

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"*A Mechanical Test of the Equivalence Principle*" [1] has not been successfully refuted in the 17+ years it has been in the public domain – in fact it has been mostly ignored – especially by orthodox physics. It is only fair to say, however, that a satisfactory explanation of the anomalous 'energy loss' documented there has also not been completely explained either. By way of a more straightforward physical experiment, the current paper seeks to demonstrate a possible explanation of the former experiment and also shed new light on the conventional classical laws of motion (non-relativistic and non-quantum). Newton's Second Law, as applied to linear acceleration (where *work* is being performed by electromagnetic forces), is directly pitted against the acceleration of gravity. The results leave little doubt that the cornerstone of General Relativity is incorrect; but more importantly, the results demonstrate that Newton's Second Law, in this situation, is also incorrect by a significant amount (approx 3.0% of the projected inertial force of a test mass having *work* performed on it by a falling gravitational mass, *i.e.*, having its kinetic energy increased horizontally). We cannot escape the conclusion that it is a grave error to always treat gravitational mass and inertial mass the same. *** From 2009**

Introduction

The prime motivation for testing Newton's well-established Second Law of motion (for non-relativistic speeds and non-quantum sizes) came from the unanswered questions raised by [1], still unresolved 17 years later. Chief among the questions is whether there exists a simpler way of demonstrating the anomalous energy loss suffered by the magnetic 'Hover-Craft' (HC) revolving through a circular magnetic field keeping it suspended vertically and being activated by the pseudo-gravity of a spinning centrifuge which is equivalent to a constant vertical gravity field? Admittedly [1] contains some comparatively exotic (yet still rather simple) elements.

Another motivating factor was the realization (after years of contemplation) that if [1] indeed showed Einstein's Equivalence Principle to be untenable in a rather dramatic way, then classical mechanics was almost certainly being violated in some equally impressive way as well. This conclusion was reached owing to the fact that neither relativity nor classical mechanics allows for any residual changes to mass - like increased internal energy - caused by acceleration of rigid bodies other than increasing or decreasing kinetic energy for low speed motion. And by design (the Correspondence Principle), relativity essentially collapses to classical physics at low speeds and small amounts of gravitation. Consequently, if one is wrong at these slow speeds, the other will be also.

So, the overall objective of the current experiment was to find a way to eliminate the more esoteric features of [1] yet accentuate the direct comparison of real (rather than pseudo) gravitational acceleration against linear (and horizontal) acceleration of rigid mass having real *work* being done on it by electromagnetic forces increasing its kinetic energy. The critical point of the test, of course, was to see if any anomalous behavior, that would have to be considered non-classical, exhibited itself in the process.

Basic Test Configuration

Figure 1 shows the main features of the test apparatus. This is in essence a quite straightforward setup commonly depicted in basic physics and/or mechanical engineering textbooks [3] to illustrate the interaction of gravitational versus linear (and horizontal) acceleration. One big difference between our test evaluations and the textbook' is that we could not assume massless and frictionless pulleys, bearings and connecting strings. In fact, as we shall see, the devil is in these very details in order to gain a full understanding and do a comprehensive evaluation of the test results.

The Activator mass, M1, is shown suspended vertically along the left side of Figure 1. M1 is attached via a connecting wire over a pulley to the target mass or carriage, M2, shown sitting on a level runway extending horizontally across the drawing. The carriage is supported with three industrial grade roller bearings (NTN corp., pn Z0009), one in front and two in back. Using 3 rollers instead of 4 insures that all the rollers are in constant contact with the runway surface at all times. The empty carriage was designed to be as close to a 1 kilogram mass as possible and allow for the addition of seven precision weights in increments of a half a kilogram; this yields a range of 1.0 – 4.5 kilograms of mass for M2. Different activator masses were tried; but the primary one was a half a kilogram precision weight of the same kind as the seven used to load up the carriage. The carriage design and other test considerations will be discussed in greater detail in the Detail Descriptions Section later in this paper.

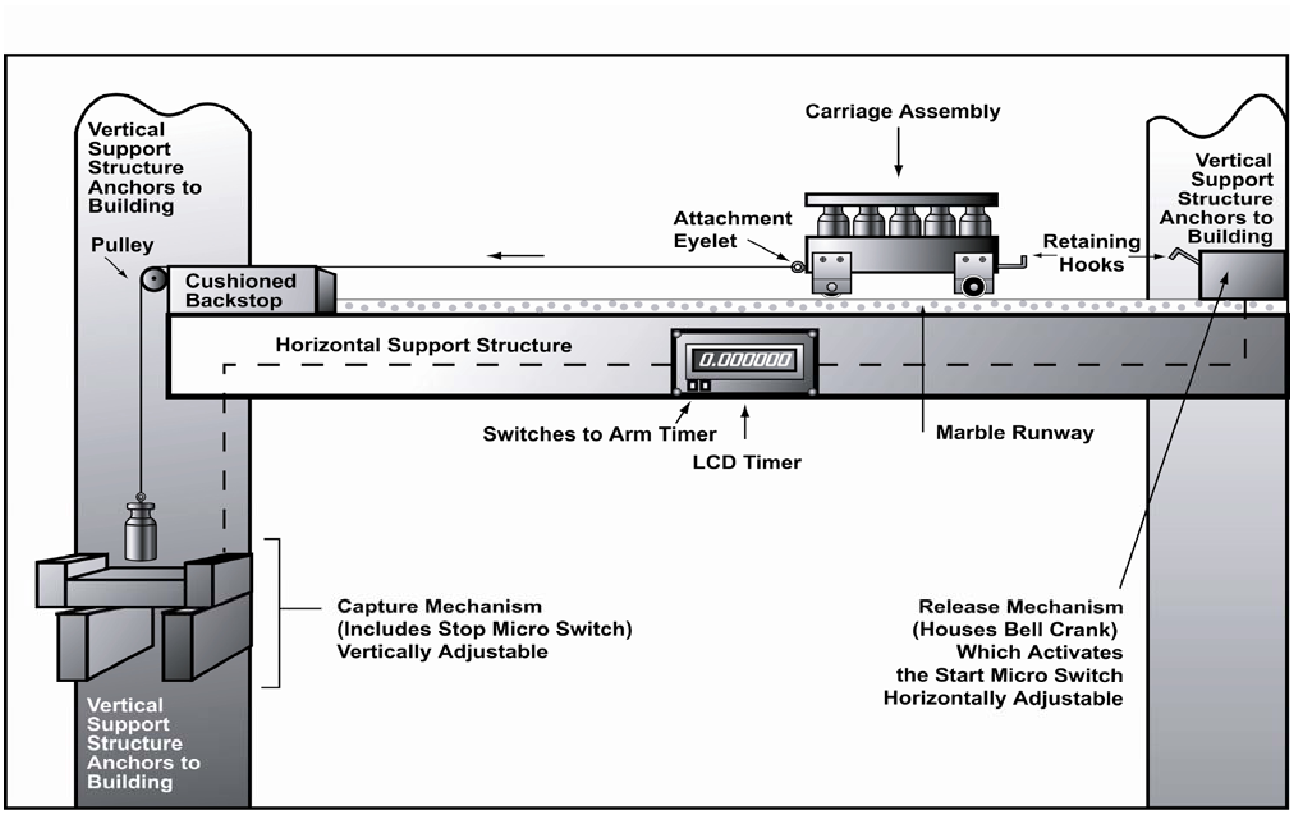

Figure 1 – Test apparatus Overview

The runway consists of a solid marble slab (14 mm × 152 mm × 1350 mm) supported by a wooden platform that facilitates easy attachment to the support structure (which is securely anchored to the building) and manipulation of the ramp such as leveling. The slab is smooth on the upper surface much like a ledge leading into a bathroom shower enclosure. However, the clean dry mating surfaces of the marble and the outer casings of the roller bearings, (stainless steel), are sufficiently course to cause the bearings to roll uniformly as opposed to skidding along the smooth marble surface. Were this not the case, the coefficient of friction would instantaneously change throughout a test run, changing the timing data in unpredictable ways.

The release mechanism is mounted to the support platform at the far right of the runway. The mounting holes are slotted to allow for fine-tuning of the drop length without moving the capture platform or changing the length of the connecting wire. The function of the release mechanism is to retain the carriage assembly until the start of a test run. The mechanism contains a bell-crank that does two things when activated by a lever arm: 1) quickly pivot forward, up and away from the retaining clip mounted on the back of the carriage. This ensures a clean release that does not interfere with the movement of the carriage. 2) The activated bell-crank also simultaneously trips a micro-switch that signals the timing device (shown in the middle of the runaway) to begin counting elapsed time in seconds (displayed to 6 decimal places). The timer is stopped when the activator mass bottoms out at the capture platform, simultaneously activating another micro-switch. A more detailed description of the test apparatus is included below that will hopefully answer any questions the reader may have.

Design Objective

The overall design objective was to find the cleanest and easiest way to apply a constant acceleration to the test mass M2; then using the electronic timing device, specifically designed for this experiment by Cronos Engineering in Boca Raton, Florida, to accurately measure the time it takes for the activator mass, M1, to drop a predetermined vertical distance while, of course, pulling (via connecting wire and pulley) the target mass, M2, horizontally across the runway. After knowing the time, the constant acceleration is easily determined by solving this familiar classical formula for *a,* [2, 3]:

$$t = \sqrt{d / 0.5a} \tag{1}$$

where t is the time, d is the drop distance and a is the constant acceleration. So, $a = d / 0.5t^2$. Once the acceleration is known, the primary forces operating during any given test run can be easily obtained mainly because the acceleration value will be the same for both test masses, M1 and M2. This is the case because the connecting wire has sufficient tensile strength to preclude any appreciable stretching during a test run. The maximum tension the wire is exposed to during a test run is ≈ 4.5 Newtons. The connector of choice and the one most often used is a flexible 24-gauge stranded/coated wire commonly used in electronic connecting circuits which has a tensile strength > 100 newtons. Other connecting wires were tried for comparison purposes and will be discussed in more detail below.

Other implementations were considered besides the one in Figure 1, but finally rejected for various reasons. For example, a ballistic device with a known amount of explosive material could be mounted to the test mass that would accelerate it down the horizontal runway. This was ruled out owing to the technical challenge of accurately determining the exact intensity and duration of the accelerating impulse and the exact friction produced in the process. A coiled spring was also considered but ruled out for similar reasons; another problem with a spring is that the accelerating force is not constant and part of the spring gets accelerated (for a time) along with the target mass making accurate calculations tedious if not impossible.

The test configuration of Fig. 1 was settled on for several reasons. First, it does not suffer the technical difficulties of the ones mentioned above – it should be safe to assume a constant accelerating force provided the retarding forces are not variable in any appreciable way. Again, this feature will be discussed more fully below. Second, this configuration is quite familiar to most people and it is well documented in easily obtainable textbooks – with the exception of readily available descriptions of the retarding forces. Last, (and perhaps most importantly) this configuration allows for the simultaneous measurement of gravitational and inertial acceleration for known masses – the major point of this entire exercise.

Operational Formula

The fundamental formula used in the experiment to describe the forces and resulting motion should be familiar to anyone ever exposed to a basic physics and/or mechanical engineering textbook. We actually use a slightly expanded formula which includes the key variables normally left out of textbooks for simplicity's sake. The basic classical formula focuses on the main forces and is normally presented as follows:

$$m_1 g(1 - a / g) = m_2 a \tag{2}$$

where m_1 is the vertical activator mass, g is the acceleration of gravity, which at sea level is taken to approximately equal 9.8067 m/s^2 [2], m_2 is the horizontal test mass and a is the constant acceleration common to both masses. This formula basically says that the effective weight of m_1, on the left side should just equal the inertial force of m_2 ($m_2 a$) opposing the resulting acceleration on the right side of the equation as the motion proceeds (with no frictional losses). A companion formula used in the texts calculates the predicted constant acceleration, which is a straightforward application of Newton's Second Law $f = ma$, or $a = f / m$ in this case) [2]:

$$a = (m_1 g / m_1 - m_2) \tag{3}$$

This says that the initial activating force (which equals the stationary weight of m_1, which equals $m_1 g$) divided by the total amount of mass being accelerated gives an estimate of the magnitude of the constant acceleration.

Eq. (3) was rarely used - only in cases where a sanity test was needed to see what the acceleration classically should be with no frictional losses. However, an expanded version of (2) was constantly used throughout the experiment that goes as follows:

$$m_1 g - m_1 a = (ifi) m_2 a + \text{frictional losses (pulley and roller bearings)} \tag{4}$$

What we have on the left side of (4) is simply another way of expressing the effective weight of the activator mass, m_1. This value is obtained by reducing the stationary weight, $m_1 g$, of the activator mass, by the inertia of m_1, $m_1 a$. This makes perfect mathematical sense when one realizes that as the actual acceleration goes to zero, the entire weight of the m_1 mass is 'felt' and reflected as tension in the connecting wire. If and when the actual acceleration equals g, the acceleration of gravity, there would be no force 'felt' as tension in the wire and m_1 would be free-falling with nothing slowing it down.

However, it should be noted at this point that it is highly questionable whether or not it is proper to refer to the factor, $m_1 a$, in the gravitational case as inertia because this term usually refers to the resistance of mass to being accelerated. As everyone knows, one of the hallmarks of gravitational acceleration is the complete lack of resistance to being accelerated! This is one of the points that impressed Einstein so much about gravity.

Nevertheless, by Newton's Third Law, the activating force on the left must match all the forces of opposition on the right side of (4). A couple of clarifying remarks are needed for the terms on the right side. First, this is by no means a complete list of all retarding variables, just the most important ones. Air resistance, for example, is not included. As explained below, it was considered such a small factor at the speeds we are dealing with that it was reasonable to ignore it. Also not included is the angular acceleration of the pulley and rollers, which will naturally drain a small amount of the available energy. However, the extremely small *moments-of-inertia*, mr^2, owing to the small radius being squared in both cases, made this factor virtually immeasurable, regardless of the normal frictional drag of the pulley and bearings. So, these values are simply included in the normal friction, independently measured prior to the test runs.

Also excluded from (4) is the mass of the 24-gauge connecting wire. This is justified as follows: The wire mass is 8 grams, representing a ratio ≈ .0053 when compared to the smallest total mass of 1500 grams when an 'empty' carriage is being tested; this ratio drops to .0016 when a fully loaded carriage is being tested. Furthermore, at the beginning of a test run, approximately 85% of the wire's mass (6.8 grams) adds to the M2 load and approximately 15% (1.2 grams) adds to the M1 activator mass (500 grams). However, for a full 1.0 meter drop, this situation is almost completely reversed as the wire goes over the pulley. In any case, this omission is not a significant factor that would change the data appreciably and is well covered by the error margin assigned to the data. This situation does argue, however, for selecting the lightest yet most flexible and strongest connecting wire available.

The reader will also notice that a modifying factor, (ifi), has been appended to the first term, the inertial force of m_2. This factor stands for what became known as the "Inertial Force Index." The expectation was that if our measurements were consistent with classical physics, this term would always equal 1.0, (or be extremely close to it), which doesn't change the value of the right side of (4). On the other hand, if a non-classical retarding factor is operating during the test, a value other than 1.0 would have to be assigned. The whole experiment consists of setting up the test parameters, measuring the time elapsed between release and the bottoming out of M1 at the capture platform, converting this time to acceleration using (1) then solving (4) for the value of (ifi). This process will be fully explored in the Test Results section below.

Technical Descriptions of Test Apparatus

Some of the test apparatus and preliminary tests require further elaboration. However, the reader may choose to temporarily skip this section to maintain better continuity.

Runway construction is obviously one of the more critical design parameters. The left end of the support platform is secured to the vertical support structure (which is anchored to the building) with a 5/16" bolt. This single bolt also performs the function of a pivot point that allows the right end of the platform to be easily raised or lowered in small increments for lengthwise leveling. A backstop (with foam padding in front) shown in Figure 1 also serves a duel purpose - not only does it provide for a 'soft landing' of the carriage at the end of a test run but also provides the means of leveling the platform assembly widthwise. The length of the connecting wire was always selected to ensure that M1 bottoms out before the M2 mass touches the padded backstop.

The **pulley assembly** consists of a rugged ball bearing (outside diameter, OD ≈ 30mm), like those used in power tools, pressed onto a 10mm stainless steel shaft firmly secured in a hard plastic circular housing. Actually, the bearing and housing were acquired by stripping down a battery powered Black & Decker hand drill. A small groove is cut in the outer plastic casing of the pulley to provide for smooth tracking of the connecting wire. The back of the pulley assembly is securely mounted to the vertical support structure just to the left of the runway platform and also supported in the front with a steel strap also secured to the runway platform. The pulley assembly was carefully positioned to insure 3 things: 1) it was not touched by any moving parts other than the connecting wire. 2) the top of the pulley was at the same height as the connecting eyelet attached to the front of the carriage. This ensured that the connecting wire was level with the runway. 3) the groove in the round plastic housing is located front to back to insure that the connecting wire and ultimately the carriage is being pulled down the center of the runway.

The **pulley angular acceleration** was determined to be a negligible factor. With the radius of the pulley groove ≈ 22 mm (.022 meters) and a mass ≈ 0.1 kilograms and conservatively placing all the mass at the radius, the *moment-of-inertia*, $I = mr^2$ is still less than 5×10^{-5}, hardly a significant factor. The **roller bearing angular acceleration** is even more negligible; with a radius of 10mm and mass ≈ 10 grams, their *moment-of-inertia is estimated at* 1×10^{-6}.

The **pulley frictional drag** was determined with a separate measurement: first, the initial force on the pulley was determined using the Pythagorean theorem for adding vectors, $F_t = \sqrt{F_1^2 + F_2^2}$. For the initial case of a latched up carriage and suspended M1 mass, this becomes $\mathbf{F}_t = \sqrt{4.92 + 4.92} =$ 6.93 newtons of force pointing down at a 45° angle. So, two weights having approximately half this force were attached using the same connecting wire as in an actual test run, with the wire draped over the pulley. Figure 2 depicts this setup.

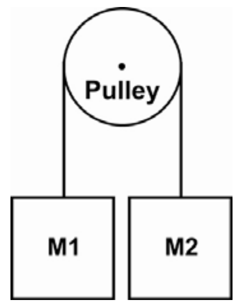

Figure 2.

The pulley frictional force measurement

Since the weights are equal, no movement is initially seen. Small additional weights are then incrementally added to one of the masses until a point is reached where a slow motion imparted to the pair manually would cause the lighter weight to steadily move up and the heavier weight to steadily move down with neither of them experiencing acceleration. This is the imbalanced point that exactly matchs the frictional force which includes the deformation/reformation of the connecting wire in quasi-static mode. Now weighing the two masses separately and calculating the retarding force, we have, $\mathbf{F}_{drag} \approx (\mathbf{F}_1 - \mathbf{F}_2)$ when a force of 6.93 normal (perpendicular) to the pulley is applied. The coefficient of friction is then $\mu = |\mathbf{F}_1 - \mathbf{F}_2|/|\mathbf{F}_1 + \mathbf{F}_2|$, which turned out to be .017 ± .001.

Two things should be noted here. First, this is a quite conservative approach to determining the coefficient of friction for the pulley because in a real test run, the connecting wire only gets deformed by 90° not 180° depicted in Figure 2. So, the real coefficient is somewhat less than .017. Nevertheless, we used the conservative value. Second, when the carriage is released in an actual test run, the force on the pulley gets reduced by an amount depending on how much acceleration is generated – the greater the acceleration, the smaller the effective weight of M1 and consequently the less force on the pulley. In evaluating the data, the actual force on the pulley was calculated for each run scenario - the force varies from approximately 4.8 to 6.4 newtons for the 1.0 kilo to 4.5 kilo test cases which produces a range of drags ≈ .08 - 0.11 newtons. Note: The initial and runtime forces at the pulley were verified using a precision force gauge from EXTECH corp., pn. 475040, mounted securely to the support structure.

Determining the coefficient of friction for the roller bearings was much simpler. Here, adding small weights attached to the carriage via fine sewing thread draped over the pulley, the weight that causes the carriage to continually move slowly without accelerating defines the force necessary to overcome the frictional drag for any given mass, M2. The coefficient of friction is then determined for the combination of the 3 rollers as μ ≈ F1 ÷ F2 where F1 is the force dangling over the pulley and F2 is the force of M2 being applied normal to the runway or simply (M2 x g). The measured value turns out to be .003 ± .0005 producing a carriage drag ≈ .03 - .13 newtons. Therefore the total quasi-static drags used in (4) were .11 - .24 newtons over the range of M2 masses used in the experiment.

It should also be noted that the coefficients of friction do vary with ambient temperature. However, this was a very small amount over the range of temperatures in the lab, 72° ± 2° F.

Air resistance was determined to be a negligible factor early in the experiment. This was really a side benefit of calibrating the time measuring technique used in the experiment. To accomplish this, activator mass M1 was allowed to freefall vertically in earth's gravitational field for a distance of 1 meter. The measured time never varied from a value of .4516 seconds rounded to the 4th decimal place. The calculated value from (1), with $g = 9.8067\ \mathrm{m/s^2}$, is .4515996 seconds. This was an indication that what little air resistance there was, reduced the time by less than 50 microseconds in a case where the peak speed of M1 was ≈ 4.4287 m/s. This represents a deviation of < .01%. Also the peak speed for the fastest test case (1.0 kilogram M2 with M1 dropping 1 meter) is ≈ 2.42 m/s. Most test cases are considerably lower than this maximum and only a few even approach it. So, this result said 2 things, 1) our measurement technique was solid. 2) Air resistance played no significant role in the experiment.

Basic **carriage construction** is depicted in Fig. 3. The main body of the carriage is made out of a wooden block with width of 90 mm, thickness of 38 mm, and length of 200 mm. The base has seven round holes bored from the top approximately 20 mm deep with a diameter of 38 mm providing a snug fit for the precision weights to sit vertically 'in' their slots. The lid of the carriage has the same dimensions as the base (accept thickness of 15 mm). The lid also has 7 round holes bored from the bottom to a depth of 10 mm and slightly smaller diameter than the ones in the base. The lid fits over the top of the precision weights and is firmly secured with 4 ¼″ stanchions coming up through the base and with each having a retaining nut on top. The positioning of the retaining holes were selected to allow the use of any number of the 7 weights while still maintaining a balanced load on the carriage. Four metal brackets were bolted to the four corners of the base to provide for mounting the 3 roller bearings. The unthreaded portion of a 5/16″ bolt is almost exactly 8mm in diameter, the size of the inner diameter of the bearings. This ensured a tight fit preventing any appreciable wobble of the bearings when bolted in place. The front axle was a one piece bolt with the bearing placed in the middle while the back bearing each had its own separate axle. This arrangement facilitates easy alignment of the roller bearing to achieve clean straight runs across the runway.

On the front of the carriage is an eyelet that has the same height as the top of the pulley to ensure the carriage is pulled in a level fashion by the connecting wire attached to the eyelet. The retaining bracket on the rear of the carriage is also mounted at the same height as the eyelet to ensure that no lifting of the carriage was experienced during the time it is being retain by the release mechanism bell-crank. Also shown in Fig. 3 is the activator mass with the connecting wire attached to another eyelet screwed into the top center of the mass and epoxied in place for added strength.

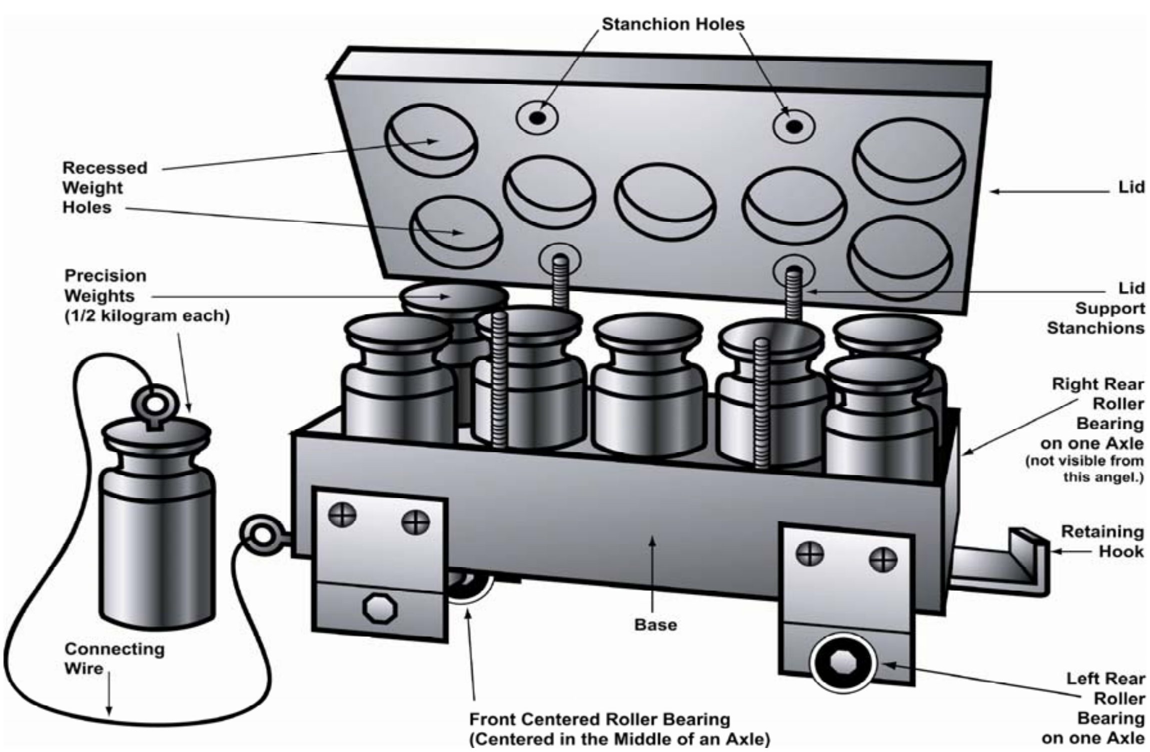

Figure 3. Basic carriage construction.

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Target mass, M2 = 4.5 kilos Activator mass, M1 = .5 kilos Drop = .25 Meters
Drag = .24 Newtons

Time/temp	run time
12:14 pm/72⁰ F.	t1 = .7399 secs
12:18 pm/72⁰ F.	t2 = .7396 secs
12:22 pm/71⁰ F.	t3 = .7399 secs

mean run time = .7398 secs ±200 microseconds

acceleration	effective weight of M1	inertia, m_2a	ifi value
.9136 m/s²	4.4734 Newtons	4.1111 Newtons	1.030

Figure 4. Typical logbook entry

M2 Kilo	m/s²	Drop length – meters 1.0	.50	.25	.125
4.5	.91	1.039 (.67)	1.031 (.48)	1.030 (.34)	1.030 (.24)
4.0	1.01	1.046 (.71)	1.032 (.50)	1.030 (.36)	1.030 (.25)
3.5	1.21	1.054 (.75)	1.036 (.53)	1.033 (.38)	1.030 (.27)
3.0	1.28	1.063 (.80)	1.043 (.57)	1.036 (.40)	1.032 (.29)
2.5	1.51	1.071 (.86)	1.052 (.61)	1.041 (.44)	1.036 (.31)
2.0	1.81	1.080 (.94)	1.061 (.67)	1.048 (.48)	1.043 (.34)
1.5	2.24	1.097 (1.05)	1.071 (.75)	1.059 (.53)	1.050 (.38)
1.0	2.99	1.118 (1.21)	1.095 (.86)	1.082 (.61)	1.065 (.44)

Figure 5. Inertial Force Index summary

Test Procedure

A typical test run consists of several steps:

1) Load the carriage with desired amount of mass.
2) Adjust apparatus for desired drop length (moving capture and release mechanisms).
3) Connect the carriage to the release mechanism and verify desired drop length ± .5mm.
4) Ensure that the carriage is aligned to make the same straight run each time.
5) Allow time for all parts to stabilize, particularly m_1 to be motionless (not swaying)
6) Reset and 'arm' the timer making it ready to start counting.
7) Rapidly activate the release mechanism lever.
8) Observe each run for continual, smooth and straight acceleration down the runway.
9) Record the elapsed time from the timer.
10) Repeat steps 1 – 9 as many times as desired.
11) Analyze the times and determine the *mean* and variability* values.

* Note: Variability of ±100 microseconds was considered excellent repeatability for a motion experiment of this kind. Variability over ±300 microseconds was considered unacceptable and the test was repeated after searching for the source of excessive variability.

Test Results

A typical logbook entry for a series of test runs is shown in Fig. 4.

The 'Drag' shown in Figure 4 is the total drag, which is the addition of the pulley and roller bearing drags. As mentioned previously, the acceleration is calculated from (1). The effective weight is obtained by setting the left side of (4) $(m_1g - m_1a)$ equal to it then solving for the weight. The classical inertia of M2 is simply ($m_2 \times a$). The value of the Inertial Force Index (ifi) could now be calculated from (4). The (ifi) values are nothing more than the degree to which the inertia of M2 has to be increased in order to make Newton's Third Law work in these cases. These measured values (repeatable to ± .005) provide a shorthand way of summarizing the test results for thousands of test runs taken over a period of 6 months. This summary is shown in chart form in Fig. 5:

Discussion

The first column (of 6) in Figure 5 shows the 8 different values of the M2 target mass used in the experiment (activator mass, M1, always equaled ½ kilograms). Again, these values were obtained by incrementally adding one (of 7) ½ kilogram precision weights to the carriage. So, for example, the '1.0 kilo' row represents data for an 'empty' carriage. The '4.5 kilo' row represents a fully loaded carriage. The second column shows the approximate acceleration achieved for each test case that remains relatively constant for the different drop lengths. The last 4 columns show the calculated (ifi) values for the 4 drop lengths, in meters, measured and calculated for each M1/M2 combination; the numbers in parentheses are the average speed for a run in m/s.

Note: The reader is reminded at this point that the (ifi) calculations from (4) include the total drag of the pulley and roller bearings which were independently measured in what the author calls 'quasi-static' mode, i.e., slow motion. A fuller discussion of this measurement technique is included above under 'Technical Descriptions.'

By far, the most salient feature of Figure 5 is that none of the entries are equal 1.0! The closest we come to this classical value is 1.030. So, something non-classical is definitely going on here. Before launching into a detail discussion, several other features of Figure 5 should be pointed out: For each of the 8 M1/M2 combinations, the (ifi) values depart from 1.0 by a wider margin as the drop length increases. Also, for each drop length, (ifi) increases as the target mass, M2, decreases. It is not difficult to figure out that in both of these cases, higher speeds are naturally being achieved during the course of a test run - in the first case owing to the greater amount of time the mass is subjected to the acceleration. In the second case, less mass is being pulled along by the activator weight; consequently, higher speeds are achieved. So, clearly, speed has something to do with the skewed data presented.

The two big questions that must be addressed regarding Figure 5 data are: 1) why do the index values depart further and further from 1.0 as the speed increases? 2) The real $64 question is why the index numbers converge on the value of 1.030, rather than 1.0, as the speeds decrease toward the quasi-static case?

Let us address the simpler question #1first. As pointed out earlier, the independently measured frictional drag of the pulley includes the deforming and subsequent straightening of the connecting wire as it goes over the pulley in slow motion. So, we see little or no deviation from 1.030 for the lower speeds in Figure 5 - those in the upper-right quadrant. Now, as the speeds increase, as we proceed to the left or downward in Figure 5, the pulley rotation rate must naturally increase in these cases. The higher rates of the deforming/reforming of the wire will quite naturally increase the heat dissipation in the wire above the quasi-static value. This, of course, represents a small energy loss for the higher speeds which causes the acceleration to slightly decrease as a test run proceeds resulting in a higher value of (ifi) being assigned. There is nothing non-classical in such a view.

This interpretation was corroborated by substituting the 24-gauge stranded/coated wire-of-choice with an otherwise identical 18-gauge stranded/coated wire that is obviously stiffer owing to its larger diameter. This substitution has the consequence of first of all increasing the quasi-static pulley drag independently measured and used in (4). Secondly, in these cases, the (ifi) values are generally higher (than the 24-gauge values) for the higher speed cases but still converge on a value of 1.030 for the upper-quadrant of Figure 5 – the ones with speeds closest to the quasi-static value.

Now, a closer look at Fig. 5 reveals that something other than sheer speed is causing the index values to depart further from the 1.030 value of the slower speeds. For example, the values in parentheses represent the average speed in m/s for each test case; and we see for the 4.5 kilogram row that only with speeds greater than ≈ .5 m/s does the index value begin to slightly depart from 1.030 (starting with a .5 meter drop, the index value goes to 1.031). However for the 2.0 kilogram case (dropping .25 meters), this same average speed is achieved but the index value is quite a bit higher (1.048). The author's interpretation of this phenomenon is that any connecting wire flexible enough to easily bend around the pulley will have some degree of elasticity - however small, it can not be zero. When the carriage is first released, it will instantaneously begin accelerating. The resulting drop in wire tension will be felt first at the carriage end of the wire and almost immediately reduce the M2 acceleration by a small amount. However, within a few microseconds, this reduced tension will be transmitted along the wire and the M1 mass will also begin accelerating and soon retighten the wire tension and in turn increase the acceleration of M2 again. This elasticity effect will no doubt form a small saw-tooth wave pattern riding on the acceleration profile. The frequency and amplitude of the waveform would seem to be a function of the transmission speed of the reducing or increasing tension along the wire and also the length of the wire. Nevertheless, it seems probable that the average acceleration will be reduced slightly in the process even though the wave will most probably dampen out quickly with a reasonably stiff wire. The data suggests that this effect is most pronounced for the lighter M2 masses, which naturally experience the greatest acceleration and is even evident for the shorter drop lengths for them which, of course, have approximately the same acceleration as the longer drops. The flatter index values for the 4.5 and 4.0 kilogram cases indicate that this saw-tooth phenomenon does not occur for them in any measurable way owing to smaller accelerations. Test results indicate that acceleration above 1.0 m/s^2 is required to produce this effect in an appreciable way.

It is also noted that the index entries in the lower-left quadrant are experiencing the greatest acceleration and drop lengths; so, subsequent higher accelerations and speeds, well above 1.0 m/s^2 and .5 m/s respectively, are produced. They are getting a double dose of the retardation effects described above and consequently all have index values well above 1.030.

Conclusions

The answers to the 2nd question posed above are the only 'new' phenomenon addressed here and therefore represents the only really interesting conclusions of this paper – unfortunately these answers are not nearly so clear-cut.

First, there appears to be no known explanation (classical or otherwise) for this strange phenomenon; consequently any 'conclusions' are necessarily partly speculative. However, they are also evaluated in the light of [1] and presented below, followed by a few additional remarks.

The behavior of the test masses, M2, requiring an additional force to achieve any given acceleration, is similar to the way charged particles react – however, we are not dealing with charged particles here. This behavior is also somewhat reminiscent of the result that *mass-increase* has – more force than the normal inertia (ma) is increasingly required at greater speeds in order to achieve a known acceleration (even starting with minute relative speeds well below that of light.) In our case, however, the additional force is required immediately and remains a constant throughout each test run; besides, any mass-increase at such small speeds in the usual sense, $(m - m_0)\big/\sqrt{1-\beta^2}$, is far below our ability to even detect, much less accurately measure, so it was ignored.

If the interpretation of question # 1 above is correct, and the dynamic increase in pulley drag (above the quasi-static values) could be somehow eliminated, along with the somewhat jerky early acceleration of the lighter weights, it seems entirely reasonable to project that all Figure 5 entries would be an index value of 1.030 ± .005 rather than the classical 1.0. This basically says that **the force of inertia is 3% higher for mass having *work* done on it than is predicted by Newton's Second Law**.

There will be a strong tendency to deny the possibility of this surprising phenomenon by saying it violates the gravitational mass/inertial mass equivalence (often called the weak equivalence principle, WEP) that has been so well verified experimentally. But this complaint would be fallacious for two reasons: 1) The above results actually have little to do with gravity. Even though we are using a gravitational force as the activator in each case, the target mass, M2 has no way of detecting or 'sensing' that gravity is ultimately causing it to accelerate. In essence, M2 is simply reacting to the electromagnetic force being exerted by the connecting wire tension; and this force could in principle be coming from any electromagnetic source doing real *work* on M2. 2) The experimental data most often cited for confirming the mass equivalency mentioned is the Hungarian Baron Loránd von Eötvös experiments (and those that followed, *e.g.* Dicke, *et al.*). These highly accurate experiments measured the earth's (or the Sun's) gravitational pull on a small mass versus the centrifugal force caused by earth's rotation of a similar mass attached with a finely tuned torsion balance. Since we are talking about an inertial force in the case of centrifugal force, no *work* was being done on the test masses. Therefore, the present experiment has no bearing on these results and leaves Galileo's assertion completely intact that all mass falls at the same rate.

In addition to testing Newton's Second Law for cases where *work* is being done, it would be much more accurate to say that the present experiment tests Einstein's stronger equivalence principle rather than the WEP. Richard C. Tolman [4] expressed in plain language the basic gist of Einstein's extension: *"To obtain a precise expression of the principle, we may first consider the hypothetical limiting case of a non-accelerating observer in a perfectly uniform gravitational field, as contrasted with a uniformly accelerated observer in a region of free space where the gravitational field can be neglected. In this case the principle of equivalence makes the definite assertion that the results obtained by the two observers in performing any given physical experiment will be precisely identical . . . ."*

So, now, by simply placing all the test masses in Figure 5 above aboard a rocket that is that constantly accelerating in a straight line at 1g in free space, we will have to conclude that the measured 'weight' of each test mass will be 3% greater than the same stationary mass on earth! Why? Simply because in the case of the rocket, *work* is being done on the test mass and in the stationary case it is not!

Now, the author hastens to add (as done in [1]) that in no way is a new force in nature being proposed here or that the laws of thermodynamics are somehow being violated. In fact, it is contended that the 'missing' energy (≈ 3%) simply increases the internal energy of the mass having *work* done on it rather than all the available energy being added to its kinetic energy directly in the classical sense, *work* = *force* × *distance* = *kinetic energy increase*. So, the familiar form of Newton's Second Law for these situations, $f = ma$, becomes $f = (1.030)\,ma$. Furthermore, these results are in perfect harmony with the conservation of mass/energy and even the spirit (if not the letter of) the Second Law of Thermodynamics (L.O.T.2). Among many other things, L.O.T.2 says that when *work* is done on mass, the internal energy is naturally increased. Of course, non-rigid systems such as stationary gas containers with movable pistons are normally being discussed when this assertion is made. L.O.T.2 also states that energy conversions can never be performed in a completely efficient manner – hence entropy (often in the form of internal energy) must increase. The author's interpretation in essence just extends L.O.T.2 to include rigid systems having *work* done on them: **increasing their kinetic energy, increases their internal energy also.**

Note: The author also contends that the so-called 'energy loss' of the revolving permanent magnet in [1] is just another demonstration of the above principle. Follow-on research after [1] was published definitely indicates that after a series of test runs, the revolving 'Hover-Craft' does in fact experience an increase in its internal energy. This increase was manifested by a reduced flying height for a given circular electromagnet coil current. Quantum theory tells us that a higher internal energy level for a magnet is a demagnetized state. It is also interesting to note that once this happened in [1], the data collected became much more erratic, i.e., the variability from run to run greatly increased. This same phenomenon occurs in the current experiment. In fact, there seems to be a window-of-opportunity of approximately two to three hours per day when solid, repeatable data could be collected. Continuing to make test runs after this window was rarely fruitful – the *mean* elapsed times did not change appreciably but the variability certainly increased to the point of making the data untrustworthy. It is as though the accelerated mass became saturated (or just plain tired) and would not recover until the next day. No such anomalous behavior was noted for the activator mass, M1.

Additional Remarks

As to the most frequently asked question, *"how could something so easily demonstrable, remain obscured for so long?"* the author can only offer some speculative possibilities: First, measurement of time intervals in seconds to 6 decimal places and beyond, only became possible with the advent of modern electronics. This observation is most definitely not meant to berate the ingenuity of investigators prior to the 20th century - quite the contrary. It is just that measurement of time intervals for physical motion with modern-day accuracy is simply inconceivable using any kind of mechanical timing device.

It also seems completely conceivable that if an accurate determination of frictional losses is not separately cared out through actual measurements apart from 'live' test runs of any configuration, the anomalous behavior noted in this paper could easily be obfuscated and simply written off as 'normal' frictional losses that were perhaps under estimated. To do otherwise is to challenge a theory that has been extraordinarily successful for over 400 hundred years - notwithstanding modifications by relativity and quantum theory in their separate realms. Researchers with reputations and future grants to protect cannot be blamed for giving Newton any possible benefit of the doubt.

Another possibility is that given the spectacular success of Newton's laws in the celestial realm, it seems like a natural extension to equate gravitational mass with inertial mass and use the same laws to describe both; gross observations certainly seemed to suggest that this was true. Newton obviously could not show analytically (or experimentally other than with pendulums) that this was the case and is said to have considered it a curiosity or lucky accident of nature and left it at that. As time progressed, this notion became so entrenched, that to question one was to question the other, which, of course, was unthinkable. Until Albert that is! Einstein seemed willing to question any and everything classical. However, rather than questioning the equating of the two masses, he further solidified the idea. Not only did he say that it was more than a curiosity or lucky accident, he said it was a necessary consequence of the fact that gravity and acceleration are one and the same thing! This experiment and [1] argue otherwise.

One last thought on this question is another question, "how could Aristotle's intuitively obvious and logical - yet grievously incorrect - assertion that heavier bodies fall faster remain so firmly entrenched for 2 thousand years, to the point of becoming dogma?" It took the great courage of Galileo to finally set the record straight and place us on the path of physically verifying principles, even our most sacred beliefs.

The second most frequently asked question is, *"how does this help us?"* Well, predicting future ramifications of modifying fundamental physical theories becomes even more speculative – but, let us try it anyway. If Einstein's Equivalence Principle (EP) is invalid, most (if not all) of modern cosmology is truly up in the air. This is the case because EP is the very cornerstone of the General Theory of Relativity, the heart and soul of modern-day celestial mechanics. Consequences, from the Big Bang all the way down to the existence of Black Holes could very well be brought into question. Also given the seminal nature of classical mechanics and its longevity, many areas of science use this model in one form or another – who knows where that degree of rethinking could one day lead. The possibility this writer finds the most exciting is the prospect of this revelation pointing the way to new sources of cheap, clean and readily available energy which the world desperately needs to power the 21st century. If, for example, we can increase the internal energy of mass without the need for adding prodigious amounts of heat energy, nuclear fusion (both hot and cold) could possibly be made more economically achievable. The sky literally seems like the limit here.

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