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A Gravity Experiment Between Commensurable Masses

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Abstract: The gravitational constant G is the least-well measured fundamental constant in nature. Several recent determinations have not reduced the uncertainty and some measurements are in severe disagreement with the accepted value. Among others, the most common characteristic of the performed experiments lies in the fact that the “source” masses of the measured gravitational field are much larger then the “test” masses. So far in the related literature we have not found the determination of G in the case of interaction between commensurable masses. Over the last few years, a very simple but highly sensitive experiment has been developed for investigating gravity by using relatively large physical pendulums. This new measuring system has been useful for finding the gravitational interaction between equal or nearly equal size masses. From such experiments it has become obvious that there is a strong dependence of gravitational attraction on the mass ratio of interactive bodies. We have observed a well-defined minimum in the gravitational interaction energy in case of equal size of masses.

Keywords: gravity, gravitational constant, mass, theory.

Introduction

The gravitation force between two masses is equal to GmM/r^2 according to the Newtonian Law of Gravity. Until now the accuracy of gravitational constant G is very crude compared to other important physical constants.[1,2] The main reason for this is due to the weakness of the force involved in gravitational interaction. The most part of the experiments searching for gravitational constant "G" are those performed with a torsion balance of Cavendish type.[3] The most common feature of these measurements is that the source masses are much larger than the mass of the torsion pendulum. For example, the worldwide accepted determination of "G" by Luther and Towler[4] that was based on torsion balance, the source masses were 10.5 kg (kilogram) while the pendulum mass was 5 g (grams).

In the usual laboratory measurements of gravity (based on the torsion balance method), the source masses most often used were very large in order to amplify the weak effect being measured. This is the only practical reason why physicists have not yet measured the gravity between equal masses. In related literature, we have not found any determination of G by using equal, or nearly equal interactive masses. To date, the use of commensurable masses to determine gravitational effect have not been done, until now.

It is also noteworthy that there are not any firm theories, which can prove the *free extrapolation of gravity law* as it relates to the interaction of equal, or near equal masses. About six years ago our Hungarian research group started an extended study on the problem of what kind of technical solution would be the most suitable for the experimental study of gravity between equal, or near equal masses. We initially concluded that the torsion balance of gravity measurement was not a proper method for the investigation of gravity between commensurable masses. Following the history of the gravity measurements, it seemed that the applied source masses were usually at least 10-50 kg. The requirement for a minimal quantity of source mass is related to acceptable signal-noise ratios. In the case of equal mass measurement, the torsion fiber would normally be loaded 10+ kg. The question for us then was, how can what type of torsion fiber and mechanical properties would be most appropriate for this purpose?

The answer that became clear to us was that we have no real possibility to solve this problem in the usual manner by using the original torsion balance principle.

Measuring Method

We initially thought about using a physical pendulum and we did perform some preliminary investigations with it. The sensitivity of the gravitational pendulum is determined by its moments of inertia and its period and it can be easily shown that the sensitivity of gravitational pendulum is proportional to the square of its period. In the case of Cavendish type experiments, the period of the torsion pendulum was usually about 600-1800 seconds. Our preliminary measurements have shown that for technical reasons the maximum reachable stable period of the physical pendulum is about 60-80 seconds. From this result, it can concluded that this is the reason why the physical pendulum is not applied to the gravity measurements (low sensitivity). Nevertheless, we have planned only a qualitative measurement that depends on the ratio of attractive masses. *This meant that we were not thinking of a new precision measurement of G, but rather the basic goal of our experimental investigation was to only achieve comparative gravitational measures between equal, or near equal masses.*

However, the detailed analysis of our preliminary experiments with the physical pendulum has shown some distinct advantages. One of the most important properties of the physical pendulum is that its operating force is the constant and homogenous gravitational field of the Earth. The adjustment and operation of the physical pendulum also is much simpler in comparison with the torsion pendulum. To compensate for the small sensitivity of physical pendulum, we have usually been using the "resonance method". The resonance method has been very successful in gravity measurement.[5] For the purpose of statistical accuracy and to achieve a better signal/noise ratio we usual used long time measurements.

Description of the Gravitational Pendulum

Initially, we built four test pendulums with different geometry, mass, and construction. Some of the technical features of the most successful physical pendulum are:

The pendulum's arm:	2.5 meter (in vertical position)
The upper mass:	24 kg (cubic lead)
The lower mass:	24 kg (cubic lead)
The total mass with frame:	54.7 kg
The support of pendulum:	two "in-line" wedges (a special steel)
The high frequency filter:	hydraulic damper
The applied pendulum period: . . .	60 - 80 sec
The position detector:	light-coupling without mechanical contact
The source masses:	cubes of lead on a rotating circular table

The relatively large dimension of our physical pendulum serves two important functions: the adjustment of the pendulum period is very easy, and the small pendulum amplitude causes very little swinging on the pendulum bearing with an acceptable level of friction.

Figure 1 below shows the simple scheme for our gravity measurement. The hydraulic damper is missing from this scheme, where a simple plastic container filled with water is used. In the water container there is a light plastic damping sheet (with about 500 cm^2 surface area) which is connected to the lower arm of the pendulum.

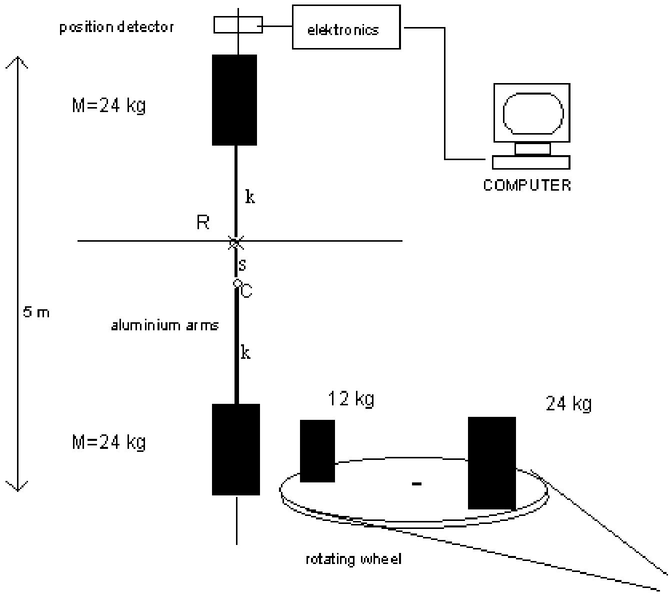

Figure 1. The setup for the gravity measurement.

The source masses had comparable geometries and center of gravities relative to the table/pendulum. Additionally, the source masses were fabricated with standard technology to be radioprotected. The source mass machine is fully automatic with a circular rotating table that was made of hard wood in an effort to avoid any magnetic effects, and is driven by a small electric motor with reduced self-vibration. While obtaining the experimental data, no person was in or near the laboratory. The data of the measured pendulum positions were collected by a personal computer with a sampling time of 0.2 – 2.0 seconds. The resolution of the position signal was almost 5 microns and the typical pendulum amplitude was 2 – 5 millimeters (mm).

Our laboratory is situated about 500 meters from the nearest traffic road and in a low noise environment. Despite this good location, we found some unexpected technical problems after the device's construction due to background disturbances. We had to apply thick rubber underlay to the support frames in order to reduce the ground noises. It is also important to reduce the vibration energy coupling between the moving machine and the pendulum. We also protected the experiment from possible electromagnetic effects.

After the measurements, we had a detailed off-line evaluation of the collected data using a Fourier analysis and error calculations.

The Result of the Quasi-Resonance Measurement

In our quasi-resonance gravity measurement, the rotational period of the circular table was about 280 seconds and the pendulum period was about 70 seconds. By using the quasi-resonance method, the gravitational excitation of the pendulum is performed by the upper (fourth) harmonic of the source mass' rotating frequency. This technical solution has an important advantage in reducing the direct vibration coupling between the moving machine and pendulum. The radius of rotating table was 0.6 meters and the nearest point of the table edge to the lower pendulum-mass surface was about 10 mm (see Figure 1). Usually we used two source masses that were opposite each other near the edge of the circular table. The two source masses form an asymmetric mass-dipole, from which the gravitational effect can easily be modeled and analyzed. The rotating mass-dipole excitation significantly increased the reliability of the comparative gravity measurement. Figure 2 shows an example of our quasi-resonance measurement where a part of the computer record represents the lower mass movement of the pendulum.

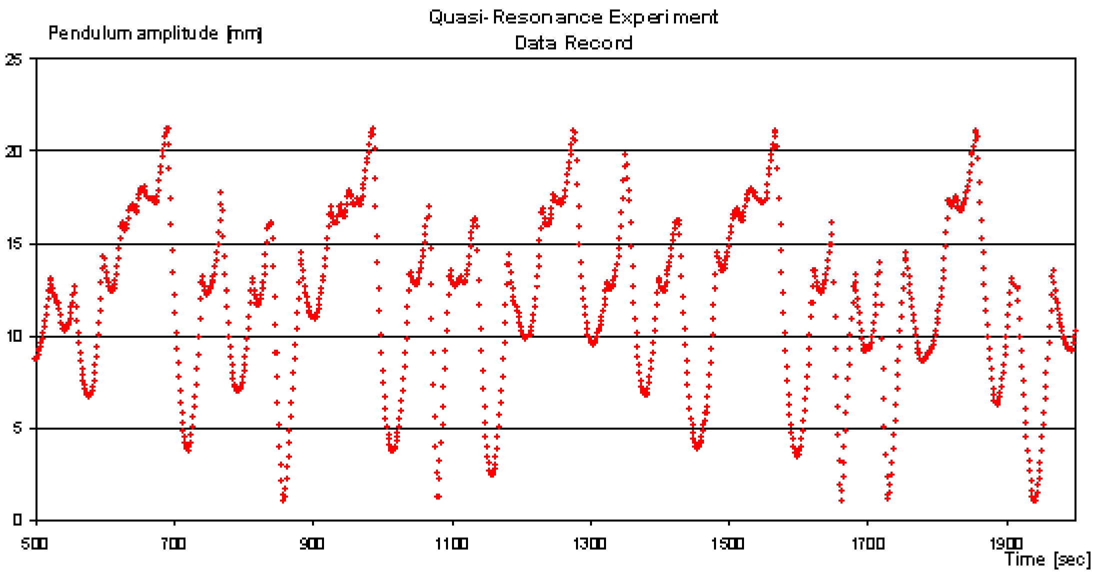

Figure: 2. The movement of the pendulum (quasi-resonance measurement).

The measured data from the Fourier analysis was compared to the theoretical calculation based on Newtonian gravitational theory. For the theoretical calculation, we used a simple mathematical model:

$$x'' + 2\lambda x' + \omega_0^2 x = \frac{F(t)}{m^*} = f(t)$$

where $\omega_0 = \frac{2\pi}{T_0}$; $T_0 \approx 70s$ (the period of the physical pendulum), *x(t)* is the one-dimensional movement of pendulum mass [if the exciting force *f(t)*=0, then the mathematical solution of the first equation is $x(t) = Ae^{-\lambda t}\sin(\omega_0 t + \varphi)$], m^* is the effective movement mass of pendulum (which was derived from the simple modeling of the pendulum when a point-like pendulum mass was used), $\lambda(\approx 0.0001)$ is the measured damping factor of the pendulum, and x' is the first derivative and x'' is the second derivative of *x(t)* pendulum movement by time. *F(t)* is the one-dimensional projection of the excitation forces caused by the moving source masses that was determined by the Newtonian formulae of gravity, for the purpose of theoretical comparison to the experimental data. The results of the Fourier analysis that was obtained from our experimental data and theoretical calculations, are shown in Figure 3 below.

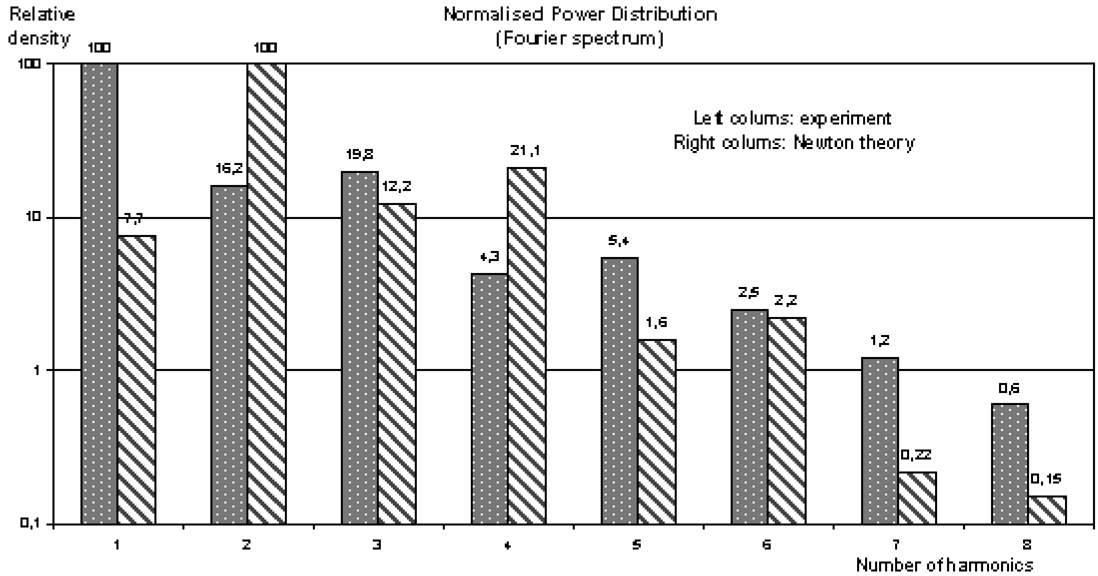

Figure: 3. The Fourier spectrum of measured and calculated pendulum movement.

The results of Fourier analysis show, that the transferred first harmonic gravitational energy is much lower compared to the theoretical calculation that was based on Newtonian theory. The reason of this discrepancy is due to the significantly decreasing interaction force between the equal masses, which was proven by a proper phase analysis of the excitation. From an evaluation of the measured data, we have concluded that the energy transfer between equal masses (both being 24 kg) was less then seven percent of the theoretical value based on the Newtonian gravity model.

Discussion/Conclusion

The most important question was whether there was any hidden systematic error. We have continued our gravity experiments for more than for three years using different types of measuring methods and conditions. **The continuation of our experimental work by elaborating different cases of interactive mass ratios, has clearly shown the minimum gravitational energy transfer between equal masses.**

We have investigated all possible disturbances, side effects, and errors, and have corrected them. We have also performed many control experiments simulating possible side effects such as vibration, external gravitational disturbances, and air drafts. Additionally, we have theoretically investigated the potential physical reasons for our extraordinary experimental results that are in contradiction to Newtonian gravitational theory. We have supposed that the gravitational interaction may depend on the preliminary dissipation process of the gravitational self-energy (or binding energy). In the usual gravitational experiments the kinetic energy of the pendulum masses (or detector masses) are very small because of their tiny values of mass and very low oscillating frequency. For this reason, they can very quickly dissipate the gravitational binding energy that is caused by the source masses. **We therefore propose that Newtonian gravitational theory may only be valid only for bounded masses** (i.e. after dissipation of their gravitational binding energy). For technical reasons, in our experiments the dissipation process is rather slow and that is why we have found unknown gravitational phenomenon.

Though a full theoretical analysis of our experiments is in progress, we can present our preliminary generalized model for the description of gravity:

$$F(m, M, t) = G[1 - exp(-\lambda t)]\frac{mM}{r^2} + G_f exp(-\lambda t)\frac{m(M-m)}{r^2},$$

where r is the distance between the interactive masses m and M where $M>m$, G is the Newtonian gravitational constant, $G_f/G \approx 450$, and the parameter λ is the damping factor of the gravitational pendulum (which generally represents the energy dissipation process of the gravitational bindings). Here in the above equation, the first term represents Newtonian gravity and the second term is the new "dynamic face" of gravity.

In conclusion, it is our hope that other independent laboratories will be able to repeat experiments similar to ours in order to further validate our findings and theories.

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