А. Л. Дмитриев

Физическая гравитация

A. L. Dmitriev
Physical Gravity

Санкт-Петербург
2018 г

УДК 53.01
ББК 22.31
Д-53

Д-53 **Дмитриев А. Л.**
Физическая гравитация – СПб:Печатный Цех, 2018. – 240 стр.

Физическая гравитация

Physical Gravity

A. L. Dmitriev

В последнее столетие, благодаря активной пропаганде релятивистских методик в истолковании всемирного тяготения, большую популярность обрела математическая теория гравитации. Абстрактная, позитивистская в своей основе «математическая гравитация» не в состоянии описать все многообразие явлений тяготения. Построение физической модели, описывающей свойства гравитации и открывающей новые пути ее прогрессивного развития, возможно только на основании данных опыта при ограниченном наборе умозрительных гипотез. Альтернативой «математической» является реалистичная, приближенная к данным опыта физическая гравитация. Сборник содержит тексты опубликованных в 1998-2018 г. статей и докладов автора, посвященных электродинамическим аналогиям и «неклассическим» экспериментальным эффектам в гравитации.

ISBN 978-5-6041192-9-7

Физическая гравитация
Physical Gravity

A. L. Dmitriev

Введение

Физика есть «наука о свойствах и строении материи, о формах ее движения и изменения, об общих закономерностях явлений природы». Значительная роль физики в научном мировоззрении, в становлении технических наук и их полезных для практики приложений общеизвестна. Физика начиналась с простейших опытов, с поисков объяснений причин взаимодействий тел и результатов многочисленных экспериментов: механических, газовых, электрических, акустических, оптических. Утверждения, что именно эксперимент лежит в основе физики и что практика - критерий истины, никогда не вызывали сомнений. Но, с введением вероятностных способов описания взаимодействий элементарных частиц и связанным с такими подходами статистическим истолкованием самих физических законов, абстрактные физические модели приобрели особую популярность. Стало очевидным, что увлечь себя в область умствования – научной схоластики, сдобренной «красивой» математикой, физика вполне в состоянии. Именно это произошло в минувшее столетие с так называемой ортодоксальной физикой гравитации принявшей форму «математической» гравитации. Здесь физика, в сущности, «исчезла», превратилась в раздел хрустально-чистой математики, а ее научное обоснование свелось к громоздким математическим построениям в довольно «смелых» попытках объяснения бесконечно далеких в масштабах времени и расстояний астрономических явлений. Трудоемкий, добросовестно выполненный лабораторный гравитационный эксперимент утратил авторитет и значимость, уступив место бойким астрофизическим фантазиям и разного рода математическим спекуляциям. Своеобразная научная «храбрость», намерение в принципе изменить якобы устаревший стиль мышления естествоиспытателя, стала новаторским приемом решения сложных научных проблем. Примерами такого новаторства явились смелое отбрасывание Эйнштейном понятия эфира (ввиду его якобы полной бесполезности) и канонизация, признание фундаментальным «законом природы», преобразований координат Лоренца, выведенных на основе простых классических представлений. Более того, «физики-теоретики» (в сущности, - бессмысленное словосочетание) вернулись к устаревшей, но удобной в житейском отношении идее о том, что для понимания физических явлений вообще нет необходимости в постановках каких-либо экспериментов, и что «красота и элегантность» уравнений теории являются главными критериями ее ценности и содержательности. Пропаганда «релятивистской» трактовки природы гравитации, тысячи красочно иллюстрированных книг, брошюр и портретов призваны внедрить в сознание читателей убеждение в справедливости именно эйнштейновской модели тяготения. Наоборот, несогласие с релятивистской риторикой, стремление построить теорию гравитации на альтернативных, основанных на опыте физических принципах, подверглись шельмованию со стороны армии ученых «энциклопедистов» и рафинированных математиков, считающих себя физиками. Между тем, нетерпимость релятивистов к критике есть один из признаков их идейной несостоятельности, если напомнить верное замечание Д. И. Менделеева: «спокойная скромность утверждений обыкновенно сопутствует истинно научному, а там, где хлестко и с судейскими приемами стараются зажать рот всякому противоречию, истинной науки нет».

Релятивисты – воинствующие приверженцы теории относительности – предпочитают замалчивание как наиболее эффективную меру борьбы с научным инакомыслием. Сегодня подконтрольные релятивистам издательства и редакции академических научных журналов без рассмотрения отклоняют научные статьи даже с отдаленной критикой теории относительности. Такие приемы «идейной борьбы» в науке известны со времен Бруно и Галилея, впрочем, они всегда приносили лишь вред научному прогрессу.

Хотя, как часто принято говорить, физика – наука экспериментальная, любому физическому эксперименту предшествует замысел, некоторая идея, без которой этот эксперимент невозможен в принципе. Такая идея зарождается в процессе обобщения результатов опытов и наблюдений, их глубокого осмысления, поиска аналогий в различных, порой весьма удаленных друг от друга областях знаний. «Философия» творческого процесса в физике, как и в других областях научной деятельности, сложна и до конца непостижима. Тем не менее, многолетний опыт развития науки подтверждает, что построение рациональной, практически полезной физической модели или теории, открывающей новые прогрессивные пути развития физики, возможно именно на основании данных экспериментов при ограниченном наборе умозрительных гипотез. Возвращение к физической гравитации неизбежно.

Настоящий сборник содержит тексты опубликованных в 1998-2018 г. статей и докладов автора, посвященных электродинамическим аналогиям и «неклассическим» экспериментальным явлениям в гравитации. Их новизна и научная значимость кратко характеризуются в нижеприводимой Таблице.

№	Авторы, название статьи и источник публикации	Новизна и научное значение
1.	А. Л. Дмитриев, В. С. Снегов Влияние ориентации стержня на его массу. Измерительная техника, № 5, 22 - 24 (1998) A. L. Dmitriev, V. S. Snegov Influence of orientation of bar on its mass. Measurement Techniques, Vol.41, No 5, pp 425 - 429 (1998)	С учетом действия различных физических факторов, экспериментально показано, что вес вертикально ориентированного немагнитного металлического стержня превышает его вес в горизонтальном положении. Этот результат может рассматриваться как гравитационный аналог усиления оптического излучения в активных средах. Подобный эффект физической ориентационной зависимости взвешиваемой массы, ранее наблюдался в метрологии при точных измерениях масс дисковых (piston- gage) гирь.
2.	А. Л. Дмитриев О влиянии внешних упругих (электромагнитных) сил на силу тяжести. Известия ВУЗ «Физика». № 12, 65 - 69 (2001) A. L. Dmitriev On the Influence of External Elastic (Electromagnetic) Forces on the Gravity. Russian Physics Journal, Vol. 44, No 12, pp 1323 – 1327 (2001)	Рассмотрена аналогия гравитационных и электромагнитных сил противодействия, введены коэффициенты взаимодействий упругих и гравитационных сил, кратко описаны эксперименты по взвешиванию механического ротора с горизонтальной осью вращения. На основе данных измерений коэффициентов восстановлений при упругом ударе шара о плиту оценен порядок величин указанных коэффициентов взаимодействий.

3.	А. Л. Дмитриев, В. С. Снегов Взвешивание механического гироскопа с горизонтальной и вертикальной ориентацией оси вращения. Измерительная техника, № 8, 33 - 35 (2001) A. L. Dmitriev, V. S. Snegov The Weighing of a Mechanical Gyroscope with Horizontal and Vertical Orientation of the Spin Axis. Measurement Techniques, Vol. 44, No 8, pp 831 - 833 (2001)	Описан эксперимент по взвешиванию двух спаренных механических роторов с примерно нулевым суммарным кинетическим моментом, продемонстрировано различие их веса при вертикальной и горизонтальной ориентациях их общей оси вращения. Данный результат подтверждает связь ускорений, обусловленных центробежными (электромагнитными) силами, с силой гравитации.
4.	А. Л. Дмитриев Неравенство коэффициентов восстановления при вертикальном и горизонтальном квазиупругих ударах шара по массивной плите. Прикладная механика, Том 38, № 6, 124 - 126 (2002) A. L. Dmitriev Inequality of the Coefficients of Restitution for Vertical and Horizontal Quasielastic Impacts of a Ball Against a Massive Plate. International Applied Mechanics. Vol. 3, No 6, pp 747 - 749 (2002).	Впервые экспериментально установлено различие коэффициентов восстановления при горизонтальном и вертикальном ударах шара по массивной плите. При этом ускорения шара достигали 10^4 нормальных ускорений силы тяжести, что позволило оценить степень влияния электромагнитных сил упругости на силу гравитации. Данный результат прямо подтверждает взаимосвязь электромагнитных (упругих) сил и силы тяжести.
5.	А. Л. Дмитриев, Е. М. Никущенко, В. С. Снегов Влияние температуры тела на его вес. Измерительная техника, № 2, 8 - 11 (2003) A. L. Dmitriev, E. M. Nikushchenko, V. S. Snegov Influence of the Temperature of a Body on its Weight. Measurement Techniques. Vol. 46, No 2, pp 115 - 120 (2003)	Первая в научной литературе публикация результатов систематических измерений влияния температуры на вес немагнитных металлических стержней, демонстрирующая отрицательную температурную зависимость веса тел. Предложена простая теоретическая модель этого эффекта и показана степенная зависимость физического веса тел от их абсолютной температуры (в классическом приближении, при температурах выше температуры Дебая).
6.	А. Л. Дмитриев, Н. Н. Чесноков Влияние ориентации анизотропного кристалла на его вес. Измерительная техника, № 9, 36 - 37 (2004)	Экспериментально подтверждено различие весов анизотропного кристалла, измеренных при различных ориентациях его кристаллографической оси. Физическая причина этого эффекта обусловлена анизотропией скоростей упругих волн в кристалле и

	A. L. Dmitriev, N. N. Chesnokov The effect of the orientation of an anisotropic crystal on its weight. Measurement Techniques, Vol. 47, Issue 9, pp 899–901 (2004)	соответствующих ускорений атомов кристалла при их тепловом движении. Данный эксперимент также подтверждает взаимосвязь электромагнитных и гравитационных сил.
7.	A. L. Dmitriev On Possible Causes of Divergencies in Experimental Values of Gravitational Constant. arXiv: physics/0610282 (2006)	Показано, что причиной заметного разброса абсолютных значений гравитационной постоянной, измеренных в экспериментах различных авторов, может быть разница абсолютных температур гравитационно-взаимодействующих пробных тел. Наблюдаемый разброс экспериментальных значений гравитационной постоянной косвенно подтверждает влияние температуры на силу гравитации.
8.	A. L. Dmitriev Temperature dependence of gravitational force: experiments, astrophysics, perspectives. arXiv: physics/0611173 (2006)	Обзорная статья по материалам доклада на международной конференции GRG-18 (Сидней, Австралия). Показано, что отрицательная температурная зависимость силы гравитации фактически наблюдалась еще в опытах Шоу и Дэви, результаты которых опубликованы в 1923 году. Отмечено, что температурная зависимость силы гравитации должна учитываться при объяснении ряда астрофизических эффектов, в том числе, прецессии орбит планет, изменениях периода двойных пульсаров, а также динамики околосолнечной плазмы (солнечного ветра).
9.	A. L. Dmitriev Experimental Study of Gravity Force Temperature Dependence, in 18th International Conference on General Relativity and Gravitation (GRG-18), Sydney, 2007, Abstract Book, pp. 77-78.	Резюме доклада автора на конференции GRG-18 по проблемам гравитации в июле 2007 года. Кратко поясняются физические основания и следствия отрицательной температурной зависимости силы гравитации.

10.	A. L. Dmitriev Measurements of the Influence of Acceleration and Temperature of Bodies on their Weight. Proceedings of *Space Technology and Application International Forum (STAIF-2008),* edited by M. El-Genk, AIP Conference Proceedings, Vol. 969, NY, 2008, pp. 1163-1169. arXiv: 0803.1730 (General Physics, 2008)	Статья по материалам доклада на международной конференции STAIF-2008 в Альбукерке (США). Кратко рассмотрена взаимосвязь силы тяжести и ускорения, обусловленного действием сил упругости. Приведены результаты экспериментов по взвешиванию спаренных роторов, по измерению коэффициентов восстановлений при упругом ударе, по температурной зависимости веса немагнитных стержней и по взвешиванию анизотропного кристалла.
11.	A. L. Dmitriev On the nature of inertial mass. arXiv: 0806. 0796 (2008)	Обсуждается физическая природа инертной массы тела. В соответствии с идеей Э. Маха, впервые показана прямая пропорциональность (не «тождественность», как в ОТО) инертной и гравитационной масс и их зависимость от коэффициентов взаимодействия упругих и гравитационных сил.
12.	A. L. Dmitriev On the Experimental Substantiation of Anisotropy of Inertial Mass of Body in the Earth Gravitation Field. arXiv: 0903.4433 (General Physics, 2009)	Приведены обоснования возможной анизотропии инертной массы тел в гравитационном поле Земли. Следствием этого должно быть различие хода механических часов при вертикальной и горизонтальной ориентациях оси вращения маятника; при этом исключается влияние технических факторов и особенностей конструкции таких часов. Приведены результаты измерений ориентационной зависимости хода маятниковых часов, изготовленных на Петродворцовом часовом заводе. На основе этих результатов дана приближенная оценка абсолютной величины ускорения силы гравитации, обусловленной «бесконечно» удаленными массами в пределах полного телесного угла, величина которой примерно в тысячу раз превышает нормальное земное ускорение силы тяжести.

13.	A. L. Dmitriev, E. M. Nikushchenko, S. A. Bulgakova Nonzero Result of Measurement of Acceleration of Free Falling Gyroscope with the Horizontal Axis. arXiv: 0907.2790 (General Physics, 2009)	Экспериментально показано различие ускорений свободного падения контейнера с установленными в нем роторами с горизонтально ориентированной осью и нулевым полным кинетическим моментом при неподвижном роторе и при его вращении.
14.	A. L. Dmitriev Analogue of Lenz’s rule in phenomenological gravitation. AIP Conference Proc. SPESIF-2009, Vol. 1103, pp 345 – 351 (2009)	Обзорная статья по материалам доклада на международном форуме SPESIF-2009. Обсуждена гравитационная аналогия правила Ленца, кратко описаны результаты экспериментов по взвешиванию механических гироскопов и по температурной зависимости веса тел. Обсуждена гравитационная природа инертной массы тела. Рассмотрены астрофизические следствия температурной зависимости веса тел.
15.	A. L. Dmitriev, E. M. Nikushchenko and S. A. Bulgakova Dynamic Weighing Experiments – the Way to New Physics of Gravitation. AIP Conference Proc., Vol. 1208, pp 237 – 246 (2010)	Обзорный доклад, представленный на международную конференцию AIP в 2010 году. Отмечено, что эксперименты по динамическому взвешиванию тел открывают новое направление в физике гравитации. Обсуждена взаимосвязь гравитационной и инертной масс тел, рассмотрена проблема анизотропии инертной массы, приведены результаты измерений ускорения свободного падения механического ротора с горизонтальной осью вращения и нулевым кинетическим моментом.
16.	A. L. Dmitriev Frequency Dependence of Rotor's Free Falling Acceleration and Inequality of Inertial and Gravity Masses. arXiv:1101.4678 (General Physics, 2011)	Представлены результаты измерений ускорения свободного падения контейнера с находящимся в нем ротором с горизонтальной осью от частоты вращения ротора. Впервые показано, что на отдельных частотах вращения ротора возникают значительные отклонения наблюдаемых величин ускорений свободного падения контейнера от нормального ускорения силы тяжести.
17.	A. L. Dmitriev, E. M. Nikushchenko Experimental confirmation of the gravitation force negative temperature dependence.	Приведены результаты измерений веса контейнера с закрепленными внутри него пьезокерамическими преобразователями. Показано уменьшение веса контейнера,

	arXiv:1105.2666 (General Physics, 2011)	связанное с увеличением температуры пьезокерамики.
18.	А. Л. Дмитриев Простой эксперимент, подтверждающий отрицательную температурную зависимость силы тяжести. Инженерная физика, №3, 48 – 51 (2012). A. L. Dmitriev Simple Experiment Confirming the Negative Temperature Dependence of Gravity Force. arXiv:1201.4461 (General Physics, 2012)	Приведены результаты измерений веса герметичного контейнера с помещенным внутри него медным образцом, нагреваемым вольфрамовой спиралью. Показано, что увеличение температуры образца сопровождается уменьшением его веса, которое не объясняется влиянием плавучести и воздушной конвекции.
19.	А. Л. Дмитриев, Е. М. Никущенко Частотная зависимость ускорения свободного падения ротора Инженерная физика, №1, 13 – 17 (2012)	Описан эксперимент по измерению зависимости ускорения свободного падения контейнера с находящимся внутри него ротором от частоты вращения ротора. Показано, что на отдельных частотах вращения ротора наблюдаются значительные отклонения величины ускорения свободного падения от нормального ускорения силы тяжести.
20.	A. L. Dmitriev Physical Substantiation of an Opportunity of Artifical Change of Body Weight. (SPESIF-2012). Physics Procedia, Vol. 38, pp 150 – 163 (2012).	Обзорная статья. Обсуждаются возможности искусственного изменения физического веса тел. Впервые изложена элементарная теория, объясняющая зависимость среднего веса механического осциллятора от частоты его колебаний. Такой эффект возможен при небольших колебаниях величины ускорения свободного падения, обусловленных нестационарными геофизическими процессами в объеме Земли. Приведены результаты измерений температурной зависимости веса различных материалов.
21.	A. L. Dmitriev, S. A. Bulgakova Negative Temperature Dependence of Gravity – A Reality. World Academy of Science, Engineering and Technology. Issue 79, pp 1560 – 1565 (2013).	Материалы доклада, представленного на международной конференции в Осло в июле 2013 года. Приведены результаты экспериментов, доказывающих отрицательную температурную зависимость физического веса тела. Рассмотрена элементарная модель этого явления.
22.	А. Л. Дмитриев, Е. М. Никущенко, Н. Н. Чесноков	Описан эксперимент по точному взвешиванию герметичного контейнера с установленным внутри него механическим вибратором. Показано, что уменьшение

	Изменение веса герметичного контейнера с встроенным электромеханическим вибратором. Инженерная физика, № 9, 27 – 30 (2014)	веса контейнера в наибольшей степени обусловлено нагреванием электромагнита вибратора и подтверждает отрицательную температурную зависимость веса тел.
23.	A. L. Dmitriev Prospects of high-frequency gravimetry. Proc. Of the International Conference APSAC 2015, Vienna, Austria, March 15-17, 2015. pp 237 – 240. International Journal of Circuits, Systems and Signal Processing. Vol. 9. pp. 275-280 (2015).	Материалы доклада, представленного на конференции APSAC-2015 (г. Вена, июль 2015 г.). Изложена элементарная теория влияния вертикальных колебаний механического осциллятора на его средний вес, приведены результаты измерений ускорения свободного падения ротора механического гироскопа. Предложено новое направление в гравиметрии – высокочастотная (ВЧ) гравиметрия как метод исследований ВЧ флуктуаций гравитационного поля Земли.
24.	A. L. Dmitriev Thermogravimetry and the Negative Temperature Dependence of Gravity. Applied Physics Research, Vol. 7, No 6, pp 43 – 48 (2015)	Рассмотрены физические принципы температурной зависимости веса тел и эксперименты, подтверждающие такую зависимость. Показано, что данные термогравиметрии – известного направления в технике физико-химического анализа материалов, подтверждают физическую температурную зависимость силы тяжести. Впервые высказана идея о возможности явления выталкивания плазмы гравитационным полем.
25.	A. L. Dmitriev, E. M. Nikushchenko Expulsion of Plasma in A Gravity Field. Applied Physics Research, Vol. 8, No 2, pp 38 – 39 (2016)	Приведены результаты экспериментов по изучению формы тлеющего разряда в воздухе, в переменном токе и давлении около 0.1 атм. Показано, что характерная параболическая форма тлеющего разряда может быть обусловлена выталкиванием плазмы гравитационным полем, что согласуется с идеей температурной зависимости силы гравитации.

26.	A. L. Dmitriev Gravitational Induction as Analog of Amplification of Light in Active Medium Applied Physics Research, Vol. 9, No 5, pp 87 – 89 (2017)	Введено понятие гравитационной индукции. С использованием результатов работы [1] оценена величина коэффициента усиления силы тяжести в титане.
27.	А. Л. Дмитриев, Н. Н. Чесноков Уменьшение веса волоконного световода при распространении в нем лазерного излучения Труды VII международной конференции по фотонике и информационной оптике (FIO 2018), г. Москва, с. 204-205.	Впервые показано уменьшение веса волоконного световода при распространении в нем лазерного излучения. Возможной причиной уменьшения веса световода является нагревание сердцевины световодов вследствие поглощения излучения лазера, что подтверждает отрицательную температурную зависимость силы тяжести.
28.	А. Л. Дмитриев, В. С. Снегов, Ю. И. Каменских, Н. Н. Чесноков Изменение веса волоконного световода под действием лазерного излучения A. L. Dmitriev, V. S. Snegov[1], Yu. I. Kamenskih[1], N. N. Chesnokov[2] Change of the weight of optical fiber under the impact of laser radiation International Journal of Advanced Research in Physical Science (IJARPS) Volume 5, Issue 4, 2018, pp 1-4	Описаны результаты высокоточного взвешивания герметичных контейнеров с находящимися в них катушками волоконных световодов (жгутов) при возбуждении световодов излучением гелий-неонового и полупроводникового лазеров. Показано уменьшение веса световодов при распространении в них лазерного излучения, причем такое уменьшение веса сохраняется в течение нескольких секунд после выключения лазеров.
29.	А. Л. Дмитриев Черные дыры: возможны варианты «Поиск», № 39 (749), 26 сентября 2003 г.	Научно-популярная статья с критикой гипотезы «черных дыр».
30.	А. Л. Дмитриев Управляемая гравитация, изд. «Новый Центр», М. , 2005 г.	Монография.

31.	А. Л. Дмитриев Экспериментальная гравитация, изд. «Реноме», СПб, 2014 г.	Монография, частично содержащая материалы [29].

Тексты оригинальных работ (1998-2018 г.)

Порядковый номер публикаций соответствует приведенным в Таблице).

№1

А. Л. Дмитриев, В. С. Снегов

Влияние ориентации стержня на его массу

Измерительная техника, № 5, 22 - 24 (1998)

A. L. Dmitriev, V. S. Snegov

Influence of orientation of bar on its mass

Measurement Techniques, Vol.41, No 5, pp 425 - 429 (1998)

Measurement Techniques, Vol. 41, No. 5, 1998

INFLUENCE OF ORIENTATION OF BAR ON ITS MASS

A. L. Dmitriev and V. S. Snegov

UDC 531.78

The influence of vertical gradients of gravity, air density and temperature, magnetic induction, as well as air convection on the measured mass of an extended specimen is theoretically estimated. An experiment designed to compare the mass of a vertically oriented nonmagnetic titanium bar to the same bar when oriented in the horizontal plane is described. Possible factors responsible for the discrepancy between the experimental results obtained and the theoretical estimates presented are discussed.

It is known that the influence of a variety of geometric and physical factors must be taken into account in precision weighing, for example, the dimensions and shape of the body, irregularities in the gravitational, temperature, electrical, and magnetic fields, as well as the density, moisture, and convection of the ambient air, and so on. In the present article the role of these factors is analyzed in a comparison of the mass of a bar with markedly different longitudinal and transverse dimensions between the case of orientation in the vertical plane as opposed to orientation in the horizontal plane. The effect of these perturbing factors on the measured mass of such a bar is considered and the influence of variations in the orientation of the bar on its weight is investigated experimentally.

VERTICAL GRADIENT OF GRAVITY

Far from massive bodies, under laboratory conditions the dependence of free-fall acceleration $g(z)$ on the altitude z of a point of observation over the surface of the Earth may be represented in the form

$$g(z) = g_0 - kz,$$

where g_0 is the free-fall acceleration at $z = 0$ and k is the normal gravity gradient, equal to $3.086 \cdot 10^{-6}$ sec^{-2} [1].

The weight P_l of a homogeneous bar with density ρ_m, cross section s, and length l in the z direction is given by

$$P = \int_0^l g(z)\, \rho_m\, s\, dz = mg_0 - mkl/2,$$

where $m = \rho_m sl$ is the mass of the bar.

The relative difference δ_g in the mass of a bar of length l_1 and thickness $l_2 = \sqrt{s}$ measured in the vertical and horizontal positions is given by

$$\delta_g = \frac{P_{l1} - P_{l2}}{mg_0} = -\frac{k}{2g_0}(l_1 - l_2).$$

For example, with $l_1 = 15$ cm, $l_2 = 3$ cm, $g_0 = 9.82$ m·sec^{-2}, we have $\delta_g = -1.9 \cdot 10^{-8}$.

VERTICAL GRADIENT OF AIR DENSITY

The vertical gradient of air density κ is governed by its normal (height) dependence κ_0 and the temperature dependence κ_t if the vertical gradient of air temperature τ is nonzero. Representing the function $\rho(z)$ of air density in the neighborhood of the specimen in the form

---

Translated from Izmeritel'naya Tekhnika, No. 5, pp. 22-24, May, 1998.

0543-1972/98/4105-0425$20.00

TABLE 1

Measured value of difference in masses	Position of specimen in balance pan	
	left	right
X_1	A↓	B→
X_1	A↑	B→
X_2	B→	A↓
X_2	B→	A↑
Y_1	A→	B↓
Y_1	A→	B↑
Y_2	B↓	A→
Y_2	B↑	A→

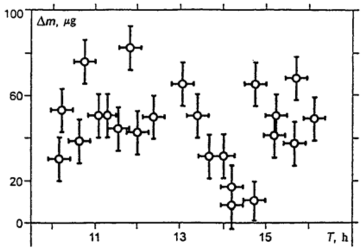


Fig. 1. Apparent difference in mass Δm of a titanium bar in the vertical plane as compared to the case of horizontal orientation measured at different times of the day T (legal summer time of the day is shown).

$$\rho(z) = \rho_0 - \kappa z, \tag{1}$$

we estimate the magnitude of the buoyancy force F_A acting on a weighed bar of height l thus:

$$F_A = gs \int_0^l \rho(z)\, dz, \tag{2}$$

where s is the horizontal cross section of the specimen and g is free-fall acceleration which, in the present estimation, is assumed to be constant. In light of Eqs. (1) and (2), it is easily proved that the relative difference δ_A between the mass of a bar when in the vertical plane as compared to the case when it is oriented in the horizontal plane and attributable to the action of buoyancy forces exclusively is given by

$$\delta_A = \frac{\kappa}{2\rho_m}(l_1 - l_2). \tag{3}$$

With a constant air temperature in the neighborhood of the specimen, the normal density gradient $\kappa_0 = 1.133 \cdot 10^{-4}$ kg·m^{-4} [2].

The temperature dependence $\rho(t)$ of the density of dry air at atmospheric pressure 760 mm Hg is described by the well-known empirical formula

$$\rho_t = \frac{1{,}2932}{1 + 0{,}00367\, t} \ \text{kg} \cdot \text{m}^{-3} \tag{4}$$

where t is temperature (in degrees Celsius). By Eqs. (1) and (4), the vertical gradient of air density κ_t attributable to its temperature gradient $\tau = dt/dz$ is given by $\kappa_t = 4.746 \cdot 10^{-3}\, \tau$.

Under laboratory conditions, even without special protective measures, a typical value of τ will not exceed 0.3°C/m, with $\kappa_t = 1.42 \cdot 10^{-3}$ kg·m^{-4}, which is more than 12 times the value of κ_0. Substituting this value into Eq. (3) for a specimen, for example, one made of titanium ($\rho_m = 4.5 \cdot 10^3$ kg·m^{-3}) with dimensions $l_1 = 15$ cm and $l_2 = 3$ cm, we obtain $\delta_A = +1.9 \cdot 10^{-8}$.

ELECTRICAL AND MAGNETIC FIELDS

In weighing dielectrics, for example, glass or plastic specimens, electrical polarization induced by simple impact of the specimen may exert an influence on the results of exact weighing. If the body that is being weighed is a good conductor (metal), the difference in the potentials of the specimen and of the parts of the mechanism of the scale will be negligibly small, and the electrostatic forces will have virtually no influence on the readings of the scale. Thus, the force F_e of interaction of a plane metallic balance pan with the base of the scale, assuming a potential difference U between them, is given by

$$F_e = \frac{\varepsilon_0 A U^2}{2d^2},$$

where A is the area of the pan; d, the distance between the pan and the base; and ε_0, the permittivity of a vacuum. Supposing, as an example, that $A = 30$ cm^2, $d = 0.5$ cm, and a clearly overstated value $U = 1$ V, we obtain $F_e = 5.3 \cdot 10^{-10}$ N, a quantity that is a small fraction of the ultimate sensitivity of modern mechanical scales.

Magnetic fields may have a more noticeable effect on the results of exact weighing of metallic specimens. In a nonhomogeneous magnetic field with induction $B(z)$, the force F_B acting on a specimen with vertical projection of the magnetic moment M_z is given by

$$F_B = M_z \frac{\partial B}{\partial z}.$$

The influence of a magnetic field on the results of weighing is characterized by the dimensionless ratio $\delta_B = F_B / m g_0$, where m is the mass of the specimen. This ratio may assume comparatively great values (10^{-6}-10^{-4}) when weighing magnetized specimens made, for example, from iron alloys. In comparing the mass of a bar made of nonmagnetic substances (brass, titanium, etc.) and weighing up to 0.5 kg between the case of horizontal versus vertical orientation of the bar, the intrinsic magnetic moment of such specimens will not exceed 10^{-4} A·m^2. With a typical laboratory value of the vertical gradient of the magnetic induction $\partial B / \partial Z \lesssim 10^{-5}$ T·m^{-1}, the relative variation of the mass of such bars upon reorientation amounts to at most $\delta_B \approx 2 \cdot 10^{-10}$.

CONVECTION AND AIR HUMIDITY

Disturbances induced by thermal convection of air in direct proximity to a specimen that is being weighed are very difficult to control, since their magnitude depends on the distribution of air temperature and the shape and dimensions of the specimen. Free convection is due to a difference in the temperature Δt of the specimen and of the ambient air within the scale housing. Moreover, as a consequence of heat exchange, Δt is not a constant quantity (it is exponentially falling) and the effect of convective forces is also decreasing over time. In [3] the following expression was presented for the excess (apparent) mass Δm (expressed in grams) of a cylindrical specimen attributable to the action of convective air flows:

$$\Delta m_c = -9.2 \cdot 10^{-7} A l^{1/4} \Delta t^{3/4}, \tag{5}$$

where l is the height of the cylinder in centimeters; A, the area of its lateral surface, expressed in square centimeters; and Δt, the difference in the temperature of the specimen and of the ambient air, expressed in degrees.

The relative difference δ_c in the mass of a bar when it is oriented in the vertical plane as compared to the case in which it is oriented in the horizontal plane and attributable to the effect of air convection is given by

$$\delta_c = \frac{\Delta m_{c1} - \Delta m_{c2}}{m}, \tag{6}$$

where Δm_{c1} and Δm_{c2} are the excess masses of the specimens calculated according to Eq. (5) with $l = l_1$ and $l = l_2$, respectively.

Note that it is not entirely correct to apply Eq. (5) for calculation of the excess mass of a horizontally oriented cylinder. Nevertheless, bearing in mind the noncritical dependence $\Delta m_c(l)$, by means of the expression in Eq. (6) it is possible to estimate, at the least, the highest value of δ_c. Supposing, as an example, $l_1 = 15$ cm, $l_2 = 3$ cm, $A = 141$ cm^2, $m = 500$ g, and $\Delta t = 0.1$ °C (a virtually overstated value), we obtain $\delta_c = \pm 3.0 \cdot 10^{-8}$ (the "+" sign corresponds to $\Delta t < 0$).

The humidity of the ambient air is responsible for adsorption of moisture by the surface of the specimen, which must be taken into account in precision measurements of the absolute mass of bodies. In comparing the mass of a bar oriented in the vertical plane to the case in which it is oriented in the horizontal plane, the influence of air humidity on such measurements will be practically immaterial assuming that all necessary safety measures have been observed in the process of reorientation.

Cylindrical bars made of brand VT1 titanium measuring $l_1 = 15$ cm in length and $l_2 = 3$ cm in diameter, and with mass 476 g were used as the specimens in experimental investigations of the influence of orientation on the weight of bodies. Measurements of the difference $g\,\Delta m$ of a bar when oriented in the vertical plane as compared to the case in which it is oriented in the horizontal plane, in either case resting on the balance pan of a scale, were conducted on a first-class mechanical specimen scale with range of weighing up to 1000 g. A laboratory compartment expressly designed for exact weighing at an air temperature of around 20 °C and relative humidity 60% was used. A differential method of measurement was employed, with two specimens A and B with different orientations being placed in the balance pan. The mass of the bar when oriented in the vertical plane was compared to the case in which it was oriented in the horizontal plane according to method of Gauss substitutions. Each simple weighing was repeated twice with reorientation (shown in Table 1 by an arrow) of the vertically oriented specimen. Measurements were performed successively according to Table 1.

The mass of the bar in the case in which it is oriented in the vertical plane was compared to the case in which it is oriented in the horizontal plane, with the actual difference in masses Δm being calculated by means of the following formula:

$$\Delta m = \frac{1}{8}\left\{\left[\left(X_1 + \bar{X}_1\right) - \left(X_2 + \bar{X}_2\right)\right] - \left[\left(Y_1 + \bar{Y}_1\right) - \left(Y_2 + \bar{Y}_2\right)\right]\right\}.$$

In the calculations of elongations, the oscillation period of the scale's lever amounted to around 9 sec. The adjustment error of the specimens on the balance pans did not exceed ±3 mm. According to the estimates, the difference in temperatures between the upper and lower edges of the vertically oriented bar in the closed housing of the scale did not exceed 0.03°C and the difference in air temperatures in the housing of the scale and the specimen did not exceed 0.1°C. According to data of direct magnetic measurements, the vertical gradient of magnetic induction in a neighborhood of the scale's balance pan was in the range $0.3 \cdot 10^{-5}$-$3.2 \cdot 10^{-5}$ T·m^{-1}.

In the experiments we are describing, the standard deviation of measurements of the difference in masses Δm amounted to 10 μg. The standard deviation of the measurement results averaged over the entire data file did not exceed 5 μg.

The experimental values of the difference in masses Δm for a specimen made of titanium and obtained at different times of the day for a period of several days of observations are presented in Fig. 1. The mass of the bar in the case in which it was oriented in the vertical plane was compared to the case in which it was oriented in the horizontal plane, with the mean value of the relative difference in weights (masses) amounting to $\delta = \pm 1.0 \cdot 10^{-7}$ with error ±10%.

According to the theoretical estimates presented here, the total relative value δ of the difference in the mass of a specimen between the case of vertical and horizontal orientation $\delta = \delta_g + \delta_A + \delta_B + \delta_C$. Substituting into this formula the numerical values obtained earlier, which correspond quite closely to the conditions of the experiment we are describing, we find $\delta = \pm 3.0 \cdot 10^{-8}$. The magnitude of these estimates is only slightly affected by the fact that the weighed specimen has the shape of a cylinder, and not that of a bar. Obviously, even if there is uncertainty as to the direction of the convective air currents, which determine the sign of δ_C, the result obtained in the experiment does not correspond to the theoretical estimates.

This discrepancy is apparently attributable to the following factors: the fact that the theoretical models were not properly applied; incorrect numerical estimates of the temperature and other conditions of the weighing process; and systematic (hardware or procedure) errors in the course of weighing the specimens. From the available data it is not clear which of these factors should be given preference.

Note, too, that, in theory, the possibility that there are other physical factors that could account for the experimental result is not precluded. Thus, a decrease in the value of Δm is observed at around 1400 in summer legal time, which is close to astronomical noon. It should also be kept in mind that in the experiment we have described, the comparison of the mass of a specimen in both of the positions was, in fact, carried out in a dynamic weighing mode, i.e., with weakly damping oscillations of the weight lever. Under these conditions, the weighed bodies shifted along the vertical with periodic accelerations, a circumstance that, together with factors related to the dimensions of the bodies could, in theory, influence the nature of the gravitational interactions. Note that the dynamic mode of weighing is essentially an indirect method of measurement that does not correspond to the strict definition of weight as a force acting on a support that is fixed relative to the Earth.

Thus, the actual factors responsible for the observed inequality between the mass of a nonmagnetic bar when in the vertical plane as opposed to its mass when in the horizontal plane will have to be established in the course of further precision experiments carried out under the conditions of a vacuum under strictly controlled weighing conditions.

REFERENCES

1. E. A. Mudretsova and K. E. Veselov (eds.), Gravitational Prospecting. Manual of Geophysics [in Russian], Nedra, Moscow (1990).
2. Yu. S. Sedunov (ed.), The Atmosphere [in Russian], Gidrometeoizdat, Leningrad (1991).
3. M. Gläser, Metrologia, 27, No. 2, 95 (1990).

Примечание: На стр. 17 оригинала, 16-я строка снизу, имеется опечатка. Правильный знак относительной разности масс положительный: $\delta = +1.0 \cdot 10^{-7}$.

№ 2

Russian Physics Journal, Vol. 44, No. 12, 2001

ON THE INFLUENCE OF EXTERNAL ELASTIC (ELECTROMAGNETIC) FORCES ON THE GRAVITY

A. L. Dmitriev

Abstract. Consequences of the possible effect of external elastic (electromagnetic) forces applied to a test body on the gravity are considered phenomenologically. The results of experimental estimates of the coefficients of interaction between elastic and gravitational forces are briefly described.

Direct measurements of gravity, as a rule, are carried out when the gravity is compensated by external forces electromagnetic in nature. For example, in the Cavendish and Eötvös experiments, the gravitation force acting on a test body was determined from measurements of the elasticity of a twisted thread [1]. As a matter of fact, already in these classic experiments a close relation between gravitation and electromagnetism forces in their phenomenological interpretation was directly manifested. However, a question arises: is there a reaction force when this relation is described? Or can an elastic (in its essence, electromagnetic) force influence the gravity force applied to a test body? This problem formulation is natural if we take into account numerous analogies in the behavior of many physical and chemical systems that tend to preserve their steady state (including the Lenz rule and the Le Chatelier–Brown principle).

It should be noted that modern treatment of gravitational interaction as a manifestation of space-time curvature and modern field (including quantum) theories of gravitation impede or completely eliminate the formulation of the problem on the influence of external electromagnetic forces on the gravitation force. Meanwhile, simple phenomenological approaches to a description of interactions of bodies repeatedly demonstrated their usefulness and efficiency for solving many physical problems. Consequences of the possible influence of external elastic forces applied to a body on the gravity experienced by it are examined below.

Let an acceleration due to gravity of a body in a homogeneous gravitational field, which is at rest relative to the Earth or is freely falling, be constant and equal to g_0 . If under the action of an external elastic force this body, for example, a ball, moves upward with acceleration, the increment to the gravity force acceleration Δg_c in the first approximation can be set directly proportional to the acceleration of the external force, namely,

$$\Delta g_c = \alpha_c a_g \tag{1}$$

where a_g is the vertical component of acceleration caused by the external force. For accelerated (also under the action of the external force) motion of the test ball downwards, the corresponding acceleration due to gravity changes its sign and generally magnitude:

$$\Delta g_p = -\alpha_p a_g \ . \tag{2}$$

Nondimensional coefficients α_c and α_p entering into Eqs. (1) and (2) characterize a degree of influence of external nongravitational, for example, elastic forces on the gravity. The question arises: are these coefficients nonzero? What are their numerical values? This question can be answered only experimentally. To this end, it is necessary to perform a high-precision weighing of the test body which strongly accelerates under the action of external nongravitational forces.

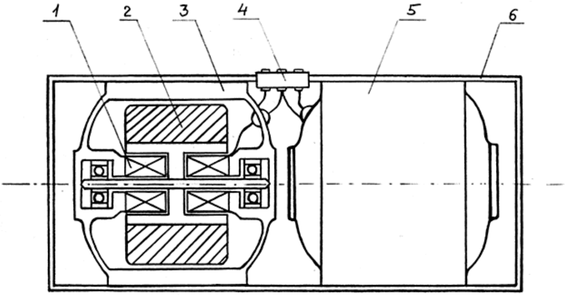


Fig. 1. Design of the container being weighed comprising electrical windings 1 of the stator of an asynchronous gyroscope motor, massive cylindrical rotor part 2, housing of the first gyroscope 3, terminals of the gyroscope motor supply unit 4, housing of the second gyroscope 5 (shown without sectional view), and housing of the container 6.

In practice, precise weighing of bodies is quite often accompanied by their accelerated motion, because during such measurements a scale beam undergoes slowly decaying angular oscillations. Small values of accelerations of test bodies during their weighing could be a reason for the influence of these accelerations on the results of precise weighing that remained unnoticed for a long time. Until recently, no special investigations into the influence of test body accelerations on the results of their weighing have been conducted (some anomalies observed during precise weighing of extended test bodies indicate that such influence is possible in principle [2]).

A simple method of estimating the difference between the coefficients Δg_c and Δg_p is based on weighing the rotor of a mechanical gyroscope with the horizontal gyration axis. Gyration of the solid rotor is accompanied by centripetal accelerations of material particles forming it; in this case, the role of external nongravitational forces acting on particles of the rotor is played by elastic forces. Based on Eqs. (1) and (2), and integrating the increments Δg_c and Δg_p over the entire rotor volume, we can demonstrate that the weight P of the horizontally oriented rotor shaped as a cylinder with the internal radius R_1 and the external radius R_2 is

$$\boldsymbol{P} = \boldsymbol{mg}_0\left[1-\left(\alpha_p-\alpha_c\right)\frac{2\left(\boldsymbol{R}_2^3-\boldsymbol{R}_1^3\right)}{3\pi\boldsymbol{g}_0\left(\boldsymbol{R}_2^2-\boldsymbol{R}_1^2\right)}\omega^2\right], \qquad (3)$$

where m is the rotor mass and ω is the angular velocity of its gyration.

The high-precision weighing of rotors with large kinetic momenta is complicated by the gyroscopic effect caused by the diurnal rotation of the Earth [3]. This difficulty is eliminated by weighing of a pair of coaxial rotors with vectors of kinetic momenta opposite in directions and equal in absolute values. The total kinetic momentum of the container being weighed with rotors placed in them is equal to zero. This eliminates the influence of the gyroscopic effect. Such experiment was carried out with the use of two GMS-1 high-quality evacuated rotors of aircraft gyroscopes placed in a closed heat-insulated container with a mass of about 1609.845 g and dimensions of 70 x 70 x 145 mm (Fig. 1).

The successive weighing of the container with horizontal and vertical gyration rotor axes was performed with a high-precision SS2000 comparator produced by the SARTORIUS corporation in a special metrological chamber at an air temperature of 20 C, a pressure of 1015 GPa, and a relative humidity of 40%. The influence of temperature effects, electromagnetic background radiation, and buoyancy was also taken into account during measurements. Figure 2 shows the measured dependence of the difference between masses of containers with horizontal and vertical gyration rotor axes on the gyration rotor frequency ν and on the time of rotor coasting.

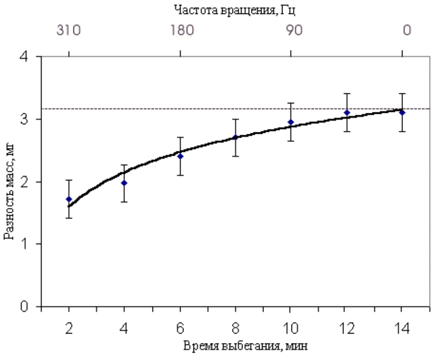


Fig. 2. Experimental dependence of the measured mass difference of the container with horizontal and vertical gyration rotor axes on the coasting time and the rotor gyration frequency.

It seems likely that the constant component of the measured mass difference of about 3.2 mg (at ν = 0) is caused by the residual magnetization of metal rotor housings. Considering this circumstance, the difference between the interaction coefficients ($\alpha_p - \alpha_c$) was estimated based on Eq. (3), which by the order of magnitude was close to 10^{-7} (internal and external rotor radii were 15 and 25 mm, respectively, and the rotor mass was about 250 g).

We note that precise measurements of masses of gyrating rotors of mechanical gyroscopes were repeatedly performed (for example, see [4–6]), and no influence of the rotor gyration on balance readings was found. The above-described experiment differed radically from [4–6] because its purpose was measuring the rotor masses with the horizontal gyration axis in addition to the vertical one, as in the above-indicated works.

As can be demonstrated based on Eqs. (1) and (2), when a body of mass m undergoes harmonic oscillations under the action of a periodic external force, its weight P averaged over the oscillation period is

$$\boldsymbol{P} = \boldsymbol{m}\boldsymbol{g}_0\left[1-\left(\alpha_p-\alpha_c\right)\frac{\boldsymbol{A}\omega^2}{\pi\boldsymbol{g}_0}\right] \tag{4}$$

where A is the amplitude and ω is the ciecular oscillation frequency. The quadratic dependence of P on ω indicates that the influence of acceleration due to external forces on the weight of the body must be significant at high, for example, ultrasonic frequencies of body oscillations. We performed preliminary experiments on weighing a piezoceramic plate (of the CTS-L trade mark) in an ac electric field at frequencies close to the natural oscillation frequency of the plate (about 6 MHz). Unfortunately, the electric field inhomogeneities in the bulk of the sample being weighed that gave rise to the ponderomotive field forces significantly impeded these measurements. In principle, careful measurements of weights of bodies oscillating in the vertical direction carried out for sufficiently large amplitudes and oscillation frequencies with allowance for a number of external physical factors can be used to verify Eqs. (1) and (2).

Weighing test bodies rotating or oscillating in the vertical plane allows one to estimate only the difference between interaction coefficients α_p and α_c . Absolute values of these coefficients can be measured, for example, based on a careful analysis of mechanical impact phenomena. Thus, on quasi-elastic impact of a ball with a massive plate, the acceleration of the test ball during the impact reaches several ten thousand normal acceleration g_0 [7]. In such impact experiments, the increments to the acceleration due to gravity Δg_c and Δg_p caused by the interaction between elastic and gravitational forces may be significant, thereby allowing one to estimate magnitudes of coefficients α_c and α_p .

For vertical impacts of a ball with a plate (Fig. 3a), the magnitude of the average force F_1 acting on the ball during the impact is ($F - G - \Delta G$), where F is the elastic force acting on the ball from the plate, $G = mg_0$, $\Delta G = m\Delta g_c$, and m is the ball mass. For horizontal impacts (Fig. 3b), the normal component of force F_2 , which causes the ball to accelerate after the impact, is equal to the elastic energy: $F_2 = F$. Obviously, for $\alpha_c \neq 0$ and $\Delta g_c \succ 0$ we obtain $F_1 \prec F_2$, and generally, the difference between these forces depends on the magnitude of ball acceleration due to the impact.

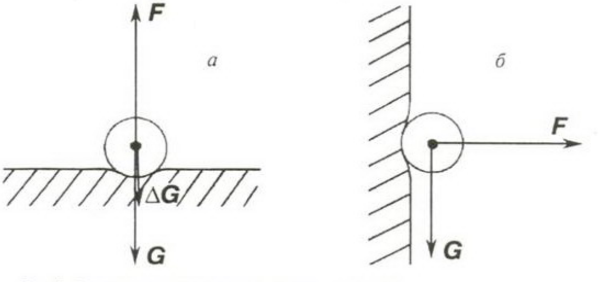


Fig. 3. Vertical (a) and horizontal (b) impacts of a ball with a plate.

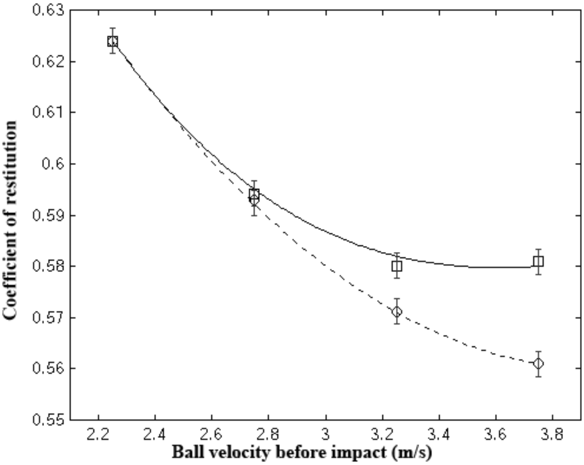


Fig. 4. Experimental dependence of recovery coefficients for horizontal (solid curve) and vertical (dashed curve) impacts of the ball with the plate on the ball velocity before impact.

The inequality of forces F_1 and F_2 , in its turn, causes the difference in recovery coefficients (the ratio of normal components of ball velocities after and before the impact) measured for vertical (k_1), and horizontal impacts (k_2). Simple manipulations yield the following approximate relation for estimation of α_c :

$$\alpha_c \approx \frac{k_2 - k_1}{1 + k_2} \quad . \tag{5}$$

It was found experimentally that quasi-elastic impacts of a steel test ball 4.7 mm in diameter with a massive polished steel plate actually yield unequal recovery coefficients k_1 and k_2 (Fig. 4) measured for ball accelerations $a_g \geq 10^5 \ m/s^2$ (in this case, the ball velocity before impact was greater than 3 m/s).

Assuming that this inequality is caused by the above-indicated impact interaction between elastic and gravitational forces, we obtain the numerical estimate of the interaction coefficient α_c , which for initial ball velocity of about 3.5 m/s is unexpectedly large: $|\alpha_c| \approx 10^{-2}$. This means that the interaction between elastic and gravitational forces is sufficiently strong and can be measured in laboratory experiments.

Some dynamic analogs borrowed, for example, from nuclear and laser physics can be useful for an analysis of the gravitation phenomena. Thus, the above-considered changes in gravity under the action of an elastic (electromagnetic) external force are associated with changes in the potential energy of a test body analogous to atomic transitions to higher or lower excited energy states. Ensuring the ordered (coherent or resonant) excitation of high or low energy levels simultaneously for a large number of matter particles forming the test body, considerable macroeffect of changing its total weight can be obtained.

The problem on the influence of external elastic (electromagnetic) forces on the gravitational force based on the phenomenological approach is worthy of notice. This is also confirmed by the results of the above-described laboratory experiments. Of course, they must be further validated and refined. High-precision measurements of interaction coefficients α_c and α_p and investigations into generally nonlinear functional dependences of the increment to accelerations due to gravity on the acceleration due to external forces are expedient. These studies will provide additional insights into the nature of gravitational interactions and their relation with electromagnetic phenomena.

The author would like to acknowledge V. S. Snegov, V. K. Ponomarev, and N. N. Chesnokov for their help in the experiments.

REFERENCES

1. Y. T. Chen and A. Cook, Gravitational Experiments in the Laboratory, Cambridge University Press, Cambridge (1993).
2. A. L. Dmitriev and V. S. Snegov, Izmer. Tekh., No. 5, 22–24 (1998).
3. K. Magnus, Gyroscope [Russian translation], Mir, Moscow (1974).
4. H. Hayasaka and S. Takeuchi, Phys. Rev. Lett., 63, 2701–2704 (1989).
5. J. E. Faller, W. J. Hollander, P. G. Nelson, and M. P. McHugh, Phys. Rev. Lett., 64, 825–826 (1990).
6. T. J. Quinn and A. Picard, Nature 343, 732–735 (1990).
7. W. Goldsmith, An Impact [Russian translation], Inostrannaya Literatura, Moscow (1965).

№ 3

Measurement Techniques, Vol. 44, No. 8, 2001

THE WEIGHING OF A MECHANICAL GYROSCOPE WITH HORIZONTAL AND VERTICAL ORIENTATION OF THE SPIN AXIS

A. L. Dmitriev and V. S. Snegov

An experiment on the weighing of two coupled mechanical gyroscopes with zero total angular momentum is described. Possible reasons for the observed difference in the masses of the gyroscopes with vertical and horizontal orientations of their spin axis are discussed.

Highly accurate weighing of bodies, which are in a state of oscillatory or rotational motion, requires a particularly rigorous consideration of a large number of factors – mechanical vibrations, temperature changes, the gyroscopic effect, buoyancy, convection etc. Interest in such measurements of the masses of bodies is due not only to purely practical problems, but also due to the information provided by such experiments when solving certain problems in gravitational physics. Mendeleev [1] pointed out the promising possibilities of such dynamic weighing. In 1989 Hayasaka and Takeuchi published a paper [2] in which they describe the change in the mass of a mechanical gyroscope with a vertical axis as a function of the velocity and sign of the rotor spin. The results obtained were placed in doubt by repeated experiments [3, 4], which showed that spinning had no effect on the mass of a gyroscope with a vertical axis. The conclusions reached in [3, 4] are fairly plausible if one takes into account that, when the axis of the gyroscope has a vertical orientation, the vectors of the centripetal acceleration of the material particles of the gyroscope rotor are orthogonal to the vector of the acceleration due to gravity. Conversely, when the spin axis of the gyroscope has a horizontal orientation the vectors of the instantaneous accelerations of the rotor particles lie in the same plane as the vector of the normal acceleration due to gravity, and the probable interaction of the forces corresponding to these vectors should be more pronounced. In this paper we describe the results of weighing a mechanical gyroscope with horizontally and vertically oriented spin axis.

Accurate measurements of the masses of mechanical gyroscopes are complicated by the influence of the gyroscopic effect (the rotation of the Earth) [5], vibrations of the gyroscope, and various temperature effects connected with the heating of the gyroscope due to loss of spin energy of the rotor. The greatest disturbing effect, namely, the gyroscopic effect, can be eliminated by weighing two coupled coaxial gyroscopes with equal but oppositely directed angular momentum vectors. The two other factors (the effect of vibration and temperature) can be minimised by an appropriate choice of the construction of the weighed container – by using high-quality gyroscopes and reliable thermal insulation and magnetic screening.

We weighed a closed container with two rotors of GMS-1 aviation mechanical gyroscopes, placed accurately coaxially in it. A sketch of the container is shown schematically in Fig. 1. Each rotor was mounted in a vacuum-tight steel body.
The mass of the heavy cylindrical part of the rotor was 250 g, the internal and external radii of the cylinder were 15 mm and 25 mm, the maximum spin frequency was 400 s^{-1}, and the coasting time of the rotor was 14 minutes. The external dimensions of the container, made of Dural, was 70 × 70 × 145 mm and the total mass of the assembled container was 1609.845 g. The container was weighed on CC2000 laboratory comparator balances made by the Sartorius Company (Germany). The

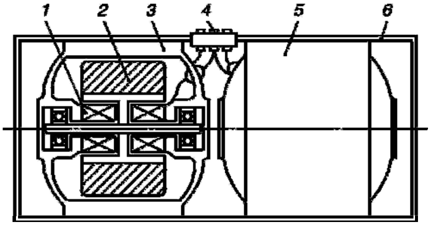


Fig. 1. The weighed container: *1* are the electrical windings of the stator of the induction motor of the gyroscope, *2* is the massive (steel) cylindrical part of the rotor, *3* is the body of the first gyroscope, *4* are the electrical supply terminals of the motors of the gyroscopes, *5* is the body of the second gyroscope (shown without the cut-away view), and *6* is the body of the container.

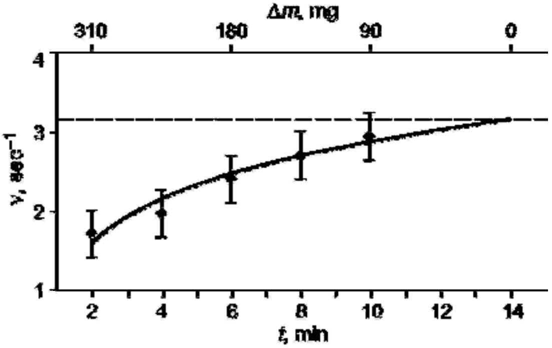


Fig. 2. Experimental curve of the measured mass difference *m* of the gyroscopes with horizontal and vertical orientation of the axis against the coasting time *t* and the spin frequency ν of the rotors.

guaranteed accuracy of the measurement of the container mass did not exceed 0.3 mg. Measurements were made in a special laboratory room at an air temperature of 20°C, a pressure of 1015 GPa and a relative humidity of 40%.

The rotors of the gyroscopes were spun in opposite directions up to a spin frequency of 400 s^{-1}, after which the electrical supply to the rotors was disconnected and, while the rotors were coasting freely, the container was measured in succession with vertical and horizontal orientations of the rotor axis. Thanks to the thermal insulation of the container and the precautionary measures taken, the change in the temperature of the container and the air in the closed container of the balance while the measurements were being made did not exceed 0.5°C.

The experimental dependence of the mass difference m of the container, measured with horizontal and vertical orientations of the axis of the rotors, on the coasting time and spin frequency of the rotors is shown in Fig. 2. The figure shows the values of the mass difference corresponding to the instants of time half way between successive measurements of the mass of the container with horizontal and vertical orientations of the axis of the rotors.

As can be seen from the figure, when the rotors are at rest ($\nu = 0$) the measured mass difference m_0 is approximately equal to 3.1 mg. This constant apparent mass difference can be explained by the effect of the small inherent magnetic moment (residual magnetization) of the steel bodies of the rotors, weighed in the uniform magnetic field of the Earth (the laboratory). The presence of this nonzero magnetic moment is confirmed by the change in the sign of Δm_0 when the weighed sample is inverted. At high angular spin rates of the rotors a reduction in the mass of the rotors with horizontal orientation of the spin axis of up to 1.4 mg is observed. The frequency dependence of the measured mass difference is close to quadratic.

Possible reasons for the time (frequency) dependence of the mass difference obtained may be temperature and magnetic changes in the sample. However, this explanation is not very convincing. First, during the first minutes of measurements, when the spin rate of the rotors is a maximum and the observed mass difference $|\Delta m - \Delta m_0|$ is a maximum, the heating of the rotors and the body of the vacuum-tight unit of the gyroscope is small and is not in such a state as to be able to change the inherent magnetic moment of the weighed container so considerably (by a factor of 1.5–2) (see Fig. 2). Second, the weak magnetization effects of the spinning rotors have practically no effect on the measurements, since the rotors of the gyroscopes are in magnetically screened steel housings and spin in opposite directions. Third, as mentioned above, the changes in the temperature of the container surface during the measurements do not exceed 0.5°C and this, as direct calculations using the theory given in [6] show, can cause an apparent change in the mass of the container due to convection phenomena in the container of the balance not exceeding 0.1 mg.

Thus, we can cautiously suggest, that the observed frequency dependence of the mass difference of the container for vertical and horizontal orientations of the spin axis of the rotors may be due to features of the interaction between gravitational and elastic (essentially electromagnetic) forces, acting on the material particles of the gyroscope rotor. Certain anoma-lies, observed during accurate weighing of oscillating extended bodies [7], also indicate that accelerations may affect the results of weighing due to the action of extraneous elastic forces on these bodies.

Highly accurate laboratory experiments to investigate the possible effect of extraneous elastic forces on the gravitational force, carried out on accelerating (oscillating, spinning or colliding) nonmagnetic test bodies of different sizes and composites, would be extremely useful for solving problems in both metrology and physics.

REFERENCES

1. D. I. Mendeleev, *Writings.* Vol. 22 [in Russian], Akad. Nauk SSSR, Moscow (1950).

2. H. Hayasaka and S. Takeuchi, *Phys. Rev. Lett.,* **63**, 2701 (1989).

3. J. E. Faller et al, *Phys. Rev. Lett.*, **64**, 825 (1990).

4. T. J. Quinn and A. Picard, *Nature*, **343**, 732 (1990).

5. K. Magnus, *The Gyroscope* [Russian translation], Mir, Moscow (1974).

6. M. Glaser, *Metrologia*, **27**, 95 (1990).

7. A. L. Dmitriev and V. S. Snegov, *Izmer. Tekh.*, No. 5, 22 (1998).

№4

International Applied Mechanics, Vol. 38, No. 6, 2002

INEQUALITY OF THE COEFFICIENTS OF RESTITUTION FOR VERTICAL AND HORIZONTAL QUASIELASTIC IMPACTS OF A BALL AGAIST A MASSIVE PLATE

A. L. Dmitriev

It is experimentally found out that there is a difference between the coefficients of restitution for horizontal and vertical quasielastic impacts of a steel ball with an initial velocity of no greater than 3 m/sec against a massive steel plate. Possible causes of the difference are considered.

A quasielastic impact of balls against plates is a classical problem in impact mechanics. This phenomenon was analyzed in many experimental and theoretical studies [1–3, 5–8]. The majority of precision measurements aimed to find how the coefficient of restitution depends on the ball velocity just before impact were performed on a ball vertically falling on a plate. However, we are not aware of experimental comparisons of the coefficients of restitution for horizontal and vertical impacts of a ball against a massive plate. The present study partially makes up this gap.

We measured the coefficients of restitution for horizontal (k_0) and vertical (k_g) impacts of a steel ball 4.7 mm in diameter against the polished surface of a steel disk 90 mm in diameter and 20 mm in thickness. The disk was rigidly fixed on a steel plate 230 mm in diameter and 25 mm in thickness, which, in turn, was fitted to a special metal rack that can take either vertical or horizontal position. The coefficients of restitution were measured for initial velocities of the ball from 2 to 4 m/s. The undesirable plastic deformation of the ball and the associated thermal effects hardly affected the results of measurements. To measure k_g , we dropped the ball on the disk, and to measure k_0, we used the spring mechanism inside the rack to impart a required horizontal velocity to the ball.

The velocities of the ball just before and just after impact were measured by the stroboscopic method: the impact area and a scale located in the immediate vicinity of it were illuminated by pulse light (a source with a pulse duration of 0.15 ms and an interpulse interval of 8 ms) and photographed. The pictures were thoroughly measured to determine the parameters of the ball trajectory and then the velocities of the ball before and after impacts and the coefficients of restitution k_0 and k_g. For the above-mentioned range of velocities, the impact time, measured by the method described in

[4], ranged from 16 to 18 μs. Note that at velocities from 2 to 4 m/s, the air drag practically does not affect the measured results.

Figure 1 shows the measured horizontal (k_0, solid line) and vertical (k_g, dashed line) coefficients of restitution versus the normal (to the disk surface) velocity (V) of the ball just before impact. These coefficients are averages over the measurement data for more than 50 impact events and four ranges of velocities (2.0–2.5), (2.5–3.0), (3.0–3.5), and (3.5–4.0) m/s. The uncertainty of measurement is specified in the figure.

As is seen from Fig. 1, for initial velocities of the ball higher than 3.2 m/s, at which the acceleration of the ball during an impact exceeds $3{\cdot}10^5$ m/s^2, the difference between the coefficients k_g and k_0 is appreciably greater than the measurement error.

Currently, it is not quite clear why the coefficients are different at high velocities of the ball. In fact, the physical conditions for the measurement of the coefficients k_g and k_0 were different: the tangential velocity practically equals zero just before a vertical impact and reaches 0.15 of the normal velocity (due to the action of gravity) just before a horizontal impact (note

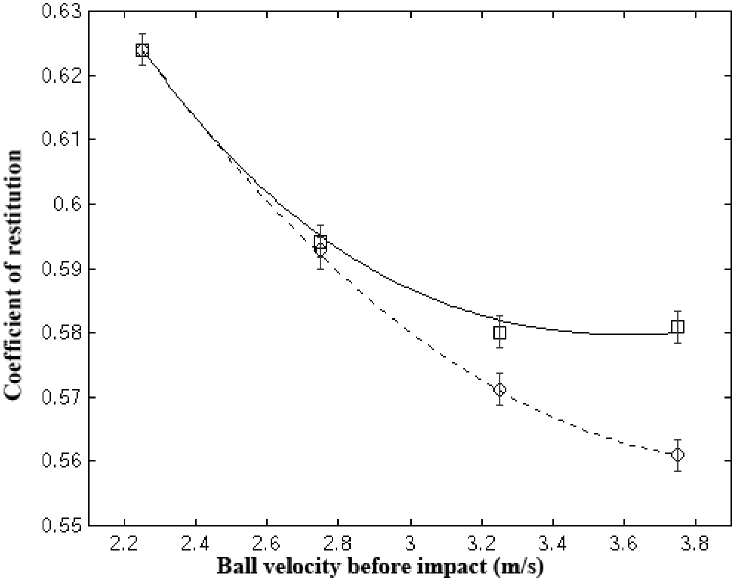


Fig. 1

that this value decreases with increase in the velocity and with increase in the difference between the coefficients k_0 and k_g, and the nonzero tangent velocity cannot be responsible for that difference).

A possible cause of the difference between the horizontal and vertical coefficients of restitution is may be an elastic longitudinal acoustic wave generated at the instant of impact and reflected from the back surface of the plate—it affects the ball at the final stage of the impact. The thickness of the two, steel plates pressed up against each other, the upper of which the ball hits, is 45 mm, which is approximately equal to half the distance the acoustic wave passes in both plates during an impact. The longitudinal elastic wave reflected from the back surface of the plate reaches the ball somewhere on its way back after the impact. The reflection factor for this wave (at the metal–air interface) in the vertically oriented rack is higher than that (at the interface between the metal and the wooden bench supporting the whole structure) in the horizontally oriented rack. Therefore, the vertical coefficient of restitution (k_0) will be greater than the horizontal coefficient (k_g). Note that our qualitative model of the phenomenon does not answer the question of how the difference $k_0 - k_g$ depends on the velocity of the ball just before impact.

Note one more possible cause of the observed difference between the coefficients k_0 and k_g, which is physical rather than physic-technical and is, in principle, consistent with well-known facts of classical mechanics. At high initial velocities, the ball experiences significant accelerations, reaching during the impact tens of thousands of the gravitational acceleration g_0. The acceleration vector of the ball and the normal gravitational acceleration vector are opposite for vertical impacts and orthogonal for horizontal impacts. If the gravity acting on the ball highly accelerating under external elastic forces was slightly different from its normal magnitude, then the coefficients k_0 and k_g might differ from each other. It is well known that precision measurements of the gravitational force are, as a rule, carried out on bodies moving with insignificant accelerations, and experimental data for bodies moving with accelerations of about $10^4 g_0$ under the action of external elastic forces are practically absent.

In further experimental and theoretical studies, we intend to find out the real causes of the observed difference between the vertical and horizontal coefficients of restitution for a ball colliding with a massive plate.

REFERENCES

1. W. Goldsmith, *Impact: The Theory and Physical Behavior of Colliding Solids*, E. Arnold (Publ.) Ltd., London (1960).

2. A. N. Guz, “Dynamic problems of the mechanics of brittle fracture of materials with initial stresses for moving cracks. *Prikl. Mekh*., **34**, No. 12, 3–15 (1998).

3. A. N. Guz, “Dynamic problems of the mechanics of brittle fracture of materials with initial stresses for moving cracks. *Int. Appl. Mech*., **35**, No. 1, 1–12 (1999).

4. A. L. Dmitriev, “An electric signal generated upon an impact of an uncharged conducting ball against a plate,” *Zh. Tekhn. Fiz*., **54**, No. 12, 2336–2341 (1984).

5. S. A. Zegzhda, *Collision of Elastic Bodies* [in Russian], Izd. Sankt-Peterburgskogo Univ., St. Petersburg (1997).

6. A. N. Guz, *Three-Dimensional Theory of Stability of Deformable Bodies*, Springer-Verlag, Berlin (1999).

7. A. N. Guz, “Dynamic problems of the mechanics of brittle fracture of materials with initial stresses for moving cracks. *Int. Appl. Mech, Vol.* ***35****, No2, P. 109-119 (1999).*

8. A. N. Guz, “Dynamic problems of the mechanics of brittle fracture of materials with initial stresses for moving cracks. *Int. Appl. Mech, Vol.* ***35****, No 3, P. 225-232 (1999).*

№ 5

Measurement Techniques, Vol. 46, No. 2, 2003

INFLUENCE OF THE TEMPERATURE OF A BODY ON ITS WEIGHT

A. L. Dmitriev, E. M. Nikushchenko and V. S. Snegov

The physical preconditions are considered for the temperature of a body to influence the force of gravity experienced by it. The results are given of experiments on weighing metal rods heated by ultrasound which confirm a dependence of the weight of the rods on their temperature.

Key words: *temperature of a body, weight, heating, ultrasound, metal rods.*

The influence of external elastic (electromagnetic) forces on the force of gravity was considered in [1–3] and experiments were described supporting this proposal. According to [1], an increment Δg in the force of gravity is in a first (linear) approximation proportional to the acceleration *a* of the external elastic forces acting on a body, the magnitude and sign of g depending on the direction of the vector *a*. If elastic forces really do influence the force of gravity, then a necessary consequence should be a dependence of the gravitational attractive force applied to a test body on the temperature of the body. A brief justification of this assertion is given below and experiments are described on measuring the influence of the temperature of a body on it weight.

It was shown in [1] that a material point (or body) of mass *m* which executes vertical harmonic vibrations under the action of an external elastic force experiences a force of gravity *p*, averaged over a period of the vibrations, equal to

$$p = mg_0\left(1 - \frac{\alpha_{pc} A\omega^2}{\pi g_0}\right), \qquad (1)$$

where g_0 is the normal acceleration of the force of gravity; $\alpha_{pc} = (\alpha_p - \alpha_c)$ is the difference between the coefficients of interaction of the elastic and gravitational forces for accelerated motions of the body which are parallel (α_p) and antiparallel (α_c) to the direction of the gravitational force; A and ω are the amplitude and angular frequency of the vibrations.

The product $A\omega^2$, equal to the maximum acceleration of the oscillating mass, is expressed in terms of the total energy E of vibrations of a mechanical oscillator as

$$A\omega^2 = \sqrt{2c}\,/\,m\sqrt{E} \tag{2}$$

where c is the coefficient of elasticity [4].

It is evident that the average force of gravity p acting on the oscillator depends on the energy E of its vibrations with $p \propto \sqrt{E}$.

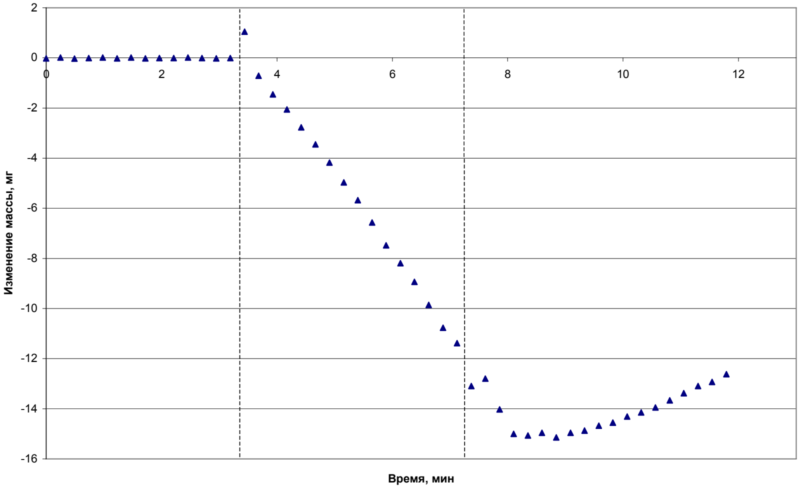


Fig. 1. Change in mass of a brass rod mounted in an open holder. Ultrasound frequency 131.25 kHz. The dashed lines indicate the moments when the ultrasound was switched on and off.

A massive weighed body can be represented by an ensemble of such mechanical oscillators linked by the elastic forces of interatomic interaction and executing chaotic thermal vibrations characterized by a frequency distribution function $g(\omega)$ [5]. The three-dimensional thermal vibrations of the particles are accompanied by their significant accelerations and the projection of the instantaneous vectors of the accelerations on the direction of the force of gravity depends on the energy of the thermal vibrations of the particles in a way similar to that given by Eq. (2). In the classical approximation, for a temperature exceeding the Debye temperature, the energy E of the oscillators is proportional to the absolute temperature T of the body and, consequently, taking into account Eqs. (1) and (2) the total weight P of the body can be represented in the form

$$P = Mg_0\left(1 - \frac{\alpha_{pc}}{\pi g_0} C\sqrt{T}\right) \tag{3}$$

where M is the mass of the body; C is a constant which depends on the physical properties of its material.

It can be shown that, assuming a slow frequency dependence of the vibrational amplitudes of the particles, the quantity C is related to the function $g(\omega)$ of the distribution of the frequencies of the thermal vibrations:

$$C = C_m \frac{\int_0^{\omega_c} g(\omega)\omega^2 d\omega}{\int_0^{\omega_c} g(\omega) d\omega}\ , \tag{4}$$

where ω_c is the maximum vibration frequency; C_m is a coefficient which depends on the density and on the elastic properties of the material of the body.

According to Eqs. (3) and (4), the temperature dependence of the weight of a body is mainly determined by the high-frequency component of the distribution $g(\omega)$. The relative change $\Delta P/P$ of the weight of a body heated from a temperature T to a temperature $T + \Delta T$ is conveniently given as

$$\Delta P / P = -D\Delta T / 2\sqrt{T}\ , \tag{5}$$

where $D = \alpha_{pc} C / \pi g_0$; $\Delta T \prec\prec T$.

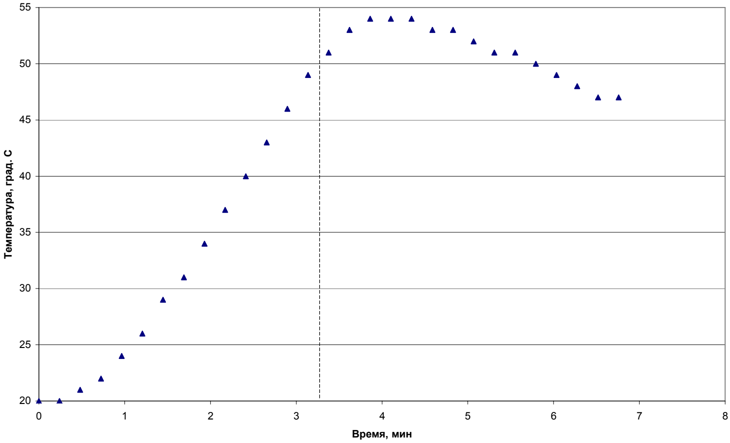


Fig. 2. Time dependence of the temperature of a part of the surface of an ultrasonically heated brass rod (open holder). Ultrasound frequency 131.28 kHz. The point ‘3.2 min’ is moment when the ultrasound was switched off.

When the latter condition is satisfied, there is evidently direct proportionality between the increments *P* and *T*, and the value of the constant *D* can be estimated by accurately weighing heated test body samples.

It is well known that the temperature regimes play an important role when weighing with high accuracy. The basic reasons for temperature influencing the results of such measurements are thermal expansion of the bodies, temperature changes in the magnetization of the weighed sample, adsorption of moisture by the surface of the sample (a change in the buoyancy), thermal convection of the air near the surface of the sample, the influence of the heated sample on the balance mechanism (through thermal radiation, heat conduction, or convection). These factors are quite well known in modern measurement technology and their contribution to the results of measuring the mass of samples can be estimated quantitatively.

In the present work, metal rods made of nonmagnetic materials were weighted while they were being heated by a standing or traveling wave. The ultrasonic method of excitation was chosen on the basis of the intention of creating vibrations of the particles of the body which were orientated along a definite direction (the axis of the rod). The wavelength of the sound in the rods was several times longer than their diameter and this provided preferentially longitudinal modes of the elastic vibrations in the cylindrical samples [6]. Ultra-short waves were excited using a piezoelectric transducer fixed to an end of the rod. A 12-mm diameter 9-mm high cylindrical transducer was used, made of ($PbTiO_3 - PbZrO_3$) piezo-ceramic (PZT). The metal rod and the transducer were mounted in a special holder and were held at the ends by foam plastic spacers providing a high reflection coefficient of the acoustic waves at the boundaries of the assembly. The electrical signal was led to the transducer contacts inside the window of the balance by 15-cm long 85-μm diameter light copper wires. The corresponding additional load-ing on the balance pans was insignificant and was eliminated by calibrating the balance prior to each weighing.

The holder with the samples mounted in it was weighed using an ADV-200 analytical balance. The temperatures in the upper and lower parts of the window of the balance were monitored with an error of less than 0.1°C and the vertical temperature gradient in the balance compartment was 0.2–0.8°C/m. During the measurements, the balance beam executed slow damped vibrations with a period of 15–17s, the readings of the balance (elongations) were continuously recorded, and the resulting error in measuring the mass of the samples was less than 50 μg .

The resonant acoustic system including the investigated sample and the piezoelectric transducer was quite sensitive to changes in the frequency of the applied electrical signal. The standing-wave regime and the accompanying effective volume heating of the rod was set for the minimum level U using the oscillator output voltage with the load (the piezoelectric transducer) connected to it. The open-circuit output voltage U_0 of the oscillator was 100 or 150 V.

Figure 1 shows a typical experimental dependence of the change of mass of a weighed sample on the duration of ultrasonic heating of the rod.

The dependence of the temperature of a section of the surface of the sample on the time for which the ultrasound was applied was measured in separate experiments under the same conditions as those used for the weighing at the resonant frequency. An example of such a dependence is shown in Fig. 2.

The temperature distribution in the volume of the rod in the field of a standing acoustic wave is periodically inhomogeneous. The rate at which the temperature in the volume of the rod equalizes is determined by the thermal conductivity of its material and the conditions of heat exchange at the boundaries of the rod. It is characteristic that the temperature rise of a considerable mass of the rod also takes place some time after the ultrasound has been switched off, depending on the heat exchange conditions on its surface.

The weighing of the ultrasonically heated sample was performed with the sample mounted in a closed and sealed container (a Dewar vessel) in order to eliminate almost completely the influence of thermal convection on the results of the measurements (see Fig. 3).

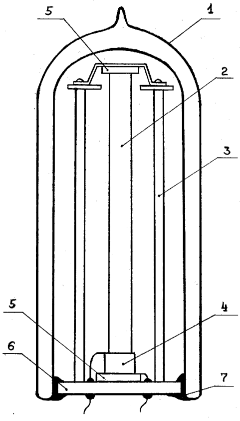


Fig. 3. Arrangement of the air-tight container: *1*- Dewar vessel; *2*- metal rod; *3*- holder pillar (textolite cloth-based laminate); *4*- piezoelectric transducer; *5*- foam plastic spacers; *6*- cold weld; *7*- holder base (ebonite).

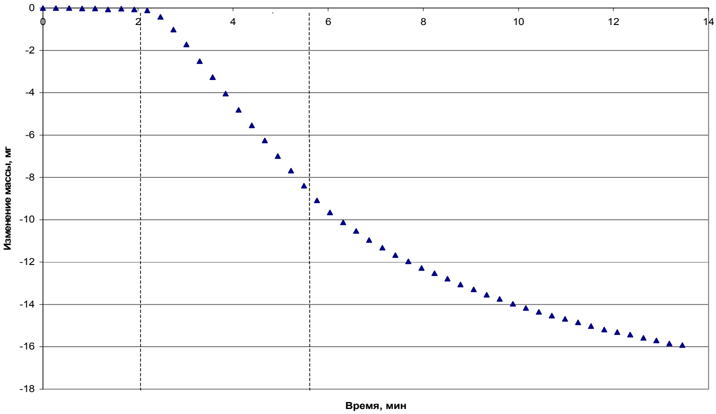


Fig. 4. Change in mass of a brass rod mounted in a closed Dewar vessel. Ultrasound frequency 131.27 kHz. The dashed lines indicate the moments when the ultrasound was switched on and off.

Figure 4 shows the corresponding dependence of the change of mass of the Dewar vessel on the heating time of a sample.

The maximum rate of change $\Delta m / \Delta t$ of the mass of the container with the sample during heating of the sample was determined from the graphs in Figs. 1 and 4. The maximum rate of change of the temperature $\Delta T / \Delta t$ of the sample was deter-mined from the graph in Fig. 2. On the assumption (not entirely rigorous) that the indicated values of the parameters $\Delta m / \Delta t$ and $\Delta T / \Delta t$ are close to those of a uniformly heated solid rod, the relative change γ of the apparent mass of the sample, reduced to 1 K, was calculated: $\gamma = \Delta m / (m \Delta t)$. In this approximate calculation, no account was taken of the influence of the heating of the piezoelectric transducer since its mass was much lower than that of the investigated metal samples. Table 1 gives the characteristics of the investigated samples and the results of calculations of the parameter γ.

TABLE 1. Characteristics of Samples and Results of Measurements

Material	Length, mm	Diameter, mm	Mass, g	Ultrasound frequency, kHz	U_0 / U, V/V	$\Delta m/\Delta t$ mg/min	$T/\ t$, K/min	$\gamma \cdot 10^6$ K^{-1}	Sample in
Lead	80.2	8.0	45.6	135.43	100/92	1.06	5.1	4.6	air
Copper (braid)	71.6	10.5	39.2	129.68	100/60	1.08	4.0	6.9	air
Copper (braid)	71.6	10.5	39.2	129.70	100/60	1.15	4.5	6.5	thermal insulator
Brass	140.0	8.0	58.5	131.25	150/140	3.43	11.6	5.0	air
Brass	140.0	8.0	58.5	131.27	150/130	2.64	H10	4.5	Dewar vessel
Duralumin	140.0	8.0	19.1	134.90	150/140	1.66	7.5	11,6	air

The spread of the experimental values of γ obtained for identical rod materials is evidently explained by the conditions for their heating not being identical and by inaccuracy of the average temperature estimates in the volume of the sample.

TABLE 2. Experimental Values of Coefficient *D*

Material	$D \cdot 10^4, K^{-1/2}$,
Lead	1.6
Copper	2.2; 2.4
Brass	1.5; 1.7
Duralumin	4.0

The copper sample used in the experiments was made in the from of a braid of 0.8-mm diameter copper wires, glued with epoxy adhesive. This achieved better suppression of undesired radial vibrational modes of the rod. The copper sample was placed in a thermal insulator in order to estimate the influence of thermal convection on the measurements (the rod was covered with thermally insulating material). The remaining samples were made in the form of monolithic cylinders having a high quality of surface machining.

The mass of the ultrasonically heated samples was measured with them orientated vertically and horizontally. In the horizontal position, the relative temperature change γ of the mass of the sample was lower, as a rule, than for the vertical orientation of the rod. The disagreement between the corresponding values of γ was evidently due to a detuning of the acoustic resonance caused by a change in the position of the holder and a change in the sample temperature caused by a change in the heat-exchange regime at its surface.

The experiments showed the same characteristic laws to be observed for all the investigated samples of rod materials, namely a marked reduction in the mass of the rods as they were ultrasonically heated. The time dependence $\Delta m(t)$ of the change of mass of the samples when they were heated ultrasonically corresponds closely to the time dependence $\Delta T(t)$ of the temperature change of the samples (see Figs. 1 and 2), i.e., there was a direct proportionality between the increments Δm and ΔT.

The change with time of the mass of a sample heated in the closed airtight Dewar vessel confirms this conclusion. Under conditions of high thermal insulation of the heated body, there is a characteristic slow change in the temperature in the Dewar vessel after switching off the ultrasound (see Fig. 4).

From among these possible reasons for the apparent change of mass of a heated sample, the most important are thermal convection caused by a difference between the temperatures of the surface of the rod being weighed and air in the balance enclosure. This question was analyzed in detail in [7]. According to [7], an apparent change of mass of an 8-mm diameter 140-mm long rod caused by convection, for example by 10 mg, is achieved with a temperature difference of the surface of the rod in air of more than 800°C. Thermal convection can evidently not be the reason for the large change in the masses of samples, up to 15–16 mg, observed in the experiments described. The closeness of the γ values calculated from the results of weighing a brass sample in an open holder and in a Dewar vessel confirms this conclusion.

Other possible reasons for a temperature dependence of the measured mass of samples, along with those mentioned above, could be particular features of the mass heat transfer in the ultrasonic field near the sample, acoustic flow, and the action of heat and ultrasound on the balance mechanism. These factors mainly influence the results of the weighing, although such an influence is small and should be strongly random in nature. For the measurements taking place in the experiments described involving low levels of ultrasonic power and temperature, these ultrasonic effects fail to explain the regular and stable temperature-related considerable reduction in mass of the samples observed in the experiments. A characteristic feature is that the change in mass of the samples occurs over a relatively long time and after the ultrasound has been switched off, and this confirms that the temperature of the bodies plays a decisive role in the phenomena considered.

Taking the above discussion into account, there are grounds for assuming that the probable reason for the observed change of mass of the ultrasonically heated metal samples is the temperature dependence of the force of gravity considered earlier. The relative change $\Delta m / m$ of the apparent mass of a sample with temperature is satisfactorily described by formula (5) if one takes in it the condition $\Delta m / m = \Delta P / P$. The corresponding experimental values of the coefficients *D* are given in Table 2.

The situation that the coefficients *D* are small for heavy and viscous materials (lead) and assume large values for light elastic media (Duralumin) agrees with the physical sense of the constant C_m in Eq. (4). The fact that a change in orientation of a rod in which a longitudinal acoustic wave has been excited fails to result in a null effect $\gamma = 0$ indicates that it is the high-frequency thermal vibrations of the particles from which it is made, characterized by a distribution $g(\omega)$, which play a dominant role in the change of mass of the sample. To a large extent, the anisotropy of the distribution $g(\omega)$ which is inherent in single-crystal media must influence the possible orientational dependence of the coefficient *D*. Relatively low-fre-quency acoustic vibrations in a rod with large amplitudes can also introduce a marked contribution to a change in the mass of a sample, especially under conditions of a resonant dependence of the maximum amplitude $A(\omega)$ of the vibrations. These questions, and certain others noted in the present article, should be the subject of special investigations. Such investigations will promote a deeper understanding of gravitational phenomena, and their results will possibly find useful application in var-ious areas of measurement technology, in gravimetry, in technical physics, and also in astrophysics.

REFERENCES

1. A. L. Dmitriev, *Izv. Vyssh. Uchebn. Zaved. Fiz.,* No. 12, 65 (2001).
2. A. L. Dmitriev and V. S. Snegov, *Izmerit. Tekh.*, No. 8, 33 (2001).
3. A. L. Dmitriev, *Prikl. Mekh.,* **38**, No. 6, 124 (2002).
4. K. Magnus, *Vibrations* [in German], Teubner, Stuttgart (1961).
5. A. I. Ansel'm, *Principles of Statistical Physics and Thermodynamics* [in Russian], Nauka, Moscow (1973).
6. R. M. Davies, *Stress Waves in Solids* [Russian translation], IIL, Moscow (1961).
7. M. Glaser, *Metrolog.*, **27**, No. 2, 95 (1990).

№ 6

Measurement Techniques, Vol. 47, No. 9, 2004

THE EFFECT OF THE ORIENTATION OF AN ANISOTROPIC CRYSTAL ON ITS WEIGHT

A. L. Dmitriev and N. N. Chesnokov

It is shown experimentally that the weight of a crystal of rutile depends on its spatial orientation. The observed difference in the apparent masses of the crystal is explained by the fact that the interaction factor of the elastic and gravitational forces depends on the direction with respect to the crystallographic axes of the sample.

Key words: *crystal, weight, mass, temperature.*

It was shown experimentally in [1] that the temperature of a body affects its weight. According to the phenomenological description, the reason for the temperature dependence of the weight of a body is the inequality of the increments of the gravitational forces, acting on the particles of the body, due to the accelerated thermal motion of these particles along and in the opposite direction to the vector $\mathbf{g}_0$ of the normal acceleration due to the gravitational force [1, 2]. In the first approximation, the temperature dependence of the weight of a uniformly heated body $P(T)$ has the form

$$P(T) = P_0(1 - a\sqrt{T}) \quad , \tag{1}$$

where $P_0 = mg_0$ (where m is the mass of the body); T is the absolute temperature of the body, which exceeds the Debye temperature; and a is the interaction factor of the elastic (electromagnetic) and gravitational forces, which depends on the physical characteristics of the material of the body (the density, elasticity, the phonon state density function, etc.) $a \approx (4...9) \cdot 10^{-4} K^{-1/2}$. According to experimental data, for light elastic metals (dural and titanium) and is considerably less than these values for heavy and tough metals (lead and brass) [1]. In anisotropic media, the constants of elasticity and the frequency spectra of thermal vibrations of the particles for different i-th directions in a crystal may differ consider-ably, which implies that there will also be a difference between the interaction coefficients a_i corresponding to these directions. For example, for a simple mechanical oscillator of mass μ and coefficient of elasticity c_i, performing vertical harmonic oscillations, the interaction factor a_i is proportional to $\sqrt{2c_i} / \mu$ [1, 2]. By representing the crystalline body by an ensemble of similar periodically arranged oscillators, connected by elastic forces, and assuming that the velocity v_i of elastic longitudinal waves in the crystal is proportional to $\sqrt{c_i/\mu}$ [3], we can assume the linear relationship $a_i \propto v_i/\sqrt{\rho}$, where ρ is the density of the material. In fact, the frequency spectrum and the nature of the elastic thermal vibrations of atoms (ions) in crystals is much more complex than mentioned above, and a description of them must include a consideration of both acoustic and high-frequency optical phonons. Hence, the directions in the crystal for which the interaction factors a_i differ considerably may not coincide with the directions of unequal velocities of longitudinal elastic waves. Nevertheless, a difference between the weights P_1 and P_2 of a crystal, measured in the positions $\mathbf{v}_1\uparrow\uparrow\mathbf{g}_0$ and $\mathbf{v}_2\uparrow\uparrow\mathbf{g}_0$, where $\mathbf{v}_1$ and $\mathbf{v}_2$ are the vectors of the greatest and least velocities of longitudinal waves in the crystal respectively, is probable.

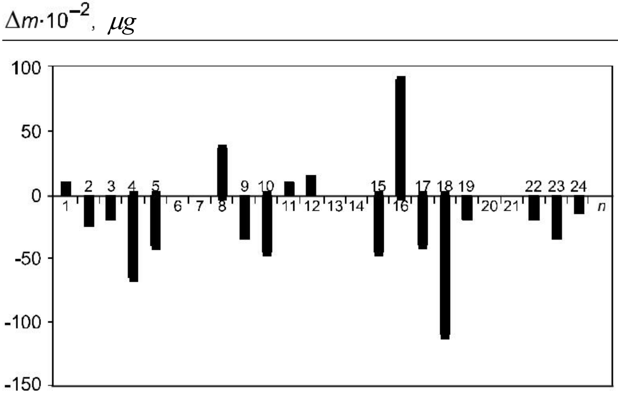


Fig. 1. Mass difference *m* of a sample of a rutile crystal, measured in two mutually perpendicular positions of the optic axis of the crystal with respect to the vertical.

In this case, the relative value γ_{12} of the measured mass difference of the crystal will be

$$\gamma_{12} = (P_1 - P_2)/P_0 = -(a_1 - a_2)\sqrt{T} \quad , \tag{2}$$

where a_1 and a_2 are the interaction factors of the elastic and gravitational forces for the directions $\mathbf{v}_1$ and $\mathbf{v}_2$.

In our experiment, we used a sample of a rutile crystal (TiO_2) of dimensions 6.2 × 7.7 × 40.1 mm and a mass of about 2.876 g. The *Z* axis ([001]) of the crystal makes an angle of 14° with the normal $\mathbf{n}_1$ to the crystal face of dimensions 6.2×14.1 mm; the velocity v_1 of longitudinal elastic waves in the *Z* direction is equal to $10.94\cdot10$m/sec. The *X* axis ([100]) is also situated at an angle of 14° to the normal $\mathbf{n}_2$ to the face of

dimensions 6.2 × 7.7 mm; the velocity v_2 of longitudinal waves in the X direction is $8.014 \cdot 10^3 m \cdot s^{-1}$[4]. The sample was weighed in the positions $\mathbf{n}_1 \uparrow\uparrow \mathbf{g}_0$ and $\mathbf{n}_2 \uparrow\uparrow \mathbf{g}_0$ a SARTORIUS C5S comparator at normal values of the temperature, pressure and humidity of the air. The discreteness of the comparator readouts was 0.1 μg and the root mean square deviation was 0.2 μg. The individual values of the measured mass difference $\Delta m = m_1 - m_2$ of the sample were determined from four readings with the orientations of the sample changed from "1" to "2" in the sequence "1212" and "1221". The experimental values of the mass difference Δm, obtained in four series of measurements, carried out on different days, are shown in the figure. From these results, the mean value of the mass difference of the crystal amounts to (- 0.20) μg with a root mean square deviation of 0.10 μg, which corresponds to a relative difference of the mass $\gamma_{12} \approx -7 \cdot 10^{-8}$.
In view of the comparatively small amount of data obtained, rigorous statistical processing of the results of the measurements is difficult. A preliminary statistical analysis shows that the distribution of the random values of the mass difference Δm is close to normal. The Student distribution coefficient for this series of measurements amounts to about 2.20, which, for a confidence coefficient of 0.90 corresponds to a confidence limit of the random error of measurements of the mean value Δm = 0.22 μg. In subsequent experiments, when the number of experiments is increased and highly stable (particularly temperature) weighing conditions are ensured, this quantity will be reduced considerably.

The considerable fluctuations in the measured mass difference, which exceed the root mean square deviations of the comparator, can obviously be explained by the temperature instability of the sample being weighed, due to fluctuations in the temperature of the air in the room and thermal disturbances when the sample is reorientated (for this, the sample was periodically removed from the glass case of the comparator for a few seconds). It can be assumed that the mean value of the interaction factor *a* for a rutile crystal has an order of magnitude close to $10^{-3} K^{-1/2}$, i.e., it is close to the value of *a* for light elastic metals [1]. In this case, temperature fluctuations of the sample of the order of 0.01° in the neighborhood of $T = 293$ K will, according to (1), cause fluctuations in the measured value of the mass of the sample of about 1 μg.

On the whole, experiment shows an inequality in the weights of an anisotropic rutile crystal for different orientations of its crystallographic axes with respect to the vertical. It is characteristic that a negative sign of the observed mass difference Δm of the sample corresponds to the inequality $v_1 > v_2$ of the velocities of longitudinal elastic waves in the crystal and agrees with (1) and (2).

The results presented in this paper were obtained using standard metrological equipment under normal conditions of the surroundings and, in view of the comparatively large measurement error, are of a preliminary nature. Nevertheless, the non-zero difference in mass Δm and the corresponding sign of the observed difference are extremely probable. In further experiments to investigate the anisotropy of the weight of crystals, to obtain more accurate data, high temperature stabilization (not less than 0.001°) of the samples being weighed and improvements in the method of reorientating the samples will be necessary. A theoretical analysis of the effects of anisotropy of the weight in a wide class of anisotropic media, taking into account the different states, types of oscillations and particular features of the oscillatory spectra of the crystals, will also be advisable. This analysis will enable the conditions for observing the anisotropy of the measured mass of the crystals to be rigorously formulated. These investigations will facilitate a deeper understanding of the phenomena of gravitation and their applications in physics, technology and metrology.

REFERENCES

1. A. L. Dmitriev, E. M. Nikushchenko, and V. S. Snegov, *Izmer. Tekh*., No. 2, 8 (2003).
2. A. L. Dmitriev, *Izv. Vyssh. Ucheb. Zaved., Fiz.*, No. 12, 65 (2001).
3. N. March and M. Parinello, *Collective Effects in Solids and Liquids* [Russian translation], Mir, Moscow (1980).
4. M. P. Shaskol'skii (ed.), *Acoustic Crystals* [in Russian], Nauka, Moscow (1982).

№ 7

arXiv: physics/0610282 (2006)

ON POSSIBLE CAUSES OF DIVERGENCIES IN EXPERIMENTAL VALUES OF GRAVITATIONAL CONSTANT

A.L. Dmitriev

St-Petersburg University of Information Technologies, Mechanics and Optics
49, Kronverksky Prospect, St-Petersburg, 197101, Russia

It is shown that discrepancies in the experimental values of the gravitational con-stant might be caused by the temperature dependence of the gravitational force and inequality of the absolute temperatures of sample masses used in various gravitational experiments.

Key words: gravitational constant, gravitational force, temperature.

It is known that some divergences in the absolute values of the gravitational constant obtained by various authors in various experiments considerably exceed the accuracy of measurements [1-3]. Differencies of the experimental average values of the gravitational constant G reaches the level $10^{-4}-10^{-3}$ as compared to value (G = 6.6742 $\cdot 10^{-11}\ m^3kg^{-1}s^{-2}$) recommended by CODATA, and it is usually explained by the effects of hypothetic factors: effect of the Earth's magnetic field, time fluctuations of G value, dependence of G on direction in space, and some others. The temperature dependence of gravity force examined in [4] explains the divergences in the experimental values of G by differences in the absolute temperatures of sample masses used in those experiments. According to [4,5], the temperature dependence of the gravi-tational constant G , in the first approximation, might be presented as

$$G = G_0\left(1 - a_1\sqrt{T_1}\right)\left(1 - a_2\sqrt{T_2}\right) \quad , \qquad (1)$$

where G_0 – the constant, a_1 and a_2 – temperature factors depending on the physical properties (density and elasticity) of interacting masses, T_1 and T_2 – their absolute temperatures exceeding Debye temperature. For heavy and viscous metals (lead, copper, brass) the experimental values of factors $a_{1,2}$ are approximately in the range of $(1.5 - 2.5)\cdot 10^{-4}\ K^{-1/2}$, and for light and elastic metals (duralumin, titanium) - $(4.0 - 9.5)\cdot 10^{-4}\ K^{-1/2}$ [4]. If the sample masses have been made of one and the same metal ($a_1 = a_2 = a$) and their average temperatures are also equal ($T_1 = T_2 = T$), the relative temperature shift of the gravitational constant G value being measured is equal to

$$\frac{\Delta G}{G} = \frac{a\Delta T}{\sqrt{T}} \quad , \qquad (2)$$

where ΔT – temperature change of both masses.

For example, at $a = 5 \cdot 10^{-4} K^{-1/2}$, $T = 293K$ and $\Delta T = 5K$ the relative temperature shift of the gravitational constant G values being measured is equal to $5 \cdot 10^{-4}$. For the sample masses made of light and elastic materials (quartz glass, crystals) the value of the temperature factor might be close to $10^{-3} K^{-1/2}$, then the corresponding relative temperature shift $\Delta G/G$ is in the range of $10^{-4} - 10^{-3}$.

In materials of the papers devoted to measurements of the gravitational constant G values only the stability of the interacting masses temperatures is usually shown but not its absolute value [2,6]. The variance of the average absolute values of the sample masses temperatures in the gravitational experiments carried out in different laboratories practically can not be avoided and might reach a few degrees. Other physical conditions of experiments on determination of the absolute value of G might also essentially differ – different materials, dimensions and form, temperatures of the sample bodies, etc. The numerical estimates given above show that comparatively small (units of degrees) differences in the absolute temperatures of sample masses in different experiments might be one of the imported causes of the experimental average values scattering of G which has been observed for a long time.

It should be especially noted the temperature dependence of the gravitational force [4,5] does not contradict to the known facts of the classical mechanics. Such dependence is of a great importance for the present problems of the high-precision metrology of mass, gravimetry, as well as the astrophysics. Experimental investigations of the body temperature effects on the force of the gravitational interaction of bodies are of current interest and expedient.

References

1. Gillies G. T. Rep. Prog. Phys. 60 151-225 (1997)
2. Jun Luo, Zhong-Kun Hu Class. Quantum Grav. 17, 2351-2363 (2000)
3. Karshenboim S. G. Uspekhi Fizicheskikh Nauk 175 (3) 271-298 (2005); Phys-ics-Uspekhi 48 (3) (2005)
4. Dmitriev A. L. , Nikushchenko E. M., Snegov V. S. Measurement Techniques 46 (2) 115-120 (2003)
5. Dmitriev A. L. Upravljaemaja gravitacia , “Novy Centr” Publ., Moscow, 2005
6. Grundlach J. H., Merkowitz S. M., Phys. Rev. Lett. 85 (14) 2869-2872 (2000)

№ 8

arXiv: physics/0611173 (2006)

TEMPERATURE DEPENDENCE OF GRAVITATIONAL FORCE: EXPERIMENTS, ASTROPHYSICS, PERSPECTIVES

A.L. Dmitriev

St-Petersburg University of Information Technologies, Mechanics and Optics
49, Kronverksky Prospect, St-Petersburg, 197101, Russia. E-mail: dalexl@rol.ru

Abstract

The consistency of the results of measuring the gravitational force temperature dependence obtained by Shaw and Davy in 1923 and by the author in 2003 was shown. Such dependence is observed in the laboratory experiments, it does not contradict the known facts of classical mechanics and agrees with astrophysics data. It was pointed out that experimental research into temperature influence on gravitation was needed and perspectives of developing that trend in gravitation physics was promising.

The problem of influence of temperature of bodies on their gravitational interaction was naturally raised at the very early period of development of gravitation physics. The first attempts to experimentally determine the relation between temperature and gravitation did not produce any results due to low accuracy of measurements [1]. Late in the XIX-th century, following the development of electromagnetic theories of gravitation predicting an increase in body gravitation force with an increase in their temperature the interest to relevant experiments rose. By 1916 the most accurate measurements of dependence of gravitational force F (t) in the temperature interval of t 20 – 220° C (for big mass),

$$F(t) = F_0(1+\alpha t) \quad , \qquad (1)$$

were carried out by Shaw who obtained positive value of temperature coefficient $\alpha = +(1.20 \pm 0.05) \cdot 10^{-5}$ degree^{-1} [2]. In 1923 Shaw and Davy pointed out the fallibility of that result and on the basis of measurements carried out with higher accuracy they concluded “that the effect, if it exists, is less than $2{\cdot}10^{-6}$ per degree, and may well be zero” [3]. Actually, Shaw and Davy obtained a negative value $\alpha = -\,2.0 \cdot 10^{-6}$ degree^{-1} which is illustrated in Fig. 1.

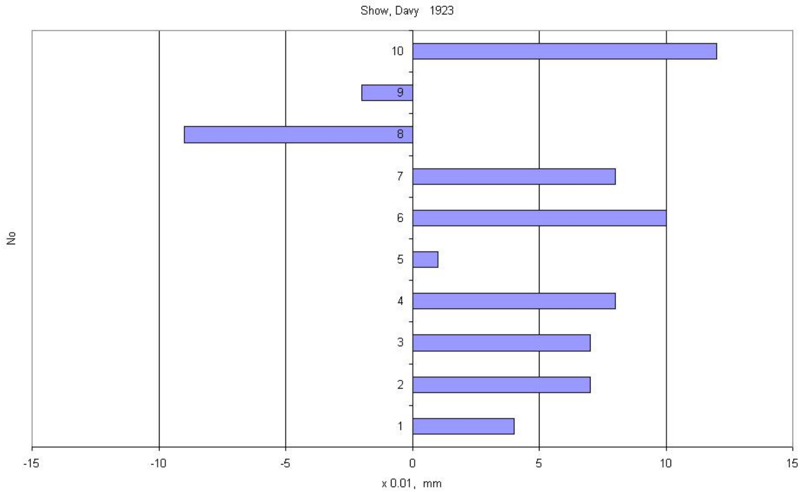


Fig. 1. The generalized results of experiments by Shaw and Davy ([3], Table II). The abscissa corresponds to the difference in the forces of gravity created by heated and cold massive bodies.

Nevertheless, the authors did not insist on the accuracy of the nonzero result which they obtained and regarded it as approximately equal to the measurement error magnitude; the actual measurement error of the average magnitude α, according to the data of [3], is less than 40%. Such a conservative estimate probably was caused by the fact that in the early 20ties the general theory of relativity (GTR) began to become rather popular, according to which the temperature effect on gravitation in experiment was practically not observed [4]. The impact of GTR was so great that over next 80 years any experimental research into temperature dependence of the force of gravity was not carried out due to its "nonscientific nature". Incidentally, the basic in GTR principle of equivalence was experimentally checked only with strict stabilization of temperatures of interacting bodies; the direct experimental evidences justifying that principle under different temperatures of test bodies are not available till the present time.

In 2003 our work [5] was published which experimentally confirmed physical dependence of body weight on its temperature. The physical prerequisite of temperature dependence of the force of gravity, according to the phenomenological model, is the dependence of acceleration of the force of gravity on the magnitude and sign of accelerations caused by influence of external elastic forces on the test body [6]. With increase of body temperature the accelerated movement of its component particles becomes more intensive which causes exponential, $\propto T^{1/2}$, depend-ence of the force-of-gravity acceleration on absolute temperature T of the body [5,7]. An exam-ple of experimental dependence of apparent mass of brass rod on duration of its heating (and temperature) is shown in Fig. 2.

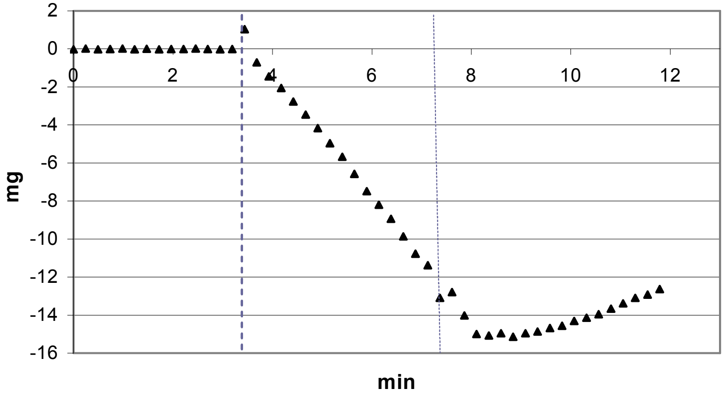


Fig. 2. Change of apparent mass of brass rod in the process of its heating [5].

Temperature dependence of attractive force of two bodies, in the first approximation, can be described by the known Newton's gravity law with gravity constant in the form of

$$G = G_0\left(1 - a_1\sqrt{T_1}\right)\left(1 - a_2\sqrt{T_2}\right) \tag{2}$$

where G_0 – constant, T_1 и T_2 – absolute temperatures of interacting masses (exceeding Debye temperature), a_1 and a_2 - temperature coefficients the magnitude of which depends on density and elastic properties of body materials. With a constant temperature of one of the masses (for example, $T_1 = \text{const}$) the coefficients α (see (1)) and $a_2 = a$ (see (2)) are directly proportional,

$$\alpha = -\frac{a}{2\sqrt{T}} \quad , \tag{3}$$

where $T = T_2$ – average temperature of the other mass.

According to the experimental estimates the magnitude of coefficient a is minimal for viscous and dense bodies and, for example, for lead and brass, it is close to $a \approx 1.5 \cdot 10^{-4} K^{1/2}$ [5]. For example, with $T = 470K$ for lead we find $\alpha \approx -3.5 \cdot 10^{-6} \deg ree^{-1}$. Obviously, the signs of temperature change of gravitational force in experiments [3] and [5] coincide, and the magnitudes of corresponding temperature coefficients, with account for measurement errors, are close to each other. That's why both Shaw and Davy's of 1923 and our experiments of 2003 give evidence of the laboratory-observed physical temperature dependence of the force of gravity: decrease of attractive force of bodies with increase in their temperature.

It is interesting to consider some astrophysical consequences of the above dependence.

Slow change of the planet average temperature due to either the radiant heat exchange on its surface or to internal heat processes within its volume changes, according to (2), the effective magnitude of gravity constant. As a result, the **planet orbit precesses** with angular deflection of perihelion for one planet revolution equal to

$$\delta\varphi \approx \frac{\pi k P}{2(1-e^2)} \quad , \tag{4}$$

where coefficient k describes changes in time of the average planet temperature,

$$k = -\frac{a}{2\sqrt{T}}\frac{dT}{dt} \,, \tag{5}$$

P – period of planet turnover, e – orbit eccentricity (taken as $e \ll 1$), t – time [7]. For example, in slow cooling of the planet the force of its gravitational interaction with the sun increases (we take constant the average temperature of the sun), coefficient k is positive and orbit precession is direct.

The next example is a **double pulsar**. Slow cooling of the stars involved in the system of double pulsar determines the increase in the force of their gravitational interaction. As a result, the period of turnover of twin stars is reduced and their orbit periastrons are deflected. Relative change in period P of the double pulsar is equal to

$$\frac{\Delta P}{P}=\frac{1}{4}\left(\frac{a_1\Delta T_1}{\sqrt{T_1}}+\frac{a_2\Delta T_2}{\sqrt{T_2}}\right) \quad , \tag{6}$$

where T_1 and T_2 – average temperatures of stars, a_1 и a_2 – their effective temperature coefficients [7].

While analyzing the complicated **movements of near-to-the sun plasma** it was noticed that in the sun vicinity the effective magnitude of the gravity constant is less than its standard value. Taking into account the fact that the temperature of plasma near the sun is high, in the or-der of $10^4 - 10^5\ K$, the fact is directly explained by the dependence (2).

The measuring of **gravitational constant**. Divergencies of the experimental values of the gravitational constant might be caused by inequality of the absolute temperatures of sample masses used in various gravitational experiments [8].

If the temperature dependence of the force of gravity keeps in extreme processes of **black hole** formation then a similar singularity appears to produce some doubts. Formation of black holes is hindered by the pressure forces on the part of collapsing substance which might exceed those of gravitational compression. In so doing, the compression process slows down and might transform itself into the phase of scattering (heat explosion) of the substance; on the whole, that process might be both of monotone and oscillating in time nature.

So, today there are experimental grounds to consider real the marked dependence of gravitational force on the absolute temperatures of interacting mass. Such dependence does not contradict the known experimental facts of classical mechanics and naturally agrees with the data of astrophysics [7]. Comprehensive research into the temperature dependence of the gravitational forces in the wide range of temperatures (including low ones, as well) of the test bodies of various physical composition will allow in the perspective to establish new peculiarities of the gravitational interaction of those bodies. Physics of gravitation might receive new development similar to that which optics received in transition from heat to laser light sources.

References

1. Gillies G. T. Metrologia, Vol. 24 (Suppl.), Bibliography:7; 31, 1987.

2. Shaw P. E. Phil. “Trans.” Royal Soc., Ser. A, Vol, 216, p. 349 – 392, 1916.

3. Shaw P. E., Davy N. Phys. Rev., Vol. 21, Ser. 2, Iss. 6, p. 680 – 691, 1923.

4. Assis A. K. T., Clemente R. A. Nuovo Cimento, Vol. 108 B, No. 6, p. 713 – 715, 1993.

5. Dmitriev A. L., Nikushchenko E. M., Snegov V. S. Measurement Techniques, Vol, 46, No. 2, p. 115 – 120, 2003.
6. Dmitriev A. L. Russian Physics Journal, Vol. 44, No. 12, 1323 – 1327, 2001.

7. Dmitriev A. L. Upravljaemaja Gravitacija, “Novy Centr” Publ., Moscow, 2005, 70 p.

8. Dmitriev A. L. arXiv, physics/0610282, 1 Nov. 2006.

№ 9

18th International Conference on General Relativity and Gravitation (GRG-18), Sydney, 2007, Abstract Book, pp. 77-78.

EXPERIMENTAL STUDY OF GRAVITY FORCE TEMPERATURE DEPENDENCE

A. L. DMITRIEV

St-Petersburg University of Information Technologies, Mechanics and Optics. 49, Kronverksky Prospect, St-Petersburg, 197101, Russia.

As it is known the general theory of relativity (GTR) rejects practically observed positive temperature dependence of the gravity force due to extremely small, equal to $\Delta E/c^2$ changes of body mass caused by changes in ΔE of its heat energy. It has been thought for a long time that the final experimental confirmation of the fact was obtained in the work by Shaw P. E. and Davy N. published in 1923 [1]. Meanwhile, a careful analysis of the work data [1] reveals than in the authors' experiments there was actually observed, with error better than 40%, a negative temperature dependence of the gravity force in the process of heating a solid sample body made of lead with temperature coefficient $\alpha = -2 \cdot 10^{-6} K^{-1}$. In our experiments [2] an accurate weighing on non-magnetic slowly heated metals was carried out and the results taking into account the effects of external factors were obtained which also demonstrate a systematic negative temperature dependence of the gravity force close in value to the data by Shaw P. E. and Davy N. For example, the value of temperature coefficient for lead under conditions corresponding to [1] is equal to $\alpha = -3.5 \cdot 10^{-6} K^{-1}$ with an error of about 20%. The paper considers the experimental setup, measurements techniques, sources of measurement errors and the results of measurements of temperature dependence of rods made of duralumin, titan brass and lead. Physical grounds for the observed, comparatively strong negative temperature dependence of the gravity force based on

the interaction of electromagnetic and gravitational fields [3] were proposed. According to such a phenomenological model the apparent change of a body gravitational mass is related to magnitudes of accelerations of its component microparticles in the process of their chaotic heat movement, with their acceleration magnitudes being directly proportional to $\sqrt{T}$, where T - absolute temperature of the body.

Some physical applications of temperature dependence of the gravity force are discussed, including scattering of experimental absolute values of gravity constant, effects of changes in mean temperature of a planet on its orbit precession, reduction of effective value of the gravity force acceleration acting on high-temperature plasma in the sun vicinity and others. It is noted that the observed, comparatively strong temperature dependence of the gravity force does not contradict to the known experimental data of the classical and relativistic theories of mechanics and it might contribute to the further developments of GTR concepts.

References

1. Shaw P. E., Davy N. Phys. Rev., Vol. 21, Ser. 2, Iss. 6, p. 680-691, 1923
2. Dmitriev A. L., Nikushchenko E. M., Snegov V. S. Measurement Techniques, Vol. 46, No 2, p. 115-150, 2003
3. Dmitriev A. L. Russian Physics Journal, Vol. 44, No 12, p. 1323-1327,
   2001

№ 10

Proceedings of *Space Technology and Application International Forum (STAIF-2008),* edited by M. El-Genk, AIP Conference Proceedings, Vol. 969, NY, 2008, pp. 1163-1169.

arXiv: 0803.1730 (General Physics, 2008)

Measurements of the Influence of Acceleration and Temperature of Bodies on their Weight

A. L. Dmitriev

St-Petersburg State University of Information Technologies,
Mechanics and Optics 49, Kronverksky Prospect, St-Petersburg,
197101, Russia, dalexl@rol.ru

Abstract. A brief review of experimental research of the influence of acceleration and temperatures of test mass upon gravitation force, executed between the 1990s and the beginning of 2000 is provided. According to a phenomenological notion, the acceleration of a test mass caused by external action, for example electromagnetic forces, results in changes of the gravitational properties of this mass. Consequences are a dependence upon gravity on the size and sign of test mass acceleration, and also on its absolute temperature. Results of weighing a rotor of a mechanical gyroscope with a horizontal axis, an anisotropic crystal with the big difference of the speed of longitudinal acoustic waves, measurements of temperature dependence of weight of metal bars of non-magnetic materials, and also measurement of restitution coefficients at quasi-elastic impact of a steel ball about a massive plate are given. A negative temperature dependence of the weight of a brass core with relative size near $5 \cdot 10^{-4}$ K^{-1} at room temperature was measured; this temperature factor was found to be a maximum for light and elastic metals. All observably experimental effects, have probably a general physical reason connected with the weight change dependent upon acceleration of a body or at thermal movement of its microparticles. Paper presented at the 5-th Symposium on New Frontiers and Future Concepts (STAIF-2008), Albuquerque, New Mexico 10 – 14 Feb. 2008.

Keywords: Gravitational Force, Temperature, Acceleration, Impact, Weight.
PACS: 04.80.-y.

INTRODUCTION

The deep interrelation of electromagnetic and gravitational forces can and should be manifested in experiments with exact weighing of the test bodies moving with acceleration under action of elastic forces. For a long time the attention given to this problem was unduly not enough which was in part promoted by theoretical concepts of the general relativity regarding fictitiousness of the «force of gravitation» concept. Meanwhile, a number of experimental measurements have tested the influence of acceleration of external elastic forces on the value of acceleration of gravity as it will be shown in the present paper.

We propose to characterize this influence as follows. If a test body under action of external elastic forces moves upwards with acceleration value a_g, an increment Δg_c of the gravitational acceleration shall occur, which is given in a first linear approximation as

$$\Delta g_c = \alpha_c a_g \quad . \tag{1}$$

Similarily, if a body is accelerated downwards under the action of external forces, then an increment Δg_p of the gravitational acceleration shall occur with a different sign, given by

$$\Delta g_p = -\alpha_p a_g \quad . \tag{2}$$

In Equ. (1) and Equ. (2) the dimensionless factors α_c and α_p characterize a degree of interaction of elastic and gravitational forces. Vertical harmonious oscillations of a test body with a weight p will therefore lead to an average weight given by

$$p = mg_0 \left[1 - \frac{(\alpha_p - \alpha_c) A \omega^2}{\pi g_0} \right] \quad , \tag{3}$$

where m is the mass of a body, g_0 the standard acceleration of gravity, A the amplitude, and ω the circular frequency of oscillations (Dmitriev, 2001).

The experiment should give an answer to a question whether the factors α_c and α_p are different from zero, and what their ratio is.

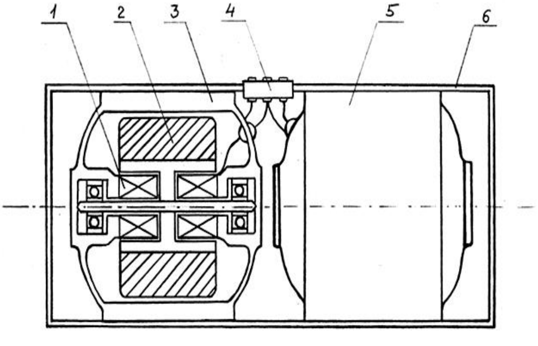
MEASUREMENTS OF INFLUENCE OF ACCELERATION ON GRAVITY

The simple way of estimation of difference value $(\alpha_p - \alpha_c)$ is based on weighing of a rotor of a mechanical gyroscope with a horizontal axis of rotation. The role of elastic forces is played here by centripetal forces. It is possible to show that the weight P of the rotor in form of a cylinder with radiuses R_1 and R_2 is equal to

$$P = Mg_0\left[1-(\alpha_p - \alpha_c)\frac{2(R_2{}^3 - R_1{}^3)}{3\pi g_0(R_2{}^2 - R_1{}^2)}\omega^2\right], \quad (4)$$

where ω is the angular speed of rotation. Such an experiment was executed in 1999-2000 at Saint Petersburg (Dmitriev and Snegov, 2001). In this case, we weighed a pair of coaxial rotors rotating in opposite directions for compensation of the total angular moment of the container (R_1=15 mm, R_2=25 mm, M=250 g), as shown in Fig. 1. The obtained experimental dependence is shown in Fig. 2.

FIGURE 1. The device of the container. 1 - electric coils of the engine of a gyroscope, 2 - a massive cylindrical part of a rotor, 3 - the case of the first gyroscope, 4 - plugs of power supplies of engines of gyroscopes, 5 - the case of the second gyroscope (it is shown without a section), 6 - the case of the container



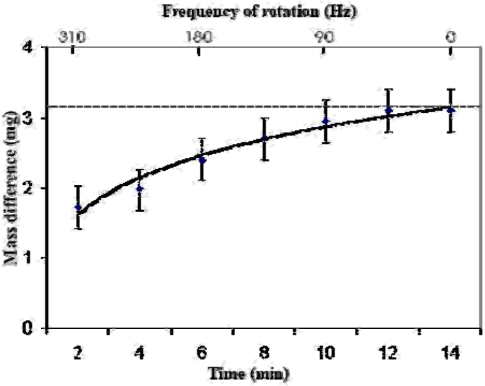


FIGURE 2. Mass difference of a horizontal and vertical rotor.

At a speed of rotation of 18.6 thousand rev/min the relative reduction of weight of a rotor was equal to $3\cdot10^{-6}$. The estimated value of $(\alpha_p - \alpha_c)$ is near to 10^{-7}. The factor α_c alone was evaluated by precision measurements for the restitution coefficients of an elastic impact of a ball against a massive metal plate. In these experiments a plate (and a ball trajectory) took horizontal and vertical positions (Dmitriev, 2002). Acceleration of the ball during impact duration exceeded of $10^4\cdot g_0$. The difference of restitution coefficients in vertical (k_1) and horizontal (k_2) quasi-elastic impacts of the ball is shown in Fig. 3.

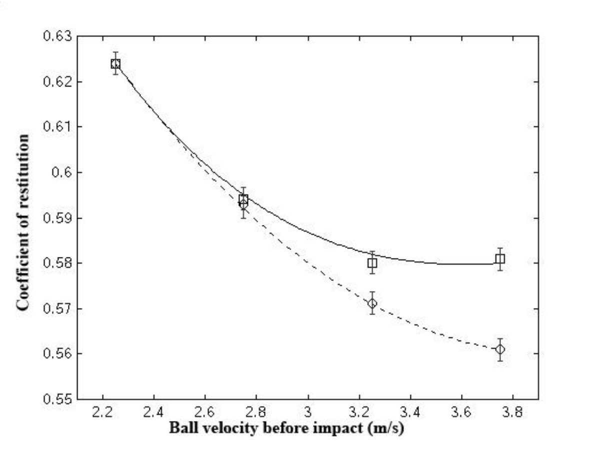


FIGURE 3. Experimental dependence of coefficient of restitution; the top line – k_2, the bottom line – k_1.

The order of value of the factor α_c can be estimated by the formula

$$\alpha_c \approx \frac{k_2 - k_1}{1 + k_2} \quad . \tag{5}$$

The speed of the ball before impact is about 3.5 m/s, which gives a $|\alpha_c| \cong 10^{-2}$ that is unexpectedly big.

Interesting results obtained by M. Tajmar's group in experiments with a rotating superconductor (Tajmar el al, 2007) probably have a physical nature close to the one discussed in the present work.

MEASUREMENTS OF TEMPERATURE DEPENDENCE OF BODY WEIGHT

If indeed there is an influence of acceleration of elastic (electromagnetic in nature) forces on gravitation, then there will be the temperature dependence of body weights due to the thermal movements inside the body. The acceleration of microparticles in their thermal movement directly depend on their energy, and therefore from the absolute temperature of body. It is possible to show that in a classical approximation at temperatures higher than the Debye-temperature, the temperature dependence of body weight is described by the formula

$$P = Mg_0\left[1-\frac{(\alpha_p-\alpha_c)}{\pi g_0}C\sqrt{T}\right] , \qquad (6)$$

where C is a the factor dependent on physical characteristics (including density and elasticity) of bodies and T is the absolute temperature.

According to Equ. (6), an increase in the absolute body’s temperature will cause a reduction of its weight. Such an effect was indeed observed in exact weighing of metal samples from nonmagnetic materials heated with ultrasound (Dmitriev, Nikushchenko and Snegov, 2003).The layout of the hermetically sealed container shown in Fig. 4.

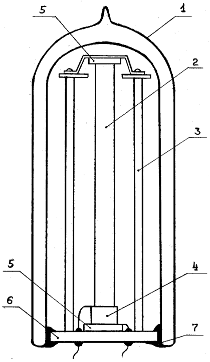


FIGURE 4. 1. Layout of hermetically sealed container. 1 – Dewar flask; 2 – metal rod; 3 – holder support; 4 – electroacoustic transducer (PZT); 5 – gaskets (foam plastic); 6 – holder base (ebonite); 7 – cold welding.

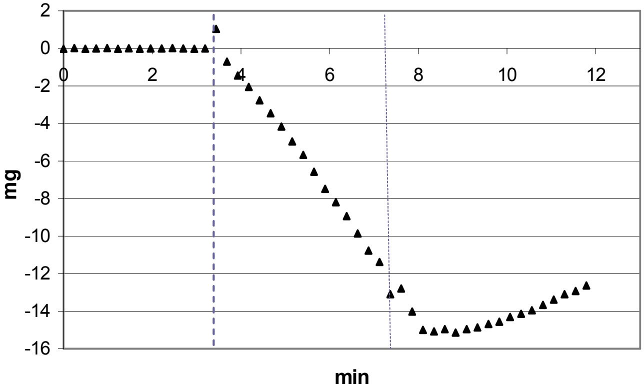


FIGURE 5. Change in mass of a brass rod. Ultrasound frequency 131.25 kHz. The touch lines indicate the moments when the ultrasound was switched on and off.

An example of the experimental dependence of a sample weight in the process of its heating and cooling is shown in Fig. 5.

The temperature dependence of weight of various samples made of lead, copper, brass, titan and duralumin was measured. Some results of measurements are shown in Table 1.

TABLE 1. Characteristics of Samples and Results of Measurement, where $a=(\alpha_p-\alpha_c)\,.\,C / \pi g_0$ and temperature factor $\alpha=-a/2\sqrt{T}$.

Sample	**Lead**	**Copper***	**Brass****	**Titanium**	**Duralumin**
Length (mm)	80.2	71.6	140.0	140.0	140.0
Diameter (mm)	8.0	10.5	8.0	8.0	8.0
Mass (g)	45.6	39.2	58.5	31.2	19.1
Ultrasound Frequency (kHz)	135.43	129.70	131.27	136.22	134.90
$\Delta m/\Delta t$ (mg/min)	1.06	1.15	2.64	1.63	1.66
$\Delta T/\Delta t$ (K/min)	5.1	4.5	10.0	6.0	7.5
$\alpha.10^6$ (K^{-1}) at $T \cong 300$ K	4.56	6.50	4.50	8.70	11.60
$a.10^4$ ($K^{-1/2}$) at $T \cong 300$ K	1.6	2.3	1.6	3.0	4.0

(*) - twist, (**) – Dewar

During weighing, some various physical factors were considered: convection, buoyancy, action of heat and ultrasound on the balance, influence of magnetic and electric fields, and others. According to quantitative estimations, the accuracy of the temperature factors was about 20-25 %.

The authors also constructed a thermo-physical model of reduction of the apparent weight of non-uniformly heated samples which model agreed well with the experiment. It is typical that the negative temperature dependence of body weight is always observed, with the greatest values of factor being obtained for the samples made of light and elastic materials. Let's note that for the first time the negative temperature dependence of weight of bodies was actually observed in experiments of Show and Davy described in 1923 (Shaw and Davy, 1923); however, the authors then did not dare to insist on their results (Dmitriev, 2006).

MEASUREMENTS OF ANISOTROPYOF RUTILE CRYSTAL WEIGHT

The elementary analysis shows that the acceleration of microparticles of a test body in their thermal movement is directly proportional to c/μ, where c is the factor of elasticity and μ is the mass of the particles. If V is the speed of elastic longitudinal waves in a considered body and ρ the density of the body’s material, then the following ratio is true

$$a \propto \sqrt{c} / \mu \propto V / \sqrt{\rho} \tag{7}$$

The consequence of Equ. (7) should be the dependence of weight of an anisotropic crystal on its orientation (Dmitriev and Chesnokov, 2004).

If the speeds V_1, V_2 of longitudinal waves in a crystal for orthogonal directions noticeably differ, then at the constant crystal temperature the relative difference P/P of its weight measured in two positions "1" and "2" is equal to

$$\frac{\Delta P}{P} \propto -\frac{V_1 - V_2}{\sqrt{\rho}} \tag{8}$$

The experimental results of measurement of weight differences of a rutile crystal measured at its mutual - perpendicular positions are given in Fig. 6.

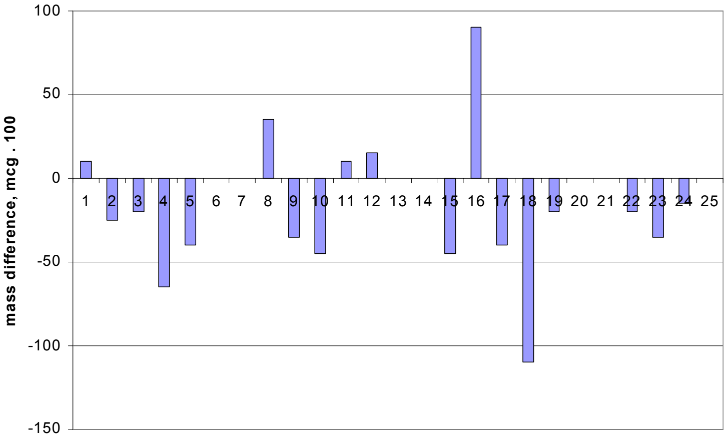


FIGURE 6. Weight differences of rutile crystal measured at its mutual - perpendicular positions; one division of a ordinate-scale corresponds to 0.5 mcg; results of four series of measurements are shown.

The average weight of a sample is 2.876 g, speeds of longitudinal sound waves are $V_1=10.94\cdot10^3$ m/s and $V_2=8.014\cdot10^3$ m/s. The relative difference of weights is equal to $-7\cdot10^{-8}$ with root-mean-square deviation of 0.10 mcg. Big fluctuations of measured differences of weights are caused by instability of temperature regimes of weighing. Nevertheless, there prevails the regular character of inequality of weight observed in case of anisotropic crystal the sign of which corresponds to the ratio in Equ. (8).

CONCLUSION

So, the four described experiments show that the accelerated movement of a body caused by action of elastic (electromagnetic in nature) forces influences the force of its gravitational interaction with others, conditionally motionless, bodies. Indirectly, such an influence causes a negative temperature dependence of body weight that has a big practical value for precision gravimetry, for fundamental problems of physics of gravitation, and also in interpretation of some phenomena of astrophysics (Dmitriev, 2005; Dmitriev, 2006a, 2006b).

In the immediate prospects, it seems necessary to conduct the following experimental research

- precision measurement of physical temperature dependence of weight of various materials in a wide range of temperatures,
- dynamic measurements of weight of bodies in a condition of elastic effects: acoustic (including, ultra-and hypersonic) and impact, and also while their oscillatory and rotary movements,
- measurement of a mutual attraction forces of accelerated moving weights at the lowest temperatures.

Experimental and theoretical research of problems of interaction of acceleration and gravitation, and also the problems of temperature dependence of forces of gravitation connected with them, has rather big value both for the development of physics of gravitation and for perspective technologies of the future.

REFERENCES

Dmitriev A. L., "On the Influence of External Elastic (Electromagnetic) Forces on the Gravity," *Russian Physics Journal,* **44**(12), 1323-1327, (2001).

Dmitriev A. L., Snegov V. S., "Weighing of the Mechanical Gyros with Horizontal and Vertical Orientations of Axis of Rotation," *Izmeritelnaja Tekhnika*, **8**, 33 – 35 (2001), (in Russian).

Dmitriev A. L., "Inequality of the Coefficients of Restitution for Vertical and Horizontal Quasielastic Impacts of a Ball Against a Massive Plate," *International Applied Mechanics*, **38**(6), 747 – 749, (2002).

Dmitriev A. L., Nikushchenko E. M., Snegov V. S., "Influence of the Temperature of a Body on its Weight," *Measurement Techniques*, **46**(2), 115 – 120, (2003).

Dmitriev A. L., Chesnokov N. N., "Influence of Orientation of Anisotropic Crystal on its Weight, "*Izmeritelnaja Tekhnika*, **9**, 36 – 37, 2004, (in Russian).

Dmitriev A. L., "*Upravljaemaja Gravitacija,*" Novy Centr, Moscow, 2005, 70 p., (in Russian).

Dmitriev A. L., "On Possible Causes of Divergence in Experimental Values of Gravitation Constant," http://arxiv.org/ physics/0610282, accessed November 1, 2006.

Dmitriev A. L., "Temperature Dependence of Gravitational Force: Experiments, Astrophysics, Perspectives," http://arxiv.org/ physics/0611173, accessed November 20, 2006.

Shaw P. E., Davy N., "The Effect of Temperature on Gravitative Attraction," *Phys. Rev.*, **21**(6), 680 – 691, (1923).

Tajmar M., Plesescu F., Seifert B., Schnitzer R., Vasiljevich I., "Search for Frame-Dragging in the Vicinity of Spinning Superconductors," http://arxiv/org/gr-gc/07073806, accessed July 25, 2007.

№11

arXiv: 0806. 0796 (2008)

On the nature of inertial mass

Alexander L. Dmitriev

St-Petersburg State University of Information Technologies,
Mechanics and Optics 49, Kronverksky Prospect, St-Petersburg,
197101, Russia

Abstract

It is shown that gravitational nature of inertial mass (Mach's principle) agrees with idea of interaction of gravitational and electromagnetic forces and does not contradict the laws of classical mechanics. According to the simple phenomenological model the body inertial mass is directly proportional to its gravitational mass and the sum of coefficients α_p and α_c which characterize degrees of interaction of gravitational forces in accelerated motion of the body in accompanying and opposite directions relative to the gravitational force.

PACS number: 04.80. Cc

Inertial mass of the body which is a component of the second law of dynamics has long been an object of scientific discussions. A wide-known concept indicating the cause and physical sense of inertial mass is presented by Mach's principle according to which the inertial mass of the body is a result of that body gravitational interaction with all surrounding bodies of the universe [1,2]. Gravitational interaction of bodies is directly connected with the concept of gravitation propagation rate. Extreme remoteness of massive formations – stars, galaxies, clusters of galaxies, etc. – provides grounds for assumption that the condition for Mach's principle realization must be rather high speed of gravitation propagation which might considerably exceed light speed.

The present paper shows that the gravitational nature of inertial mass when described as a phenomenon naturally agrees with the concept of interaction of electromagnetic and gravitational forces. Such an interaction is characterized by dependence of gravity force acceleration change $\Delta\vec{g}$ and acceleration $\vec{a}$ which is caused by action of external, for example, electromagnetic forces on the test body [3]. Similar to Lenz's law, directions of vectors $\Delta\vec{g}$ and $\vec{a}$ are mutually opposite, and coefficients of proportionality α_p, α_c depend on acceleration direction $\vec{a}$ relative to gravitational force acceleration $\vec{g}_0$. In the first (linear) approximation, "the induction" of gravity force acceleration is equal to

$$\Delta\vec{g}_{p,c} = -\alpha_{p,c}\vec{a} \qquad , \qquad (1)$$

where α_p corresponds to parallel vectors $\vec{a}$ and $\vec{g}_0$, and α_p - to antiparallel ones – Fig. 1.

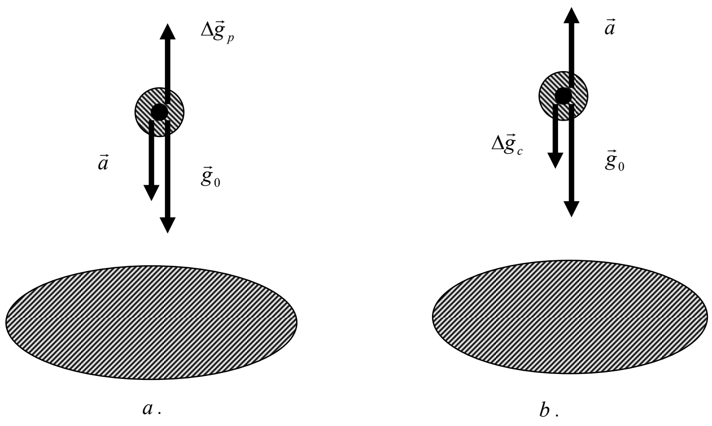


Fig. 1. a. Changes in gravity force acceleration acting on test body while body is falling down with acceleration. b. Changes in gravity force acceleration while body is moving up with acceleration.

Validity of equation (1) is confirmed by experiments on precise weighing of bodies moving with acceleration, as well as - indirectly – by negative temperature dependence of weights of bodies [4-6]. Absolute magnitude of interaction coefficients $\alpha_{p,c}$ measured in experiments with non-magnetic metal samples is comparatively high $\alpha_c \sim 10^{-2}$, and the order of positive difference magnitude $(\alpha_p - \alpha_c) \sim 10^{-7}$.

Let's assume that in conditional-inertial system of coordinates related to "infinitely remote" masses, a test body with gravitational mass m_g is stationary in the initial state (Fig. 2a).

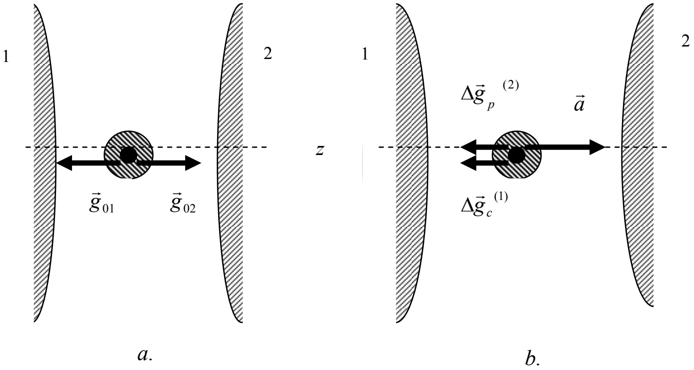


Fig. 2. a. Test body in counterbalanced state. b. Increments in gravity force acceleration under effect of outside non-gravitational force.

In isotropic space along a randomly chosen axis Z, the resultant force of gravitational forces acting on the body from the side of remote masses 1,2 located on different sides of the body is equal to zero. In so doing, the accelerations corresponding to those forces which are the sum of projections on axis Z of gravity forces accelerations created by such masses are equal in magnitude $|\vec{g}_{01}| = |\vec{g}_{02}|$. If there is an outside non-gravitational force $\vec{F}$ acting on the body along the indicated direction, then according to the second law of dynamics the corresponding acceleration $\vec{a}$ of the body is equal to

$$\vec{a} = \vec{F} / m_i \quad , \qquad (2)$$

where m_i - body inertial mass. Such an acceleration, according to (1), causes changes $\Delta\vec{g}_c^{\,(1)}$ and $\Delta\vec{g}_p^{\,(2)}$ of gravity force accelerations acting on the test body from the side of remote masses 1,2, with directions of vectors $\Delta\vec{g}_c^{\,(1)}$ and $\Delta\vec{g}_p^{\,(2)}$ coinciding (Fig. 2b).

According to the third law of dynamics the resultant force of those applied to the body is equal to zero,

$$m_g(\vec{g}_{01} + \Delta\vec{g}_c^{\,(1)}) + m_g(\vec{g}_{02} + \Delta\vec{g}_p^{\,(2)}) + m_i\vec{a} = 0 \quad . \qquad (3)$$

Whence the inertial mass of test body

$$m_i = (\alpha_p + \alpha_c)m_g \quad . \qquad (4)$$

Expression (4) explains the physical sense of inertial mass: body inertial mass is proportional to its gravitational mass, caused by interaction of gravitational and electromagnetic forces applied to the body, and determined by magnitudes of coefficients α_p , α_c which characterize the degree of such an interaction. If the interaction of gravitational and electromagnetic forces were nonexistent, that is with $\alpha_c = \alpha_p = 0$, the body inertial mass would be equal to zero as well. Such an assumption directly agrees with Mach principle according to which inertia of matter is determined by masses surrounding it. On the other hand, proportionality of gravitational and inertial masses is proved by numerous experiments and agrees with corpuscular model of matter: an increase in number of particles making up test body proportionally increases both inertial and gravitational masses. Mass ratio m_i / m_g is determined by magnitudes of coefficients α_p , α_c which might be constants; this expression can be equated to one by choosing corresponding magnitude of gravitational constant.

Thus, the gravitational nature of inertial mass does not contradict the principles of classical mechanics supplemented by concept of interaction of gravitational and electromagnetic forces (in particular, elastic forces). Experimental and theoretical investigations of gravity force acceleration “induction” caused by accelerated motion of the body under effect of outside non-gravitational forces will contribute to development of physics of gravitation and its supplements.

References

1. Misner C W, Thorn K S and Wheeler J A 1973 *Gravitation* (Freeman, San Francisco)
2. Lichtenegger H and Mashhoon B 2008 Mach’s Principle *Preprint* physics/0407078v2
3. Dmitriev A L 2001 On the Influence of External Elastic (Electromagnetic) Forces on the Gravity *Russian Physics Journal* **44** (12) 1323-1327
4. Dmitriev A L, Nikushchenko E M and Snegov V S 2003 Influence of the Temperature of a Body on its Weight *Measurement Techniques* **46** (2) 115-120
5. Dmitriev A L 2007 Experimental Study of Gravity Force Temperature Dependence *18th International Conference on General relativity and Gravitation, Sydney, 8-13 July 2007, Abstract Book*, 77-78
6. Dmitriev A L 2008 Measurement of the Influence of Acceleration and Temperature of Bodies on their Weight *Proc. of Space Technology and Applications International Forum – STAIF 2008 Albuquerque NM 10-14 February 2008* 1163-1169

№12

arXiv: 0903.4433 (General Physics, 2009)

ON THE EXPERIMENTAL SUBSTANTIATION OF ANISOTROPY OF INERTIAL MASS OF BODY IN THE EARTH' GRAVITATIONAL FIELD

Alexander L. Dmitriev

St. Petersburg State University of Information Technologies, Mechanics and Optics Kronverkskiy Prospekt 49, St. Petersburg, 197101, Russia, alex@dmitriyev.ru

Abstract. *On the basis of the field' concept of gravitation and gravitational analogue of the Faraday's induction law the difference of inertial mass of a body at its accelerated movement in horizontal and vertical directions relative to the Earth is shown. For an illustration of such a distinction the results of comparison of a motion of balance mechanical watch at horizontal and vertical orientations of balance' axis are given. The expediency of statement of precision mechanical experiments with measurement of anisotropy of the inertial mass is noted, allowing to estimate the validity of the "field" approach in the description of gravitation.*

Keywords: Gravitation, Acceleration, Inertial Mass, Anisotropy of Mass, Mach' Principle **PACS**: 04.20.Cv, 04.80.-y

---

In distinction from "geometrical", the "field" concept of gravitation describes the gravitational interaction of bodies similarly to other kinds of physical interactions - electric and magnetic. Thus the concept of the "material" gravitational field related to sources - the gravitational mass - and characterized by the set of parameters (potential, velocity, impulse, moment) is considered. The advantage of the field, basically phenomenological concept of gravitation consists in an opportunity to use for its development some separate analogies of the gravitational and electromagnetic phenomena, and in their direct experimental check. Thus, gravitational fields, certainly, should have the properties similar, but not identical to properties of electromagnetic fields.

In [1] on the basis of the noted analogies the assumption of original reaction of the gravity force acting on a test body, on its acceleration $\vec{a}$ caused by action of external not gravitational (for example, elastic) forces is put forward. Change $\Delta\vec{g}$ of acceleration of the gravity, similar to the phenomenon of Faraday's induction law in view of Lenz' rule, is equal to

$$\Delta\vec{g}_{p,c} = -\alpha_{p,c}\vec{a} \qquad (1)$$

where indexes p, c indicate mutual, passing (p) or a contrary (opposite) (c), orientation of a vector $\vec{g}_0$ of normal acceleration of a gravity and vector $\vec{a}$ of acceleration of external force.

Estimations of the order of value of dimensionless factors α_p and α_c , which the gravitational interrelation of gravitational and electromagnetic fields specify, were executed in mechanical experiments with weighing of two coupled mechanical rotors with the zero full moment, with a horizontal axis of rotation, and in the analysis of the shock phenomena [2,3]. By consideration of thermal chaotic movement of microparticles of solid bodies the consequence 1, in view of an inequality $\alpha_p \succ \alpha_c$, is the negative temperature dependence of gravity, also ob-served in the experiment [4-7].

In [8,9] in the description of balance of the elastic (electromagnetic) and gravitational forces acting on the test mass on the part of remote mass (for example, stars), according to idea of E. Mach about the gravitational nature of inertial forces, the ratio between inertial (m_i) and gravitational (m_g) masses is obtained,

$$m_i = m_g(\alpha_p + \alpha_c) \quad . \qquad (2)$$

Equation 2 shows the direct proportionality of inertial and gravity masses of a body, and the relation of theses masses, contrary to the known postulate of "geometrical" model of gravitation, generally speaking, is not a constant.

Equation 1 shows the relation of change of gravity acceleration with acceleration $\vec{a}$ of external forces, in so doing it is necessary to take into account that the absolute size $\Delta g_{p,c}$ of an increment of acceleration should also depend on magnitude g_0 of normal gravity acceleration. Generally, in view of influence of forces of the gravitation caused by remote surrounding masses (stars), in movement of a test body on a vertical there should be carried out the equation

$$\alpha_{p,c} = A_{p,c}(g_0 + g') \qquad (3)$$

where g' - a projection of acceleration of forces of gravitation on the part of the remote masses located in a solid angle 2π , on the direction of the accelerated movement of body, and factors $A_{p,c}$ characterize the action on a test body of not only Earth' gravitational field, but also a field of the gravitation created by all surrounding masses.

The resultant forces of gravitation acting on the motionless or moving with the constant speed test body from direction of remote masses, uniformly distributed in space in a full solid angle 4π , it is approximately equal to zero, while the magnitude g' determines the inertial properties of a body, Fig. 1.

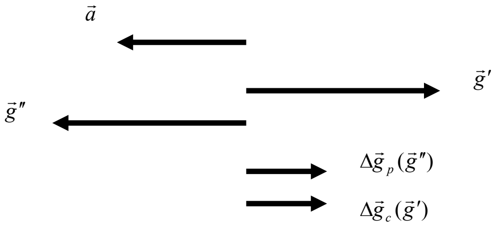


Fig. 1. Mutual orientation of a vector of acceleration of not gravitational forces $\vec{a}$ and increments vectors $\Delta\vec{g}_p, \Delta\vec{g}_c$ of accelerations of the gravitation forces acting on test mass from the direction of remote masses (stars). The resulting accelerations' vectors $\vec{g}'$ and $\vec{g}''$, caused by action of the remote masses located in the left and the right half-spaces in the solid angles 2π are equal in magnitude and are oppositely directed.

The consequence of 2,3 is the difference of inertial masses of a test body in its accelerated movement relatively to the Earth in horizontal and vertical directions.

For the harmonious, caused by the action of external elastic force, oscillatory movement along a vertical, the average, for the period of oscillation, inertial mass m_i of a test body is equal to

$$m_i = m_g(A_p + A_c)(\frac{g_0}{2} + g') \quad . \qquad (4)$$

In oscillatory movement of this test body along the horizontal, its average inertial mass $\overline{m_i}$ is equal to

$$\overline{m_i} = m_g(A_p + A_c)g' \quad . \qquad (5)$$

In 4.5, the resulting magnitude g' of projections of accelerations of gravity forces created by the remote masses in a solid angle 2π, is believed constant and independent from the direction in space. The relative difference of "vertical" and "horizontal" inertial masses, taking $g' \succ\succ g_0$, is equal to

$$2\frac{m_i - \overline{m_i}}{m_i + \overline{m_i}} \approx \frac{g_0}{2g'} \quad . \qquad (6)$$

Experimental estimations of magnitude of inertial mass anisotropy of a body can be made, comparing the periods of oscillations of linear mechanical oscillator with vertical and horizontal orientations of its axis. For the same purpose it is convenient to use the rotation oscillator, for

example a pendulum of high-quality mechanical balance watch, by changing orientation of the balance axis.

The period *T* of free oscillations of system a balance - spiral of mechanical watch is equal to

$$T = 2\pi\sqrt{\frac{I}{C}} \quad , \qquad (7)$$

where *I* - the moment of inertia of balance ($I \propto m_i$) and *C* - factor of elasticity of the spiral [10].

According to 6,7, the period *T* of oscillations of balance in a vertical plane should be more than the period *T* of oscillations of balance moving in a horizontal plane, that is the ideal mechanical watch in position "on an edge" goes more slowly, than in position "flatwise".

The position-sensitivity of mechanical watch is influenced many factors, including, the moment of inertia of a spiral, conformity of an axis of rotation and the centre of inertia of a pendulum, friction in axes of a suspension bracket of a pendulum etc [11]. With high quality of watch and its careful adjustment, the influence of the specified factors can be reduced practically to zero, and in that case the comparison of daily motion of balance watch in vertical and horizontal positions can be used for an estimation of magnitude of anisotropy of inertial mass 6. In view of 4-7, the relative difference γ of the daily motion of an ideal watch is equal to

$$\gamma = 2\frac{T-\overline{T}}{T+\overline{T}} \approx \frac{1}{4}\frac{g_0}{g'} \quad . \tag{8}$$

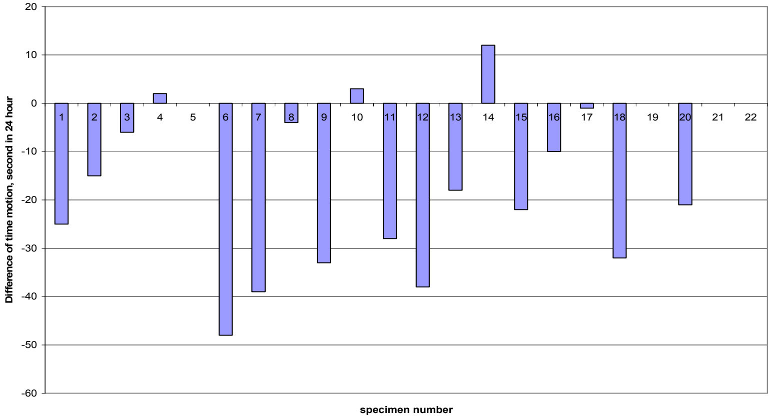


Fig. 2. A difference of a daily motion of mechanical balance watch "Raketa 2609" in positions "flatwise" and "on an edge".

In Fig. 2 the results of measurements of position sensitivity of twenty one samples of mechanical watch "Raketa 2609" manufactured by "Petrodvortsovy watch factory" are given. The difference of an average daily motion of watch in positions "flatwise" and "on an edge" was measured, each of them was measured as an average for two different positions of the head and plane of a dial of watch. The average magnitude of watch motion delay in position "on an edge" has come to about 15 seconds over one day which corresponds to $\gamma \approx 1.7 \cdot 10^{-4}$.

The question of what part of the given value γ is caused by action of physical factors (anisotropy of inertial mass in a gravitational field of the Earth), and what – by technical imperfection of the mechanism of watch still remains open. The difficulty is that even with an appreciable influence on a motion of watch of anisotropy of inertial mass of the pendulum of watch, the position-dependence of a daily motion of watch can be reduced almost to zero by technical means of adjustment. Thus the "physical" delay of a watch motion can be compensated by adjustment of watch which complicates an objective estimation of magnitude of such effect. Therefore the careful analysis of all technical factors influencing the position sensitivity of balance watches and clockworks used in such experiments is necessary for obtaining of objective data. Nevertheless, the given average result is in agreement with physical preconditions noted above and can be the basis for setting up precision experiments with use of mechanical oscillators on measurements of prospective anisotropy of inertial mass.

For reduction of an error of the measurements connected to reorientation of an axis of rotation of mechanical pendulum, more reliable results, probably, will be received in measurements of self-frequency of linear mechanical oscillator with horizontally located axis which direction can be changed in a non-uniform gravitational field of the Earth (for example, in mountains).

If the result shown in Fig. 2 gives a true estimation of magnitude order of a relative difference of inertial masses in horizontal and vertical directions, then, according to 8, gravitational field-intensity g' created by all indefinitely remote masses located in a solid angle 2π relative to a point of observation, the said intensity is approximately one thousand times the magnitude of normal acceleration of gravity on the surface of the Earth. In view of gravitational analogue of the Faraday's induction law 1, such rather strong "interstellar" gravitational field, apparently, is also the physical reason of inertial properties of bodies.

The precision measurements of anisotropy of inertial mass of bodies in a non-uniform gravitational field will confirm validity or an fallacy of the above estimation and as a consequence the validity of the phenomenological "field" concept of gravitation in the description of inertial properties of bodies.

Appendix.

If the average density ρ of a matter in the volume of sphere of radius R is constant, from the Newton's law of gravitation follows

$$g' = 2\pi G\rho R \quad , \tag{9}$$

where G – the gravitational constant. Taking into account the temperature dependence of G and non-uniform distribution of ρ , certainly, the 9 only for rough estimates is suitable.

REFERENCES

1. Dmitriev, A. L., "On the Influence of External Elastic (Electromagnetic) Forces on the Grav-ity," *Russian Physics Journal,* **44**(12), 1323-1327 (2001).

2. Dmitriev, A. L., and Snegov V. S., "The Weighing of a Mechanical Gyroscope with Horizon-tal and Vertical Orientations of the Spin Axis", *Measurement Techniques*, 44 (8), 831-833 (2001).

3. Dmitriev, A. L., "Inequality of the Coefficients of Restitution for Vertical and Horizontal Qua-sielastic Impacts of a Ball Against a Massive Plate," *International Applied Mechanics*, **38**(6), 747 – 749 (2002).

4. Dmitriev, A. L., Nikushchenko, E. M., and Snegov, V. S., "Influence of the Temperature of a Body on its Weight," *Measurement Techniques*, **46**(2), 115 – 120 (2003).

5. Dmitriev, A. L., "Temperature Dependence of Gravitational Force: Experiments, Astrophysics, Perspectives," http://arxiv.org/physics/0611173, accessed November 20, 2006.

6. Dmitriev, A. L., “Experimental Study of Gravity Force Temperature Dependence,” in *18th In-ternational Conference on General Relativity and Gravitation (GRG-18),* Sydney, 2007, Ab-stract Book, pp. 77-78

7. Dmitriev, A. L., “Measurements of the Influence of Acceleration and Temperature of Bodies on their Weight,” in proceedings of *Space Technology and Application International Forum (STAIF-2008),* edited by M. El-Genk, AIP Conference Proceedings, Vol. 969, NY, 2008, pp. 1163-1169.

8. Dmitriev, A. L., “On the Nature of Inertial Mass,” http://arxiv.org/physics/0806.0796, accessed June 4, 2008.

9. Dmitriev, A. L. “Analogue of Lenz's Rule in Phenomenological Gravitation”, in proceedings of *Space, Propulsion & Energy Sciences International Forum (SPESIF-2009)*, Huntsville, AL, 24-26 February 2009, AIP Conference Proceedings, Vol. 1103, NY 2009, pp. 345 - 351.

10. Magnus K., “Schwingungen”, B. G. Teubner, Stuttgart, 1976.

11. Paramonov D. A., “Regulirovka balancovyh chasov”, “Mashinostroenie”, Moscow, 1977.

№13

arXiv: 0907.2790 (General Physics, 2009)

NONZERO RESULT OF MEASUREMENT OF ACCELERATION OF FREE FALLING GYROSCOPE WITH THE HORIZONTAL AXIS

A. L. Dmitriev, E. M. Nikushchenko, S. A. Bulgakova

St-Petersburg State University of Information Technologies,
Mechanics and Optics 49, Kronverksky Prospect, St-Petersburg,
197101, Russia Tel/Fax+7.812.3154071, alex@dmitriyev.ru

Resume: In our experiment we measured the free fall accelerations of the closed container inside which a mechanical rotor (gyroscope) with a horizontal axis of rotation was installed. There was observed an appreciable, essentially exceeding errors of measurements increase of acceleration of free falling of the container at angular speed of rotation of a rotor up to 20 000 rpm.

Keywords: Gravity Force, Weighing, Acceleration, Free Falling, Gyro, Equivalence Principle .
PACS: 04.80.Cc, 04.80.-y.

To laboratory weighings of rotors of mechanical gyroscopes the set of works [1, 2] is devoted. Such measurements were usually carried out with the purpose of experimental check of a equivalence principle, or various gravitoelectric (gravitomagnetic) models. In most cases, in these experiments the axis of a rotor was oriented vertically and, as a whole, the positive effect was absent. In our paper [3] the results of exact weighing of two coaxial rotors with a horizontal axis and with the zero total moment J_Σ are given, and its weights which have shown little change, dependent on angular speed of rotation of a rotor. The explanation of these results the possible precession a gyroscope is complicated, connected to rotation the Earth, which essentially could to influence indications of weights, owing to inexact performance of equality $J_\Sigma = 0$. In much smaller degree the precession effects influence on results of measurement of size of acceleration by freely falling of rotor. Thus physical conditions of interaction of a falling rotating rotor with the centre of gravitation (Earth) essentially differ from conditions of weighing of a rotor on based laboratory weights.

In described experiment the acceleration of free falling of container with the two, located coaxially, rotors of mechanical gyroscopes placed inside it was measured; the device and characteristics of the container are given in [3]. On the container the compact highly stable generator of pulses connected to two differ-coloured light-emitting diodes, located along a trajectory of falling of the container is fixed. Distance on centre to centre of aperture stop (holes), established before light-emitting diodes is $l =$ 76.25*mm*, frequency of impulses $F = 56.25Hz$, duration of impulse optical signals 0.13*ms*. The trajectory of the falling container was photographed by the digital camera with exposure 0.6 – 0.8*s* and coordinates of marks (the centres of holes) were digitized by computer.

The calculation of acceleration g of free falling container was carried out under the formula

$$g = \frac{(\Delta_2 - \Delta_1)F^2}{N^2}$$

where Δ_1 , Δ_2 - absolute lengths of the next sites of the trajectories, containing N marks; the scale of the image was defined by distance l between light-emitting diodes. For reduction of influence of aberration of the image owing to distorsion, the average scale of the image paid off on three readout of length l - in the top, central and bottom parts of a trajectory. The size $\bar{g}$ in separate measurement was determined as average value of acceleration, designed on two trajectories appropriate to two groups of color marks on the image.

The example of the measured values of acceleration of free falling container in conditions (1) $\omega = 0$, (2) $\omega \neq 0$ and (3) $\omega = 0$ (upon termination of time rotation of rotor) is shown in figure.

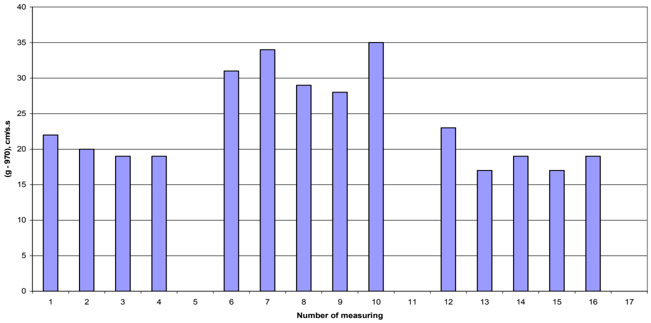


Fig. The example of the measured values of acceleration of free falling container. 1(n. 1-4) $\omega = 0$, 2(n. 6-10) $\omega \neq 0$, 3(n. 12-16) $\omega = 0$.

The maximal angular speed of rotation of a rotor $\omega \approx 20000 rpm$, rotation time of rotor is 14-15 mines, duration of one cycle of measurements from 4-5 pictures about 2 minutes.

It was processed over 200 pictures, thus the increase of acceleration of free falling of a rotor was regularly observed at transition from a condition (1) to a condition (2) with average size $\Delta\bar{g} = 10 \pm 2 cm / s^2$. At smooth reduction of speed ω of rotation of a rotor the size $\Delta\bar{g}$ also decreased, falling up to zero at $\omega = 0$. In the specified in figure measurements both rotors rotated in one direction and the maximal full moment of rotation of rotors was equaled $J_\Sigma \approx 0.2 kg \times m^2 / s$. At rotation of rotors in counter directions when $J_\Sigma \approx 0$, small reduction of size $\bar{g}$ was observed.

The reason of an appreciable divergence of the measured absolute value of acceleration $\bar{g}$ of a gravity at $\omega = 0$ (about 990 cm / s^2) and standard, at latitude of Saint Petersburg (about 982 cm / s^2), apparently, are discrepancies in display of scale l , errors of absolute value of frequency F of the generator and also the small local (technical) changes of g . Geographical orientation of a vector of the moment of rotation of a rotor, N-S or W-O, did not influence on results of measurements $\Delta\overline{g}$. Daily dependence of size $\Delta\overline{g}$ also it was not observed.

At horizontal orientation of an axis of rotation of a rotor the each of its particles simultaneously participates in two linear oscillation in horizontal and vertical planes.

Thus of acceleration of particles at their vertical oscillations by an infinite set of derivatives on time from linear displacement are described. As it was marked in [4,5] in these conditions it is possible to expect display of "nonclassical" properties of gravitation which mentioned some more D.Mendeleev [6].

Free falling of masse oscillated along a vertical physically essentially differs from circular (orbital) movement of such masse. Therefore the result received by us does not contradict the results of exact measurements of precession a gyroscope in a circumterraneous orbit.

The further experimental researches of free falling rotating (or oscillated in a vertical plane) masses with application of precision, for example, interferometrical measuring engineering, will promote the deeper understanding of the difficult phenomena of gravitation and inertia.

References

1. J. E. Faller et al., Phys. Rev. Lett. **64**, 825, (1990); T. J. Quinn and A. Picard, Nature (London), **343**, 732 (1990); J. M. Nitschke and P. A. Wilmarth, Phys. Rev. Lett. **64**, 2115 (1990).
2. J. Luo et al., Phys. Rev. D, **65,** 042005 (2002).
3. A. L. Dmitriev and V. S. Snegov, Measuring Techniques, **44**, 831 (2001).
4. A. L. Dmitriev, E. M. Nikushchenko, V. S. Snegov, Measurement Techniques, **46**, 115 (2003).
5. A. L. Dmitriev, AIP Conf. Proc. **969**, 1163 (2008).
6. D. I. Mendeleev, Works, **22**, AN SSSR (1950) (in Russian).

№14

AIP Conference Proc. SPESIF-2009, Vol. 1103, pp 345 – 351 (2009)

Analogue of Lenz's rule in phenomenological gravitation

Alexander L. Dmitriev

St-Petersburg State University of Information Technologies, Mechanics and Optics 49, Kronverksky Prospect St-Petersburg, 197101, Russia
+7.812.3154071, dalexl@rol.ru

Abstract. Analogies of the various physical phenomena for a long time are contributed to their understanding and progress of physical science. The basis of modern theories of gravitation is the equivalence principle, experimentally confirmed in experiments with slowly moving bodies. However, the physical situation changes in case of big accelerations of the bodies caused by external non-gravitational forces. Similarly to Lenz's rule, the force G of gravitation changes proportionally to value F of external force. Thus the sign of increment ΔG is opposite to sign F, and the values of increments depend on orientation of vectors G and F. A consequence of it, for example, is the dependence of weight of a rotor of a mechanical gyroscope with a horizontal axis on angular speed of rotation, and also the temperature dependence of weight of bodies according to analysis of thermal movement of micro-particles. The gravitational analogy of Lenz's rule, on the basis of a Mach' principle, naturally explains proportionality of inertial and gravitational mass. The laboratory experiments confirming the above-stated ideas are briefly considered. Some astrophysical consequences of temperature dependence of force of the gravitation, agreed with observations are given. Opportunities of creation of new principles of propulsion by using the gravitational analogue of Lenz's rule are considered.

Keywords: Gravitation, Acceleration, Temperature, Weight, Inertial Mass, Mach' Principle
PACS: 04.20.Cv, 04.80.-y

INTRODUCTION

As it is known, the general theory of relativity (GR) is based on the thesis of equivalence of forces of gravitation and inertia, which are characteristic for accelerated moving readout systems. The experimental basis proving the correctness of such a «principle of equivalence» is thought to be the experiments of Eotvos and others which had confirmed the direct proportionality of inertial and gravity mass (Chen and Cook, 1993). The accelerated (not inertial) readout systems are physically realized as a result of electromagnetic forces action on massive bodies of electromagnetic nature, for example, of elastic forces causing acceleration or braking of a body. Therefore, the principle of equivalence actually contains the idea of the single nature, or strict interrelation of gravitational and electromagnetic forces in its phenomenological representation. But does the classical GR characterize such an interrelation full enough?

Practically in all experiments for check- up of the proportionality of inertial and gravity mass, the accelerations of test bodies under action of external, not gravitational forces, were smallest, much smaller than a normal acceleration of gravity g_0 . Obviously, the check-up of validity of the principle of equivalence at big accelerations of test bodies is natural and necessary. The analysis of the general physical situation is convenient at first stage for executing with use of simple electrodynamic analogies (Dmitriev, 2001). Thus, the basic thesis of GR - «acceleration produces the gravitation» is preserved.

Let the test body be placed in the homogeneous gravitational field of the Earth characterized by normal acceleration of gravity g_0 , Figure 1. If under the action of an external, not gravitational force, for example, elastic (electromagnetic in nature) force, the body with acceleration a moves downwards, then an increment Δg_p of acceleration of the gravity, similar to counteraction forces in the Faraday law of induction with account for Lenz's rule, is equal to

$$\Delta \vec{g}_p = -\alpha_p \vec{a} \quad . \tag{1}$$

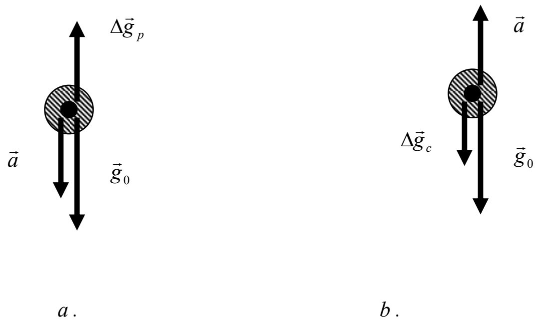


FIGURE 1.(a) Changes in gravity force acceleration acting on test body while body is falling down with acceleration and (b) Changes in gravity force acceleration while body is moving up with acceleration.

At the accelerated upward movement of a body, the corresponding increment of acceleration of gravity Δg_c changes sign and, generally speaking, value:

$$\Delta\vec{g}_c = -\alpha_c\vec{a}\ . \qquad (2)$$

In equations (1) and (2) the dimensionless factors α_c and α_p characterize a degree of influence of acceleration of external forces on the force of gravitation or, actually, a degree of interaction of gravitational and electromagnetic forces. The inequality of these factors to zero displays the general property of stable, "equilibrium" physical systems - their conservatism, a tendency to keep a stable state for a long time. On the other hand, the inequality of α_c and α_p values to each other characterizes the specific nature of gravitational fields - absence (in contrast to electrodynamics) of gravitational field sources of opposite “charge”.

MECHANICAL EXPERIMENTS

The results of the first experiments on approximate measuring of factors α_c and α_p were published at the beginning of the second millennium and reported at conferences "GRG-18" and "STAIF-2008" (Dmitriev and Snegov, 2001; Dmitriev, 2002; Dmitriev, 2005 2007 and 2008a). In particular, the dependence of weight W of a mechanical rotor with a horizontal axis on the angular speed of rotation ω ,

$$W = mg_0\left[1-(\alpha_p-\alpha_c)\frac{2(R_2{}^3-R_1{}^3)}{3\pi g_0(R_2{}^2-R_1{}^2)}\omega^2\right] , \qquad (3)$$

(m - mass of a rotor, R_1 , R_2 - external and internal radiuses of a cylindrical rotor) such a dependence allows to estimate a difference of factors $(\alpha_p-\alpha_c)\approx 10^{-7}$. The inequality of coefficient of restoration in horizontal and vertical quasi-elastic impacts of a ball on a plate surface, causing acceleration $|\vec{a}|$ of a sphere exceeds $3\cdot 10^4 g_0$ allows to rough estimate the order of value for factor $\alpha_c \approx 10^{-2}$.

The most precise measurements of weight of rotors with vertical axis have shown zero result (Quinn and Picard, 1990; Faller *et. al*., 1990; Nitschke and Wilmarth, 1990). Only in experiments of Nitschke the weight of a rotor with a horizontal axis was measured, in so doing the size of relative reduction of weight of a rotor was close to our results. Comparatively big error of those measurements is probably connected with poor quality of rotor: in Nitschke's experiments the turn-time of rotor is about 5 minutes, and in our experiments - 14 minutes.

TEMPERATURE DEPENDENCE OF WEIGHT

The important consequence of difference in values of factors α_c and α_p is a physical negative temperature dependence of a body weight (Dmitriev, Nikushchenko and Snegov, 2003; Dmitriev, 2005, 2006b and 2007). Thus, the influence of acceleration on gravitation is caused by the chaotic accelerated thermal movement of micro-particles of a body. It is possible to show that in classical approximation at absolute body temperature T higher than Debye temperatures, the temperature dependence of weight W of a body is described by equation (4)

$$W = mg_0\left[1 - \frac{(\alpha_p - \alpha_c)}{\pi g_0}C\sqrt{T}\right] , \qquad (4)$$

where C - the factor dependent on density ρ and elastic properties of a body material for the case of solid bodies

$$C \propto v/\sqrt{\rho} , \qquad (5)$$

where v – the speed of elastic longitudinal waves. In fact, at weighing the non-magnetic metal samples heated up with ultrasound, the reduction of apparent mass of samples is observed.

For light elastic materials (duralumin, titan) the experimental values of factors C are higher than for heavy and viscous metals (lead, brass) which agrees with equation (5).

If the test body is an anisotropic crystal at constant temperature, but having various speeds v_1 , v_2 of longitudinal sound waves along orthogonal directions 1, 2, then, according to equations (4) and (5), the weight of such a crystal measured at different positions of axes of crystals 1, 2 relative to the perpendicular will be, strictly speaking, different. Such a difference in weight of a rutile crystal with relative value near $7 \cdot 10^{-8}$ was observed in experiments (Dmitriev and Chesnokov, 2004).

Let's note that temperature dependence of weight of bodies and its connection to physical characteristics of material C at first sight really contradicts the equivalence principle: the values of factors C for different bodies (as seen by equation 4) are included into expression for the full angular moment of rotation of torsion balance beam in experiments of Eotvos and Dicke (see; Chen and Cook, 1993). This question demands a special careful analysis with account for all conditions of experiments, including the influence of temperature not only on force of gravitation, but also on the size (for example, length) of the beam, and directly influencing the value of the angular moment. It is necessary to take into account that temperature-induced change of force of gravitation does not mean yet temperature change of gravitational mass.

Temperature dependence of weight of bodies indicates that a "weak" equivalence principle in the usual (“technical”) formulation, strictly speaking, is not realized: one and the same body at different temperatures falls with different accelerations. It is remarkable that experimental researches of temperature dependence of gravity had been carried out in the 20ies of the last century and negative temperature dependence of weight of bodies was actually registered in experiments of Shaw and Davy (1923). Unfortunately, probably owing to growth of authority of GR which rejected observable temperature dependence of weight of bodies, these authors have doubted their results, and up to the end of the 90ies the exact experimental measurements of the major temperature dependence of weight of bodies were not made.

The temperature correction to the Newtons’ law of gravitation in classical approximation can be described as temperature dependence of “gravitational constant”

$$G = G_0(1 - a_1\sqrt{T_1})(1 - a_2\sqrt{T_2}) \quad , \qquad (6)$$

where G_0 - a constant, T_1, T_2 - absolute temperatures of interacting masses, a_1, a_2 - average effective values of temperature factors (Dmitriev, 2005 and 2007).

Such temperature dependence of the gravitational constant can cause a wide scatter of experimental values of *G* (Dmitriev, 2006a) . The researches into temperature dependence of force of gravitation until recently were not given due enough attention (Luo and Hu, 2000; Gilles, 1997) and the time has now come for careful studying of the given problem.

THE GRAVITATION NATURE OF INERTIAL MASS

It is necessary to note that the above-described experiments, confirming nonzero values of factors α_c and α_p, do not contradict the idea of direct proportionality of inertial and gravity masses, and just point to the non-trivial character of interrelation of these masses. It is possible to show it, having considered relations 3, 4 in connection with Mach principle according to which inertial properties of a body are caused by its gravitational interaction with all surrounding bodies, Fig. 2 (Dmitriev, 2008b).

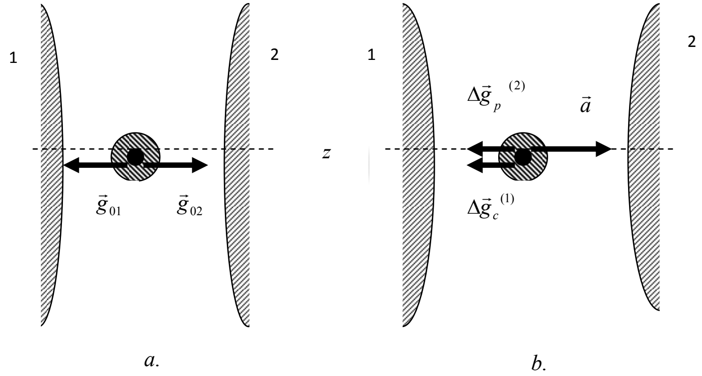


FIGURE 2. Test body in counterbalanced state (a); increments in gravity force acceleration under effect of outside non-gravitational force (b).

Let’s assume that in conditional-inertial system of coordinates related to “infinitely remote” masses, a test body with gravitational mass m_g is stationary or moving with constant speed in the initial state (Fig. 2a). In isotropic space along a randomly chosen axis z, the resultant force of gravitational forces acting on the body from the side of remote masses 1, 2 located on different sides of the body is equal to zero. In so doing, the accelerations corresponding to those forces which are the sum of projections on axis z of gravity forces accelerations created by such masses are equal in magnitude $|\vec{g}_{01}| = |\vec{g}_{02}|$. If there is an external non-gravitational force $\vec{F}$ acting on the body along the indicated direction, then, according to the second law of dynamics, the corresponding acceleration $\vec{a}$ of the body is equal to

$$\vec{a} = \vec{F} / m_i, \qquad (7)$$

where m_i - body inertial mass. Such an acceleration, according to

(1, 2), causes changes $\Delta\vec{g}_c^{(1)}$ and $\Delta\vec{g}_p^{(2)}$ of gravity force accelerations acting on the test body from the side of remote masses 1, 2, with directions of vectors $\Delta\vec{g}_c^{(1)}$ and $\Delta\vec{g}_p^{(2)}$ coinciding Fig. 2b.
According to the third law of dynamics the resultant force of the forces applied to the body is equal to zero,

$$m_g(\vec{g}_{01} + \Delta\vec{g}_c^{(1)}) + m_g(\vec{g}_{02} + \Delta\vec{g}_p^{(2)}) + m_i\vec{a} = 0 . \qquad (8)$$

Whence the inertial mass of

$$m_i = (\alpha_p + \alpha_c)m_g . \qquad (9)$$

Equation (11) explains the physical sense of inertial mass: body inertial mass is caused by interaction of gravitational and electromagnetic forces applied to the body, proportional to its gravitational mass and determined by magnitudes of factors α_p, α_c which characterize the degree of such an interaction. If the interaction of gravitational and electromagnetic forces were nonexistent, that is with $\alpha_c = \alpha_p = 0$, the body inertial mass would be equal to zero as well. Such an assumption directly agrees with Mach principle according to which inertia of matter is determined by masses surrounding it. On the other hand, proportionality of gravitational and inertial masses is proved by numerous experiments and agrees with corpuscular model of matter: an increase in number of particles making up test body proportionally increases both inertial and gravitational masses. Mass ratio m_i / m_g is determined by magnitudes of factors α_p, α_c which might be constants; this expression can be equated to one by choosing corresponding magnitude of gravitational constant.

ASTROPHYSICAL APPLICATIONS

The negative temperature dependence of weight of bodies is of great importance for metrology, gravimetry and can play an appreciable role in interpretation of some phenomena of astrophysics (Dmitriev, 2005 and 2006b). So the known significant divergence of experimental values of the gravitational constant can be explained as a discrepancy of absolute temperatures of the test bodies used in such experiments. The relative change of the measured values of the gravitational constant is represented by the equation

$$\frac{\Delta G}{G} = -\frac{a\Delta T}{\sqrt{T}} \qquad (10)$$

here we assume the test mass to be made of one material ($a_1 = a_2 = a$), their average temperatures to be identical $(T_1 = T_2 = T)$ and ΔT change of temperature of test mass. For example, at $a = 5 \cdot 10^{-4} K^{-1/2}$, $T = 293$ and $\Delta T = 5K$ the relative temperature shift of measured values of the gravitational constant is equal to $1.5 \cdot 10^{-4}$, that is close to modern scattering of experimental values of G (Dmitriev, 2006a).

The precession of perihelion of planets to some degree can be caused by slow change of average temperature of the Sun. At low values of eccentricity e of orbits ($e \prec\prec 1$), the angular displasement $\delta\varphi$ of perihelium for one full revolution of a planet is approximately eqal to

$$\delta\varphi \approx \frac{\pi P}{4(1-e^2)} \frac{a_1}{\sqrt{T_1}} \frac{dT_1}{dt} \quad , \qquad (11)$$

where P - a period a planet, T_1 - its average absolute temperature, a_1 - temperature factor, t - time (temperature of the Sun is assumed to be a constant) (Dmitriev, 2005).

The known reduction of the period of a double pulsar can also be connected to reduction of average temperatures T_1 , T_2 of the stars which are included in such double system. Relative change of period P of the pulsar, caused by changes ΔT_1 and ΔT_2 of stars temperatures is equal to

$$\frac{\Delta P}{P} \approx \frac{1}{4}\left(\frac{a_1 \Delta T_1}{\sqrt{T_1}} + \frac{a_2 \Delta T_2}{\sqrt{T_2}} \right) \qquad (12)$$

According to equation (12), slow cooling of stars caused, for example, by radiant heat exchange on their surfaces causes reduction of the period of a double pulsar.

Temperature dependence of the gravity can appear useful in the analysis of difficult processes of movement of plasma (solar wind) in vicinities of the Sun whose temperature achieves one million K (Hundhausen, 1972).

Taking into account the negative temperature dependence of force of gravitation, the general astrophysical picture of development of a gravitational collapse can be supplemented with appreciable corrective amendments: due to a decrease of gravitational forces with growth of temperature of collapsed mass, the opportunity of achievement of a singularity point condition («black hole») becomes doubtful. Such collapse should demonstrate the monotonous character without formation of singularity, or to be accompanied by fading periodic changes of temperature and luminosity of collapsed mass, owing to consecutive phases of compression (heating) and expansions (cooling) of such environment.

At last, temperature dependence of force of gravitation of equation (6) can be cause of the known flyby anomaly: slow reduction of average temperature of a space vehicle increases the force of its attraction to the Sun.

The mentioned above examples do not mean a denial of the known theories explaining the listed astrophysical phenomena (including GR), and only show a necessity of taking into account the influence of temperature on force of gravitation in the analysis of difficult astrophysical processes.

AT PROBLEM OF PROPULSION

The careful experimental searches into the character of influence of a body’s accelerations, caused by external electromagnetic forces, on forces of gravitation should be of great importance for search of new principles of bodies’ movement. The first stage of such researches should be high-precision measurements of interaction factors α_c and α_p in equations (1) and (2) made in the process of both the analysis of the centrifugal and impact phenomena and in the course of measurements of physical temperature dependence of bodies weight. Of special interest are the measurements of forces of gravitational interaction at low temperatures during which the anomalies of these interactions should be especially appreciable. Today, it is still difficult to present a realistic breadboard model of propulsion-system of a new type based on the above-stated principles. Probably, the appreciable integrated effect of movement will be achieved in case of a joint electromagnetic and mechanical influence (for example, by means of a hypersound) on a massive body.

In any case, the detailed researches of influence of acceleration and temperatures on the gravitation, executed with the samples of materials of various physical and chemical structures, should precede such attempts of modelling the new principles of movement. Historical analogies to development of quantum electronics, the beginning of which is connected to producing and laboratory analysis of rather weak maser and laser signals, and the mature period - with development of high-power generators of light, can be a stimulus in support of a new direction in experimental physics of gravitation. It is possible that the old idea of Brillouin about creation of a gravitational analogue of the laser - "graser" will become a reality in the future.

CONCLUSION

We shall note that research into the features of gravitational interactions with use of electrodynamic and optical analogies (Lenz's rule, laser effect and others) certainly does not set as the purpose an intention to deny known geometrical and field theories of gravitation, including GR. The question is expansion and specification of existing models of gravitation, which have already positively distinguished them in describing the real processes. The gravitational nature of inertial mass does not contradict the principles of classical mechanics supplemented by concept of interaction of gravitational and electromagnetic forces (in particular, elastic forces). Experimental and theoretical investigations of gravity force acceleration “induction” caused by accelerated motion of the body under effect of external non-gravitational forces will contribute to development of physics of gravitation and its applications.

NOMENCLATURE

$|\vec{a}|$ = value of acceleration vector of external elastic forces ($m \cdot s^{-2}$)

α_p = degree of interaction of elastic and gravitational forces by passing directions of $\vec{a}$ and $\vec{g}_0$

α_c = degree of interaction of elastic and gravitational forces by counter directions of $\vec{a}$ and $\vec{g}_0$

C = coefficient dependent on physical characteristic of bodies ($m \cdot s^{-2} \cdot K^{-1/2}$)

e = eccentricity

F = force (N)

$\delta\varphi$ = angular displacement of perihelion (rad)

G = gravitational constant ($N \cdot m^2 \cdot kg^{-2}$)

g = acceleration of gravity ($m \cdot s^{-2}$)

m_i = inertial mass (kg)

m_g = gravitational mass (kg)

v = speed of elastic longitudinal waves ($m \cdot s^{-1}$)

P = period (s)

ρ = density ($kg \cdot m^{-3}$)

T = temperature (K)

W = weight of a body (N)

ω = angular speed of rotation ($rad \cdot s^{-1}$)

a, a_1, a_2 = temperature factor for the temperature dependence of weight of a body ($K^{-1/2}$)

Δg_p, Δg_c = increments of acceleration of the gravity (value of vectors, $m \cdot s^{-2}$)

M, m = mass of body (kg)

R_1, R_2 = internal and external radiuses of cylinder (m)

REFERENCES

Chen, Y. T., and Cook, A., *Gravitational Experiments in the Laboratory,* Cambridge University Press, Cambridge, (1993). Dmitriev, A. L., "On the Influence of External Elastic (Electromagnetic) Forces on the Gravity," *Russian Physics Journal,* **44**(12), (2001), pp. 1323-1327.

Dmitriev, A. L., and Snegov V. S., "Weighing of the Mechanical Gyros with Horizontal and Vertical Orientations of Axis of Rotation," *Izmeritelnaja Tekhnika* (in Russian), **8**, (2001), pp. 33 – 35.

Dmitriev, A. L., "Inequality of the Coefficients of Restitution for Vertical and Horizontal Quasielastic Impacts of a Ball Against a Massive Plate," International *Applied Mechanics*, **38**(6), (2002), pp. 747 – 749.

Dmitriev, A. L., Nikushchenko, E. M., and Snegov, V. S., "Influence of the Temperature of a Body on its Weight," *Measurement Techniques*, **46**(2), (2003), pp. 115 – 120.

Dmitriev, A. L., and Chesnokov, N. N., "Influence of Orientation of Anisotropic Crystal on its Weight," *Izmeritelnaja Tekhnika* (in Russian), **9**, (2004), pp. 36 – 37.

Dmitriev, A. L., *Upravljaemaja Gravitacija* (in Russian), Novy Centr, Moscow, (2005).

Dmitriev, A. L., "On Possible Causes of Divergence in Experimental Values of Gravitation Constant," http://arxiv.org/ftp/ physics/papers/0610/0610282.pdf, (2006a).

Dmitriev, A. L., "Temperature Dependence of Gravitational Force: Experiments, Astrophysics, Perspectives," http://arxiv.org/ftp/ physics/papers/0611/0611173.pdf, (2006b).

Dmitriev, A. L., "Experimental Study of Gravity Force Temperature Dependence," in *18th International Conference on General Relativity and Gravitation (GRG-18),* Sydney, Abstract Book, (2007), pp. 77-78.

Dmitriev, A. L., "Measurements of the Influence of Acceleration and Temperature of Bodies on their Weight," in proceedings of *Space Technology and Application International Forum (STAIF-08),* edited by M. El-Genk, AIP Conference Proceedings **969**, New York, (2008a), pp. 1163-1169.

Dmitriev, A. L., "On the Nature of Inertial Mass," http://arxiv.org/ftp/arxiv/papers/0806/0806.0796.pdf, (2008b).

Faller, J. E., Hollander, W. J., Nelson P. G. and McHug M. P., “Gyroscope-Weighing Experiment with Null Result,” *Phys. Rev. Lett.* **64**, (1990), pp. 825-826.

Gilles, G. T., “The Newtonian gravitational constant: recent measurements and related studies,” *Rep. Prog. Phys.,* **60**, (1997), pp. 151-225.

Hundhausen, A. J., *Coronal Expansion and Solar Wind*, Springer-Verlag, Heidelberg-New York, (1972).

Luo, J. and Hu, Zhon-Kun, “Status of measurement of the Newtonian gravitational constant G,” *Class. Quantum Grav.*, **17**, 2351-2363 (2000).

Nitschke, J. M. and Wilmarth, P. A., “Null results for the weight change of a spinning gyroscope,” *Phys. Rev. Lett.*, **64**, (1990), pp. 2115-2116.

Quinn, T. J. and Picard, A., “The mass of spinning rotors: no dependence on speed or sense of rotation,” *Nature*, **343**, (1990), pp. 732-735.

Shaw, P. E. and Davy, N., “The Effect of Temperature on Gravitative Attraction,” *Phys. Rev.*, **21**(6), (1923), pp. 680 – 691.

№15

AIP Conference Proc., Vol. 1208, pp 237 – 246 (2010)

Dynamic Weighing Experiments - the Way to New Physics of Gravitation

A. L. Dmitriev, E. M. Nikushchenko, S. A. Bulgakova

St-Petersburg State University of Information
Technologies, Mechanics and Optics
49, Kronverksky Prospect, St-Petersburg, 197101, Russia
Tel/Fax+7.812.3154071, alex@dmitriyev.ru

Abstract. Dynamic weighing is a measuring of size of the average gravity force acting on a test body which is in the state of accelerated movement. The acceleration of a body, or its microparticles, can be caused both by forces of gravitation, and by a direct, electromagnetic in nature, influence on the part of other bodies. It is just dynamic weighing of bodies which is informative in studying the features of electromagnetic and gravitational forces interaction. The report gives a brief review of results of experiments with weighing of accelerated moving bodies – in case of shock phenomena, in state of rotation, and in heating. Special attention is given to measurements of free fall accelerations of a mechanical rotor. In majority of the laboratory experiments executed with the purpose of checking the equivalence principle, the axis of a rotor was oriented verticallly. In our experiment we measured the free fall accelerations of the closed container inside which a mechanical rotor (gyroscope) with a horizontal axis of rotation was installed. There was observed an appreciable, essentially exceeding errors of measurements increase of acceleration of free falling of the container at angular speed of rotation of a rotor up to 20 000 rev/min. The physical conditions of free vertical falling of a body essentially differ from conditions of rotary (orbital) movement of a body in the field of gravity and the result obtained by us does not contradict the results of measurements of a gyroscope precession on satellites. Experiments with dynamic weighing of bodies give useful information on complex properties of the gravity force which are beyond the scope of well-known theories. Their careful analysis will allow to expand and supplement the concepts based on the general theory of relativity, and probably to open a way to new physics of gravitation and to new principles of movement.

Keywords: Gravity Force, Weighing, Acceleration, Free Falling, Gyro, Equivalence Principle .
PACS: 04.80.Cc, 04.80.-y.

INTRODUCTION

Though physics is an experimental science, in modern physics of gravitation the scale of theoretical researches has considerably surpassed the scale of experiments. In a solid, over 600 pages, recently published review «100 Years of Gravity and Accelerated Frames » the experimental (and besides - astrophysical) tests of gravitational theories are given less than 30 pages (Hsu and Fine, 2005). Attempts to establish some new properties of gravitation in laboratory experiments, from the point of view of classical GR, are usually considered as unpromising. Meanwhile, the grounds for criticism of experimental basis of GR – equivalency principle – do exist. Thus, in all Eotvos-experiments the measurements of forces of gravitation were made in the extremely limited physical conditions, at constant temperature and small accelerations of test bodies (Chen and Cook, 1993, Haugan and Lammerzahl, 2001). The approximation of appropriate GR results in the area of high accelerations of bodies, strictly speaking, is incorrect. The interrelation of the external accelerations, for example, of elastic forces applied to a test body, and force of gravitation acting on this body, follows from the deep unity of electromagnetic and gravitational interactions and, according to the phenomenological description, can be considered as gravitational analogue of Faraday' law of induction and Lentz' rules (Dmitriev, 2001, 2009a). The search for non-classical effects in gravitation in experiments with precision weighing of accelerated moving bodies (oscillating, rotating, being heated up etc.) is logical and expedient. Yet D.I.Mendeleev pointed out: « If it is possible to achieve something in understanding of gravitation and weight, then in no other way and most likely by the most precise weighings and observations of oscillations taking place at that time» (Mendeleev, 1950).

There are distinguished two ways of exact weighing of bodies: static and dynamic. In static weighing the test body is motionless relative to the Earth and weight of the body is determined by the size of elastic or electromagnetic force compensating the gravity; this technique directly corresponds to definition of concept « weight of a body ». In dynamic weighing the beam of weights and a test body make slowly fading oscillations, and average value of the weight measured is determined by elongations'method, by fixing and averaging some extreme values of readings displayed on the scale of weights; in that case the test body experiences some well marked accelerations, which are described by an infinite set of time derivatives from body displacement. Obviously, the physical conditions of dynamic and static weighings essentially differ, though in practical metrology of weight the results of both techniques of weighing are often believed to be identical. Just dynamic weighing is informative in researches into interrelation of gravitational and electromagnetic (elastic) forces.

Of special interest are the measurements of acceleration of free falling of the test bodies underlying the ballistic methods of gravimetry. At free falling a body the interaction of gravitational and foreign forces, by definition, is excluded, but this ideal state is achieved only under condition of absence of own oscillatory or rotary movement of a test body.

Preconditions of search of interaction of electromagnetic and gravitational forces are the results of various Gravity Electro-Magnetism theories which are based on modified GR'equations (Bini et al., 2008, Schmid, 2009). Though the observable effects predicted in such theories are usually extremely small, some worthy positive results were received in some laboratory experiments (Tajmar et al., 2008, Woodward, 2009).

The interrelation of gravitational and electromagnetic forces is especially important in the analysis of properties and reasons of inertia, propulsions' problems, and search for new principles of movement. Correctly executed gravitational laboratory experiment can and should be the basis for formulations of new concepts in gravitation including, supplementing and developing the known GR approaches.

ACCELERATION OF EXTERNAL FORCES, GRAVITY AND INERTIAL MASS OF A BODY

In distinction from "geometrical", the "field" concept of gravitation describes the gravitational interaction of bodies similarly to other kinds of physical interactions - electric and magnetic. Thus the concept of the "material" gravitational field related to sources - the gravitational mass - and characterized by the set of parameters (potential, velocity, impulse, moment) is considered. The advantage of the field, basically phenomenological concept of gravitation consists in an opportunity to use for its development some separate analogies of the gravitational and electromagnetic phenomena, and in their direct experimental check. Thus, gravitational fields, certainly, should have the properties similar, but not identical to properties of electromagnetic fields.

In (Dmitriev, 2001) on the basis of the noted analogies the assumption of original reaction of the gravity force acting on a test body, on its acceleration $\vec{a}$ caused by action of external not gravitational (for example, elastic) forces is put forward. Change $\Delta\vec{g}_{p,c}$ of acceleration of the gravity, similar to the phenomenon of Faraday's induction law in view of Lenz' rule, at simple linear approximation, is equal to

$$\Delta\vec{g}_{p,c} = -\alpha_{p,c}\vec{a} \quad , \qquad (1)$$

where indexes p,c indicate mutual, passing (p) or a contrary (opposite) (c), orientation of a vector $\vec{g}_0$ of normal acceleration of a gravity and vector $\vec{a}$ of acceleration of external force, Figure 1.

a.

b.

FIGURE 1. a. Changes $\Delta\vec{g}_p$ in gravity force acceleration acting on test body while body is falling down with acceleration $\vec{a}$.

b. Changes $\Delta\vec{g}_c$ in gravity force acceleration while body is moving up with acceleration $\vec{a}$.

Rough estimations of the order of value of dimensionless factors α_p and α_c, which the gravitational interrelation of gravitational and electromagnetic fields specify, were executed in mechanical experiments with weighing of two coupled mechanical rotors with the zero full moment, with a horizontal axis of rotation, and in the analysis of the shock phenomena (Dmitriev, 2002). For metal not magnetic test bodies it is $\alpha_c \approx 10^{-2}$, $(\alpha_p - \alpha_c) \approx 10^{-7}$. By consideration of thermal chaotic movement of microparticles of solid bodies the consequence 1, in view of an inequality $\alpha_p \succ \alpha_c$, is the negative temperature dependence of gravity, also observed in the experiment (Dmitriev, Nikushchenko and Snegov, 2003, Dmitriev. 2008). Measurements of anisotropy of weight of a crystal with a big spatial difference of speeds of longitudinal acoustic waves also specify to nonzero value of a difference $(\alpha_p - \alpha_c)$ (Dmitriev and Chesnokov, 2004).

Definition of factors α_p and α_c of electromagnetic (elastic) and gravitational forces interaction has allowed to give a simple physical interpretation to inertial mass of a body. In (Dmitriev, 2008b, 2009b) in the description of balance of the elastic (electromagnetic) and gravitational forces acting on the test mass on the part of remote mass (for example, stars), according to idea of E. Mach about the gravitational nature of inertial forces, the ratio between inertial (m_i) and gravitational (m_g) masses is obtained,

$$m_i = m_g(\alpha_p + \alpha_c)\,. \qquad (2)$$

Equation 2 shows the direct proportionality of inertial and gravity masses of a body, and the relation of theses masses, contrary to the known postulate of "geometrical" model of gravitation, generally speaking, is not a constant.

Equation 1 shows the relation of change of gravity acceleration with acceleration $\vec{a}$ of external forces, but in so doing it is necessary to take into account that the absolute size $\Delta g_{p,c}$ of an increment of acceleration should also depend on magnitude g_0 of normal gravity acceleration. Generally, in view of influence of forces of the gravitation caused by remote surrounding masses (stars), in movement of a test body on a vertical there should be carried out the equation

$$\alpha_{p,c} = A_{p,c}(g_0 + g'), \tag{3}$$

where g' - a projection of acceleration of forces of gravitation on the part of the remote masses located in a solid angle 2π, on the direction of the accelerated movement of body. Here the dimensional factors $A_{p,c}$ are universal and characterize the action on a test body of not only the gravitational field of the Earth, but also the fields of the gravitation created in all surrounding masses.

The resultant forces of gravitation acting on the motionless or moving with the constant speed test body from direction of remote masses, uniformly distributed in space in a full solid angle 4π, it is approximately equal to zero, while the magnitude g' determines the inertial properties of a body, Figure 2.

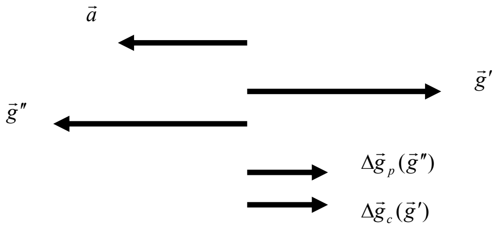


FIGURE 2. Mutual orientation of a vector of acceleration of not gravitational forces $\vec{a}$ and increments vectors $\Delta\vec{g}_p, \Delta\vec{g}_c$ of accelerations of the gravitation forces acting on test mass from the direction of remote masses (stars). The resulting accelerations ' vectors $\vec{g}'$ and $\vec{g}''$, caused by action of the remote masses located in the left and the right half-spaces in the solid angles 2π, are equal in magnitude and are oppositely directed.

Expressions 2,3 are in agreement with the principle of Mach according to which the inertial properties of bodies are determined by action on them of forces of the gravitation created by all surrounding masses, including rather remote ones.

INERTIAL MASS ANISOTROPY

As is known, GR excludes the practical observability of anisotropy of inertia (Hughes, 1960). Consequence of 2,3 is an appreciable difference of inertial mass of a test body at its accelerated movement relative to the

Earth in horizontal and vertical directions (Dmitriev, 2009b). Let's show it on an example of harmonious oscillator.

For the harmonious, caused by the action of external elastic force, oscillatory movement along a vertical, the average, for the period of oscillation, inertial mass $\hat{m}_i$ of a test body is equal to

$$\hat{m}_i = m_g(A_p + A_c)(\frac{g_0}{2} + g') . \qquad (4)$$

In oscillatory movement of this test body along the horizontal, its average inertial mass $\overline{m}_i$ is equal to

$$\overline{m}_i = m_g(A_p + A_c)g' \quad . \qquad (5)$$

In 4.5, the resulting magnitude g' of projections of accelerations of gravity forces created by the remote masses in a solid angle 2π, is believed approximately constant and independent from the direction in space. The relative difference of "vertical" and "horizontal" inertial masses, taking $g' \succ\succ g_0$, is equal to

$$2\frac{\hat{m}_i - \overline{m}_i}{\hat{m}_i + \overline{m}_i} \approx \frac{g_0}{2g'} \quad . \qquad (6)$$

Experimental estimations of magnitude of inertial mass' anisotropy of a body can be made, comparing the periods of oscillations of linear mechanical oscillator with vertical and horizontal orientations of its axis. For the same purpose it is convenient to use the rotation oscillator, for example a pendulum of high-quality mechanical balance watch, by changing orientation of the balance axis.

The period T of free oscillations of system a balance - spiral of mechanical watch is equal to

$$T = 2\pi\sqrt{\frac{I}{C}} \quad , \qquad (7)$$

where I - the moment of inertia of balance ($I \propto m_i$) and C - factor of elasticity of the spiral.

According to 6,7, the period $\hat{T}$ of oscillations of balance in a vertical plane should be more than the period $\overline{T}$ of oscillations of balance moving in a horizontal plane, that is the ideal mechanical watch in position « on an edge » goes more slowly, than in position "flatwise".

The position-sensitivity of mechanical watch is influenced many factors, including, the moment of inertia and quality of a spiral, conformity of an axis of rotation and the centre of inertia of a pendulum, friction in axes of a suspension bracket of a pendulum etc (Paramonov, 1977). With high quality of watch and its careful adjustment, the influence of the specified factors can be reduced practically to zero, and in that case the comparison of daily motion of balance watch in vertical and horizontal positions can be used for an estimation of magnitude of anisotropy of inertial masse 6.

In view of 4-7, the relative difference γ of the daily motion of an ideal watch is equal to

$$\gamma = 2\frac{\hat{T} - \overline{T}}{\hat{T} + \overline{T}} \approx \frac{1}{4}\frac{g_0}{g'} \quad . \qquad (8)$$

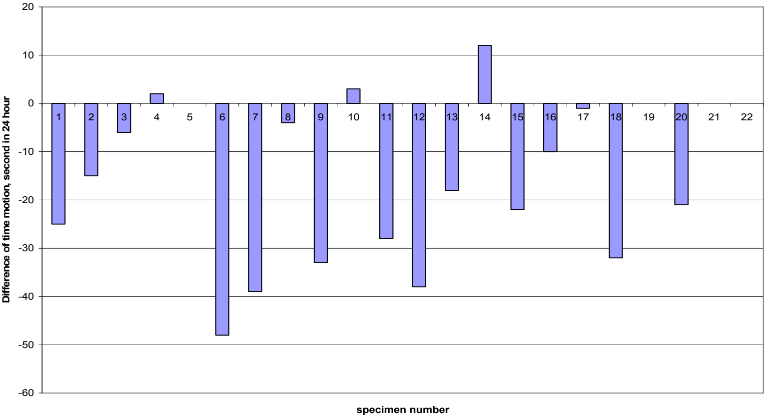


FIGURE 3. A difference of a daily motion of mechanical balance watch «Raketa 2609 » in positions "flatwise" and « on an edge ».

In Figure 3 the results of measurements of position sensitivity of twenty one samples of mechanical watch «Raketa 2609 » manufactured by “Petrodvortsovy watch factory” are given. The difference of an average daily motion of watch in positions "flatwise" and « on an edge » was measured, each of them was measured as an average for two different positions of the head and plane of a dial of watch. The average magnitude of watch motion delay in position «on an edge» has come to about 15 seconds over one day which corresponds to $\gamma \approx 1.7 \cdot 10^{-4}$.

The question of what part of the given value γ is caused by action of physical factors (anisotropy of inertial mass in a gravitational field of the Earth), and what – by technical imperfection of the mechanism of watch still remains open. The difficulty is that even with an appreciable influence on a motion of watch of anisotropy of inertial mass of the pendulum of watch, the position-dependence of a daily motion of watch can be reduced almost to zero by technical means of adjustment. Thus the "physical" delay of a watch motion can be artificially compensated by adjustment of watch which complicates an objective estimation of magnitude of such effect.

Therefore the careful analysis of all technical factors influencing the position sensitivity of balance watches and clockworks used in such experiments is necessary for obtaining of objective data. Nevertheless, the given average result is in agreement with physical preconditions noted above and can be the basis for setting up precision experiments with use of mechanical oscillators on measurements of prospective anisotropy of inertial mass.

Note, if the result shown in Figure 3 gives a true estimation of magnitude order of a relative difference of inertial mass in horizontal and vertical directions, then, according to 8, gravitational field-intensity g' created by all indefinitely remote masses located in a solid angle 2π relative to a point of observation, the said intensity is approximately one thousand times the magnitude of normal acceleration of gravity on the surface of the Earth. In view of gravitational analogue of the Faraday's induction law 1, such rather strong "interstellar" gravitational field, apparently, is also the main physical reason of inertial properties of bodies.

The precision measurements of anisotropy of inertial mass of bodies in a non-uniform gravitational field will confirm validity or an fallacy of the above estimation and as a consequence the validity of the phenomenological "field" concept of gravitation in the description of inertial properties of bodies.

FREE FALLING OF A MECHANICAL ROTOR WITH A HORIZONTAL AXIS

It is known, that weight of motionless bodies is directly determined by acceleration g_0 of free falling. For oscillating and rotating test bodies the measurement of such acceleration is not trivial. To laboratory weighings of rotors of mechanical gyroscopes the set of works (Nitschke and Wilmarth, 1990, Quinn and Picard, 1990, Faller et al., 1990) is devoted. Such measurements were usually carried out with the purpose of experimental check of a equivalence principle, or various gravitoelectric (gravitomagnetic) models. In most cases, in these experiments the axis of a rotor was oriented vertically and, as a whole, the positive effect was absent (Luo et al., 2002). In paper (Dmitriev and Snegov, 2001) the results of exact weighing of two coaxial rotors with a horizontal axis and with the zero total moment J_Σ are given, and its weights which have shown little change, dependent on angular speed of rotation of a rotor. The explanation of these results the possible precession a gyroscope is complicated, connected to rotation the Earth, which essentially could to influence indications of weights, owing to inexact performance of equality $J_\Sigma = 0$. In much smaller degree the precession effects influence on results of measurement of size of acceleration by freely falling of rotor. Thus physical conditions of interaction of a falling rotating rotor with the centre of gravitation (Earth) essentially differ from conditions of weighing of a rotor on based laboratory weights.

In described simple experiment (Dmitriev, Nikushchenko and Bulgakova, 2009) the acceleration of free falling of container with the two, located coaxially, rotors of mechanical gyroscopes placed inside it was measured Figure 4; the device and characteristics of the container are given in (Dmitriev and Snegov, 2001).

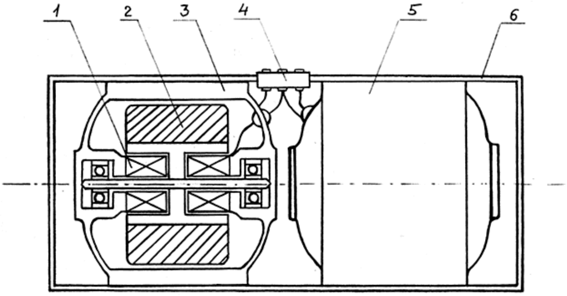
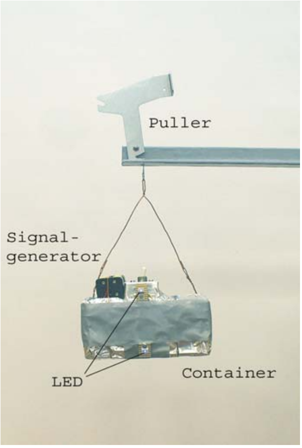


FIGURE 4. The device of the container. 1 - electric coils of the engine of a gyroscope, 2 - a massive cylindrical part of a rotor, 3 - the case of the first

gyroscope, 4 - plugs of power supplies of engines of gyroscopes, 5 - the case of the second gyroscope (it is shown without a section), 6 - the case of the container.

On the container the compact highly stable generator of pulses connected to two differ-coloured light-emitting diodes, located along a trajectory of falling of the container is fixed. Appearance of the container with the device for throwing down is shown in Figure 5.



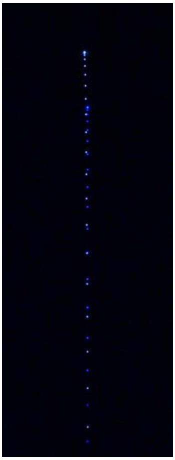


FIGURE 5. Container with the device for throwing. **FIGURE 6.** An example of the container falling trajectory photo

Distance on centre to centre of aperture stop (holes), established before light-emitting diodes is $l = 76.25mm$, frequency of impulses $F = 56.25Hz$, duration of impulse optical signals $0.13ms$. The trajectory of the falling container was photographed by the digital camera with exposure $0.6 - 0.8s$. An example of such photos is shown in Figure 6. Coordinates of marks (the centres of holes) were digitized by computer. The calculation of acceleration g of free falling container was carried out under the formula

$$g = \frac{(\Delta_2 - \Delta_1)F^2}{N^2}, \tag{9}$$

where Δ_1, Δ_2 - absolute lengths of the next sites of the trajectories, containing N marks; the scale of the image was defined by distance l between light-emitting diodes. For reduction of influence of aberration of the image owing to distorsion, the average scale of the image paid off on three readout of length l - in the top, central and bottom parts of a trajectory. The size $\bar{g}$ in separate measurement was determined as average value of acceleration, designed on two trajectories appropriate to two groups of color marks on the image.

The example of the measured values of acceleration of free falling container in conditions (1) $\omega = 0$, (2) $\omega \neq 0$ and (3) $\omega = 0$ (upon termination of time rotation of rotor) is shown in Figure 7.

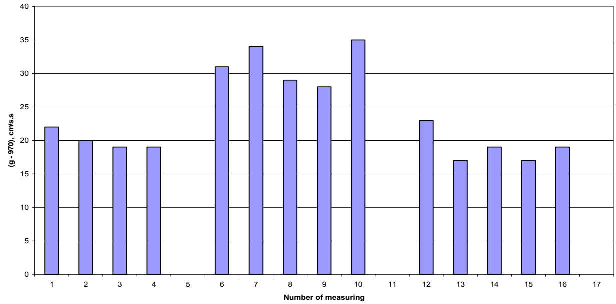


FIGURE 7. The example of the measured values of acceleration of free falling container. 1. $\omega = 0$ (N. 1-4), 2 $\omega \neq 0$ (N. 6-10), 3. $\omega = 0$ (N. 12-16).

The maximal angular velocity of rotation of a rotor $\omega \approx 20000 rpm$, rotation time of rotor is 14-15 mines, duration of one cycle of measurements from 4-5 pictures about 2 minutes.

It was processed over 200 pictures, thus the increase of acceleration of free falling of a rotor was regularly observed at transition from a condition (1) to a condition (2) with average size $\Delta\bar{g} = 10 \pm 2 cm/s^2$. At smooth reduction of speed ω of rotation of a rotor the size $\Delta\bar{g}$ also decreased, falling up to zero at $\omega = 0$. In the specified in figure measurements both rotors rotated in one direction and the maximal full moment of rotation of rotors was equaled $J_\Sigma \approx 0.2 kg \cdot m^2/s$.

The reason of an appreciable divergence of the measured absolute value of acceleration $\overline{g}$ of a gravity at $\omega = 0$ (about 990 cm / s^2) and standard, at latitude of Saint Petersburg (about 982 cm / s^2), apparently, are discrepancies in display of scale l, errors of absolute value of frequency F of the generator and also the small local (technical) changes of $\overline{g}$. Geographical orientation of a vector of the moment of rotation of a rotor, N-S or W-O, did not influence on results of measurements $\Delta\overline{g}$. Daily dependence of size $\Delta\overline{g}$ also it was not observed.

At horizontal orientation of an axis of rotation of a rotor the each of its particles simultaneously participates in two linear oscillation in horizontal and vertical planes.

Thus of acceleration of particles at their vertical oscillations by an infinite set of derivatives on time from linear displacement are described. As it was marked in (Dmitriev, 2001, 2008a, 2009a) in these conditions it is possible to expect display of "nonclassical" properties of gravitation which mentioned some more D.Mendeleev .

Free falling of masse oscillated along a vertical physically essentially differs from circular (orbital) movement of such masse. Therefore the result received by us does not contradict the results of exact measurements of precession a gyroscope in a circumterraneous orbit.

Relative change $\Delta g / g$ of acceleration of free falling of the container in the described experiment is equal to $\approx 10^{-2}$. Taking into account that the mass of a rotor (500 gram) amounts to $1/3$ mass of the whole container, the relative change $\Delta g / g$ reduced to the rotor mass is equal to $\approx 3 \cdot 10^{-2}$. It is possible to assume that if in a capacity of such "rotors" to use the nuclei of atoms with spatially oriented spins (the set of such atoms forms a macro-dimensions test body) then at high concentration of oriented nuclei in a test body the spatial dependence of acceleration of free falling of a body on orientation of rotors will be much higher than the specified one.

Further experimental researches into free falling of rotating (oscillating) in a vertical plane of either masses or samples of materials with oriented nuclear spins, with use of precision measuring instruments, for example, interferometric ones, seem rather expedient.

CONCLUSIONS

The experimental results described above are obtained by simple technical means and are certainly of a preliminary character. At the same time, it is known that viable ideas in physics quite often prove themselves in technically simple experiments. Logical transition from statics to dynamics, realized in experimental gravitation, opens the prospect of establishment of new properties of gravitation which in the future can get the big scientific and practical values. It creates the prospects of effective solutions and propulsion-problems. The leading role in achievement of such targets belongs to experiment. The practical step to new physics of gravitation should be precision experimental researches into dynamic effects in gravitation. Among them it is necessary to note:

- measurement of temperature dependence of gravitation force;
- static and dynamic measurements of weights of test bodies rotating or oscillating in a vertical plane;
- measurement of anisotropy of crystals weights and measurements of anisotropy of inertial mass of bodies;
- measurement of acceleration of a free falling rotor at various orientations of axis of rotation, and also the samples with artificial orientation of nuclear moments (spins);
- measurements of spatial dependence of restitution coefficient at elastic impacts of solid bodies.

Experiments with weighing of accelerated moving bodies will give useful information on complex, going beyond the scope of well-known theories properties of gravitation. Careful analysis of these results will allow to expand and complement the concepts based on the general theory of relativity, and probably to open the ways to new physics of gravitation and new principles of movement.

NOMENCLATURE

A_c = coefficient of interaction of elastic and gravity forces by counter of $\vec{a}$ and total vector of gravity force ($m^{-1} \cdot s^2$)

A_p = coefficient of interaction of elastic and gravity forces by passing of $\vec{a}$ and total vector of gravity force ($m^{-1} \cdot s^2$)

$\vec{a}$ = acceleration vector of external force (value of vector, $m \cdot s^{-2}$)

α_c = degree of interaction of elastic and gravity forces by counter of $\vec{a}$ and $\vec{g}_0$

α_p = degree of interaction of elastic and gravity forces by passing of $\vec{a}$ and $\vec{g}_0$

C = factor of elasticity of the spiral ($kg \cdot m^2 \cdot s^{-2}$)

Δ_1, Δ_2 = lengths of the next sites of the trajectories (m)

$\Delta\bar{g}$ = average difference of measured values of acceleration of free falling container ($m \cdot s^{-2}$)

$\Delta\vec{g}_c$, $\Delta\vec{g}_p$ = increments of acceleration of gravity (value of vectors, $m \cdot s^{-2}$)

F = frequency (s^{-1})

g = acceleration of free falling container ($m \cdot s^{-2}$)

$\bar{g}$ = average acceleration of free falling container ($m \cdot s^{-2}$)

g_0 = normal acceleration of gravity ($m \cdot s^{-2}$)

g' = resulting magnitude of projections of accelerations of gravity forces created by the remote masses in a solid angle 2π ($m \cdot s^{-2}$)

$\vec{g}'$, $\vec{g}''$ = The resulting accelerations ’ vectors, caused by action of the remote masses located in the left and the right half-spaces (value of vectors $m \cdot s^{-2}$)

γ = the relative difference of the daily motion of an ideal watch (#)

I = moment of inertia ($kg \cdot m^2$)

J_Σ = full angular momentum ($kg \cdot m^2 \cdot s^{-1}$)

l = distance (m)

m_g = gravitational mass (kg)

m_i = inertial mass (kg)

$\hat{m}_i$ = average vertical inertial mass (kg)

$\bar{m}_i$ = average horizontal inertial mass (kg)

N = number of marks

T = period of free oscillations (s)

$\hat{T}$ = period of oscillations of balance in a vertical plane (s)

$\bar{T}$ = period of oscillations of balance moving in a horizontal plane (s)

ω = angular velocity ($rad \cdot s^{-1}$)

REFERENCES

Bini, D., Cherubini, C., Chicone, C. and Mashhoon, B., "Gravitational Induction," (2008), arxiv.org/physics/ 0803.0390v2 [gr-gc] accessed Nov 3, 2008.

Chen, Y. T., and Cook, A., *Gravitational Experiments in the Laboratory,* Cambridge University Press, Cambridge, 1993.

Dmitriev, A. L., "On the Influence of External Elastic (Electromagnetic) Forces on the Gravity," *Russian Physics Journal,* **44** (12), 1323-1327 (2001).

Dmitriev, A. L., and Snegov V. S., "Weighing of a Mechanical Gyroscope with Horizontal and Vertical Orientations of the Spin Axis," *Measurement Techniques*, **44(**8), 831-833 (2001).

Dmitriev, A. L., "Inequality of the Coefficients of Restitution for Vertical and Horizontal Quasielastic Impacts of a Ball Against a Massive Plate," *International Applied Mechanics*, **38** (6), 747 – 749 (2002).

Dmitriev, A. L., Nikushchenko, E. M., and Snegov, V. S., "Influence of the Temperature of a Body on its Weight," *Measurement Techniques*, **46** (2), 115 – 120 (2003).

Dmitriev A. L. and Chesnokov N. N., "The effect of the orientation of an anisotropic crystal on its weight," *Measurement Techniques*, 47(9), 899-901 (2004).

Dmitriev, A. L., "Measurements of the Influence of Acceleration and Temperature of Bodies on their Weight," in proceedings of *Space Technology and Application International Forum (STAIF-2008),* edited by M. El-Genk, AIP Conference Proceedings 969, New York, 2008a, pp. 1163-1169.

Dmitriev, A. L., "On the Nature of Inertial Mass," (2008), arxiv.org/physics/0806.0796 [gen-ph], accessed June 4, 2008b.

Dmitriev, A. L. "Analogue of Lenz's Rule in Phenomenological Gravitation," in proceedings of *Space, Propulsion & Energy Sciences International Forum (SPESIF-2009)*, edited by G. A. Robertson, AIP Conference Proceedings 1103, New York, 2009a, pp. 345 – 351.

Dmitriev, A. L., "On the Experimental Substantiation of Anisotropy of Inertial Mass of Body in the Earth'Gravitational Field," arxiv.org/physics/0903.4433 [gen-ph], accessed Mar. 26, 2009b.

Dmitriev, A. L., Nikushchenko, E. M. and Bulgakova, S. A., "Nonzero Result of Measurement of Acceleration of Free Falling Gyroscope with the Horizontal Axis," (2009), arxiv.org/physics/0907.2790v1 [gen-ph], accessed July 17, 2009.

Faller, J. E., Hollander, W.,J., Nelson P.,G. and McHug M.,P., "Gyroscope-Weighing Experiment with Null Result," *Phys. Rev. Lett.* **64**, 825-826 (1990).

Haugan, M. P. and Lammerzahl, C., "Principls of Equivalence: Theier Role in Gravitation Physics and Experiments that Test Them," (2001), arxiv.org/physics/0103067v1[gr-qc], accessed 17 March 2001.

Hsu, J.-P. and Fine, D. (Editors), "*100 Years of Gravity and Accelerated Frames*," Advanced Series on Theoretical Physical Science, Volume 9, World Scientific, New Jersey, 2005.

Hughes, V. W., Robinson, H. G. and Beltran-Lopez, V., "Upper Limit for the Anisotropy of Inertial Mass from Nuclear Resonance Experiments," *Phys. Review Letters*, Vol. 4, N. 7, 342-344 (1960).

Luo, J., Nie, Y.X., Zhang Y.Z. and Zhou, Z.B., "Null Result for Violation of the Equivalence Principle with Free-Fall Rotating Gyroscopes," Phys. Rev. D., 65, 042005, pp. 1-6, (2002).

Mendeleev, D. I., Works, **22**, AN SSSR, Moscow (1950), (In Russian).

Nitschke, J., M. and Wilmarth, P., A., "Null results for the weight change of a spinning gyroscope," *Phys. Rev. Lett.*, **64**, 2115-2116 (1990).

Paramonov D. A., *Regulirovka balancovyh chasov*, "Mashinostroenie," Moscow, 1977 (in Russian).

Quinn, T., J. and Picard A., "The mass of spinning rotors: no dependence on speed or sense of rotation," *Nature*, **343**, 732-735 (1990).

Schmid, C. "Mach's principle: Exact frame-dragging via gravitomagnetism in perturbed Friedmann-Robertson-Walker universes," (2009), arxiv.org/physics/0801.2907v2 [astro-ph], accessed Sept. 3, 2009.

Tajmar, M., Plesescu, F., Seifert, D., Schnitzer, R. and Vasiljevich, I., "Investigation of Frame-Dragging-Like Signals from Spinning Superconductors using Laser Gyroscopes," in proceedings of *Space Technology and Application International Forum (STAIF-2008),* edited by M. El-Genk, AIP Conference Proceedings 969, New York, 2008, pp. 1180-1190.

Woodward, J. F., "Investigation of Propulsive Aspects of Mach Effects," in proceeding of *Space, Propulsion & Energy Sciences International Forum (SPESIF-2009),* edited by G. A. Robertson, AIP Conference Proceedings 1103, New York, 2009, pp. 252-259.

№ 16

arXiv:1101.4678 (General Physics, 2011)

Frequency Dependence of Rotor's Free Falling Acceleration and Inequality of Inertial and Gravity Masses

Alexander L. Dmitriev

St-Petersburg State University of Information Technologies, Mechanics and Optics, 49 Kronverksky prospect, 197101, St-Petersburg, Russia, (812)3154071 alex@dmitriyev.ru

Abstract. Results of measurements of free falling acceleration of a closed container with a rotor of a mechanical gyroscope placed inside it on the frequency of the rotor rotation are briefly described. Time of separate accelerations measurements is 40 ms, the period of sampling is from 0.5 up to 1.0 minute. In rotation's frequencies range of 20-400 Hz, the negative changes of free falling container acceleration prevail. On individual frequencies the "resonant" maxima and minima of acceleration are observed. The obtained data apparently contradict the equivalence principle of inertial and gravitating masses. The expediency of development of ballistic gravimetry of high time resolution with use of rotating or oscillating test bodies is noted.

Keywords: gravimetry, gravity acceleration, weight, gyroscope, rotor.

PACS: 04.80.-y

From Galilee's times the measurements of free falling acceleration (FFA) of bodies are one of the main techniques of quantitative determination of gravitation properties. The accuracy of modern gravimeters comes up to nm/s^2 units and long ago the gravimetry has become a basis of experimental geophysics and a geodesy [1]. High sensitivity of ballistic gravimeters is basically provided due to two circumstances. First, thermal and mechanical stability of gravimeters design and their components, including test bodies. Second, longer time of integration and bigger number of registered gravimeteric data (in the best laser gravimeters the observations are conducted daily and the number of samples runs into thousands). In these measurements it is certainly supposed that parameters of the gravitational field of the Earth are constant, at least during the time of measurements, and that quite often the observed big scattering of measured samples values of FFA is caused by measurement errors, geophysical and technical factors, or artifacts. The results obtained over long observation time periods, though they give the record values of accuracy in measurements of FFA average values, are uninformative for researches of short-time changes of the gravitation field. Such changes can be caused by both external astronomical influences and complex physical processes in the core and volume of the Earth.

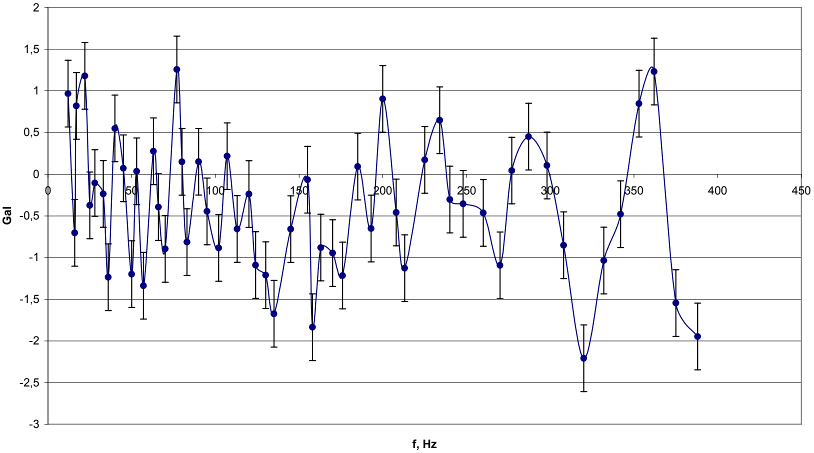
The high time resolution gravimetry , for example, at the level of the 10th - 100th fractions of a second, will give some valuable information on non-stationary geophysical processes, including interrelation of gravitational and magnetic fields of the Earth.

It is necessary to note that in ballistic measurements of FFA the physical state of a test body is of the basic importance. Movement of an accelerated, caused by external elastic (electromagnetic in nature) forces a body or its microparticles affects the measured mass of the body and the acceleration of its free fall. Such an "active" state of a test body is created during its heating (increase of intensity of chaotic movement of its microparticles), rotation, oscillations and impact effects [2-5]. Measurements of acceleration of rotor free falling of a mechanical gyroscope were usually made with the purpose of verification of «equivalence principle» (the review of the appropriate publications is given in [6]). As a rule, in these experiments the axis of a rotor was positioned vertically, the high accuracy of measurements was achieved by the big number of sample data, and measurements of FFA in a narrow range of frequencies of rotor rotation were carried out.

Measurements of free falling acceleration (or mass) of rotor with the horizontal axis of rotation are interesting due to the fact that in doing so the accelerated movement of material particles of the rotor is directed not across but along the vector of gravity force. Just in these conditions, the display of "nonclassical" properties of gravitation can probably appear, including effects which can be considered as analogues of phenomena of Faraday's law induction and Lentz's rules known in electrodynamics [7-9].

In our experiment we measured the free falling acceleration of the magnetically-, thermally-and sound-isolated container with a vacuumed aviation rotor inside it [10]. The maximal rotation frequency of a rotor is 400 Hz, the run out time of rotor is 22 min. Fall path length of the container is 30 mm, readout time of sample value of gravity acceleration is near 40 ms, the period of sampling is from 0.5 up to 1.0 minutes. The principle of measurements is based on photoregistration of movement of the scale in form of three horizontal strings fixed on the container. At the maximal falling velocity of the container equal to 60 cm/s and its dimensions of 82x82x66 mm, the joint influence of buoyancy and resistance force of air in FFA measurements did not exceed 0.1 cm/s^2. The error of some measurements of the container FFA was within the limits of 0.3-0.6 cm/s^2 and was basically determined by accuracy of readout times of registration of pulse signals in movement of the scale (near 1 microsecond).

The example of experimental frequency dependence of FFA changes $\Delta g(f)$ (in Gal) of the container, containing a rotor with a horizontal rotation axis, is shown in the Figure.



The value $\Delta g(0)=0$ correspondsto acceleration of free falling of the container with a motionless rotor; FFA measurements of the container with a motionless rotor were carried out till the moment when rotor got going and after its run out time, in so doing the FFA values of the container, averaged by results of 10 measurements with a motionless rotor, coincided to the accuracy of 0.05%.

The features of frequency dependence of FFA changes are its stochastic character, narrow extremes which are the most appreciable near frequencies of 320 and 360 Hz, and prevalence, on the average, of the negative values of $\Delta g(f)$. These results do not contradict the earlier executed measurements of the FFA of the container with two rotors in which at frequencies of rotation 380-350 Hz the appreciable increase of FFA was noted [11]. The reduction tendency of size of the change $\Delta g(f)$, averaged for run out time of the rotor, is also in agreement with the data of measurements of rotor weight carried out with use of a precision comparator [3]. Statistically significant prevalence of negative average values of $\Delta g(f)$ in tens of series of measurements was observed. The resonant character of negative changes of $\Delta g(f)$ clearly expressed in rotation frequencies near 320 Hz, also proved to be true in repeated experiments. Similar laws at vertical orientation of an axis of a rotor are observed which can apparently be explained by a nonzero vertical component of oscillations of particles of the massive body of a gyroscope in rotation of the rotor.

The "nonclassical" properties of gravitation are just found in dynamic experiments in which an influence on a test body of external, not gravitational effects is significant, and the deep interrelation of gravitational and electromagnetic fields is most clearly expressed. The development of high time resolution ballistic gravimetry with use of rotating or oscillating test bodies will contribute to a deeper understanding of physics of gravitation.

Conclusions

1. The free falling acceleration of a container with a mechanical gyroscope rotor inside it, measured in period of time less than 0.05 s, considerably differs from normal acceleration of gravity and in the range of frequencies of rotor rotation equal to 20-380 Hz the difference of such accelerations achieves several units of cm/s^2.

2. The frequency dependence of change of free falling acceleration of the container (rotor) has stochastic, and at some frequencies of rotor rotation, for example, near 320 Hz, a resonant character. Both at vertical and horizontal orientations of rotor rotation axis, a reduction of free falling acceleration of the container with a rotating rotor prevails.

3. A change, including reduction (levitation) of free falling acceleration of a closed container with a rotating rotor, seems to contradict the principle of identity of inertial and gravitation masses of a body.

4. The ballistic gravimetric researches made with the high time resolution and using rotating or oscillating test bodies are informative in measurements of dynamic characteristics of the gravitational field of the Earth and also contribute to development of physics of gravitational interaction.

References

1. W. Torge, Gravimetry, “Walter de Gruyter”, Berlin. New York, 1989.

2. A. L. Dmitriev, “On the Influence of the External Elastic (Electromagnetic) Forces on the Gravity”, Russian Physics Journal, Vol. 44, No 12, 1323 (2001).

3. A. L. Dmitriev and V. S. Snegov, “The Weighing of a Mechanical Gyroscope with Horizontal and Vertical Orientation of the Spin Axis”, Measurement Techniques, Vol. 44, No 8, 831 (2001).

4. A. L. Dmitriev, “Inequality of the Coefficients of Restitution for Vertical and Horizontal Quasielastic Impacts of a Ball Against a Massive Plate”, International Applied Mechanics. Vol. 3, No 6, 747 (2002).

5. A. L. Dmitriev, E. M. Nikushchenko and V. S. Snegov, “Influence of the Temperature of Body on Its Weight”, Measurement Techniques, Vol. 46, No 2, 115 (2003).5

6. J. Luo, Y. X. Nie, Y. Z. Zhang and Z. B. Zhou, “Null result for violation of the equivalence principle with free-fall rotating gyroscopes”, Phys. Rev. D, Vol. 65, 042005 (2002).

7. A. L. Dmitriev, “Measurements of the Influence of Acceleration and Temperature of Bodies on Their Weight”, AIP Conference Proc., Vol. 969, 1163 (2008).

8. A. L. Dmitriev, “Analogue of Lenz’s Rule in Phenomenological Gravitation”, AIP Conference Proc., Vol. 1103, 345 (2009).

9. M. J. Pinheiro, “The Fourth Law of Motion in Classical Mechanics and Electrodynamics”, AIP Conference Proc., Vol. 1208, 359 (2010).

10. A. L. Dmitriev and E. M. Nikushchenko, “Frequency Dependence of Rotor’s Free Fall Acceleration” (in Press).

11. A. L. Dmitriev, E. M. Nikushchenko and S. A. Bulgakova, “Dynamic Weighing Experiments – the Way to New Physics of Gravitation“, AIP Conference Proc., Vol. 1208, 237 (2010).

№17

arXiv:1105.2666 (General Physics, 2011)

EXPERIMENTAL CONFIRMATION OF THE GRAVITATION FORCE NEGATIVE TEMPERATURE DEPENDENCE

A. L. Dmitriev and E. M. Nikushchenko

St. Petersburg State University of Information Technologies, Mechanics and Optics, St. Petersburg, 49 Kronverksky prospect, 197101, Russia,
Tel/Fax:+7(812)3154071, alex@dmitriyev.ru

Abstract: *The experiment with weighing PZT-piezoelectric ceramics, heated up by a high-frequency signal for the temperature of 1.6* ^{0}C *is briefly described. The negative change of piezoelectric ceramics weight having relative value of* γ » -4.1×10^{-6} K^{-1} *is confidently registered. The sign and the order of the value of relative temperature change of piezoelectric ceramics weight correspond to the measurements of weight of non-magnetic metal bars which were conducted earlier. What is emphasized as expedient for development of physics of gravitation is conducting similar measurements with use of various materials as samples and in a wide range of temperatures.*

PACS numbers: 04.80.Cc, 06.30.Dr
Key Words: gravitation force, temperature, mass measuring, piezoelectric ceramic

The problem of influence of bodies’ temperature on the force of their gravitational interaction has been discussed since long ago and the first precision experiments in this field were already carried out at the beginning of the XXth century [1]. The decline of interest to such researches, which followed later, might be explained by the authority of the general theory of relativity according to which the temperature dependence of force of gravitation practically can not be observed [2]. The next stage of experimental studies of the said specified problem fell to the beginning of the current millenium when in Russia there were published the results of laboratory measurements of temperature dependence of weight of metal bars, indicating an appreciable negative temperature dependence of the gravitation forces [3-5]; recently these results were confirmed in works of Chinese scientists [6].

The physical substantiation of relatively strong influence of temperature on force of gravitation consists in deep interrelation of electromagnetic and gravitational interactions, and their dependence on the accelerated movement of the microparticles forming a massive body, with intensity growing with growth of temperature [7,8]. In experiments [3,6], the weighed samples were heated up to comparatively high temperatures - from ten degrees up to hundreds.

A possible, in such conditions, influence on results of measurements of the thermal air convection, the change of temperature of the scales mechanism, the thermal change of residual magnetization and adsorption of moisture on the surface of samples, and so on – naturally caused caution and even mistrust in estimations of the obtained results. Meanwhile, the results of weighing the heated metal samples were obtained at high enough levels of an effective signal to noise ratio, with the careful account for the influence of the mentioned factors.

In the described experiment, there was carried out the weighing of samples of PZT-piezoelectric ceramics, whose temperature increased by 1.6 degrees in respect to the normal room temperature (24 ^{0}C). In so doing, the influence of temperature factors on accuracy of measurements of weight of samples was reduced to a minimum.

The design of the weighed container is shown in Fig. 1.

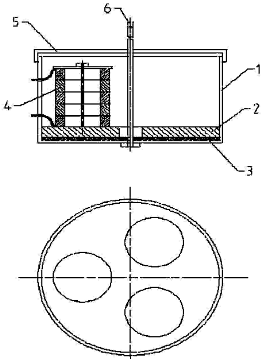


Fig. 1. The arrangement of container. 1- body, 2 – base, 3 – laying, 4 – PZT-pile, 5 – cover, 6 – hanging bar.

The container was placed in the closed box of analytical scales, the high-frequency electric signal was fed to electrodes of piezoelectric ceramics by means of elastic copper conductors 85µm in diameter and 150mm in length. The weighed sample is made in form of three "piles" ("sandwiches") of parallel-connected piezoelectric ceramic rings, 5 rings in each "pile", fixed on the massive brass base; the external diameter of rings is 22 mm, the internal diameter is 16 mm, height is 6 mm; the full weight of 15 rings is equal to 112.9g. In parallel to the power supply terminals of piezoelectric ceramics, there was connected the variable inductance for adjustment of resonance frequency of the supplied signal equal to 389 kHz, which allows to achieve the most effective heating of samples; the amplitude of the resonance signal is equal to 40 V. The readout of scales was carried out by the elongation method with the period of scale beam oscillations equal to 19.7 s. At full weight of the container equal to about 470 g, the error in reading out the changes of weight in time did not exceed 30 mcg.

An example of typical experimental time dependence of the container weight change is shown in Fig. 2.

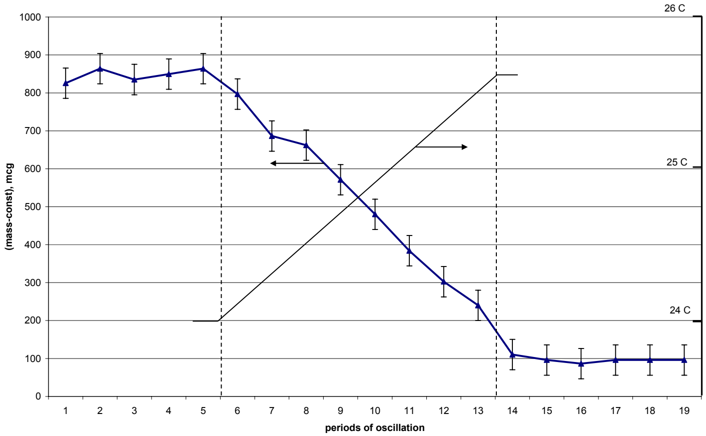


Fig. 2. Experimental time-dependence of container mass by heating PZT-pile from 24.0 till 25.6 ^{0}C. Touch lines is “in” and “out” moments. 1 period = 19.7 s.

The change of temperature of piezo-ceramic sample during the time of heating (2.95 min) is equal to 1.6 ^{0}C (it is obtained by control measurements of ceramics temperature before weighing). The temperature of walls of the container remained practically a constant, and short-term heating of air inside the non-hermetical container with volume $V \approx 10^2\ cm^3$ even for $\Delta T \approx 1-2^0 K$ changed the apparent value Δm of its weight by no more than 1 mcg ($\Delta m = \rho V \Delta T / T$, where air density $\rho = 1.29 kg / m^3$, $T \approx 297^0$ K).

According to Fig. 2, the relative temperature change γ of piezoelectric ceramics weight by 1 degree,

$$\gamma = \left(\frac{\Delta m}{m} \right) \cdot \frac{1}{\Delta T} \qquad ,$$

is equal to $\gamma \approx -4.1\times10^{-6} K^{-1}$.
This value is close to value γ for a lead sample, $\gamma \approx -4.6\times10^{-6} K^{-1}$, obtained in [3].
Let's note that close conformity of γ measurement results is realized with essentially different dimensions and configurations of the samples and containers which were used.
So, the laboratory experimental data, obtained in heating of piezo-electric ceramic samples for 1.6 ^{0}C, confirm the negative temperature dependence of such sample weights. These data will essentially agree with high-temperature measurements of weight of non-magnetic metal bars [3,6]. The further experimental researches of negative temperature dependence of force of the gravitation, carried out with use of various samples of materials in a wide range of temperatures, will promote the progressive development of physics of gravitation

References

5. P. E. Shaw and N. Davy The Effect of Temperature on the Gravitative Attraction, Phys. Rev. **21** (6), 680 (1923)

6. A. K. T. Assis and R. A. Clemente The Influence of Temperature on Gravitation Nuovo Cimento, Vol. **108** B, No. 6, 713 (1993)

7. A. L. Dmitriev, E. M. Nikushchenko and V. S. Snegov Influence of the Temperature of a Body on its Weight, Measurement Techniques, Vol. **46**, No. 2, 115 (2003)

8. A. L. Dmitriev Experimental Study of Gravity Force Temperature Dependence, 18th International Conference on General Relativity and Gravitation (GRG18), Abstract Book, 77 (2007)

9. A. L. Dmitriev Measurements of the Influence of Acceleration and Temperature of Bodies on their Weight, AIP Conf. Proc. **969**, 1163 (2008)

10. Liangzao Fan, Jinsong Feng and Wuqing Liu An Experimental Discovery about Gravitational Force Changes in Materials due to Temperature Variation, Engineering Sciences, China **12** (2), 9 (2010)

11. A. L. Dmitriev On the Influence of External Elastic (Electromagnetic) Forces on the Gravity Russian Physics Journal, Vol. **44**, No. 12, 1323 (2001)

12. A. L. Dmitriev Analogue of the Lenz's Rule in Phenomenological Gravitation, AIP Conf. Proc. **1103**, 345 (2009)

№ 18

arXiv:1201.4461 (General Physics, 2012)

SIMPLE EXPERIMENT CONFIRMING THE NEGATIVE TEMPERATURE DEPENDENCE OF GRAVITY FORCE

Alexander L. Dmitriev

St-Petersburg National Research University of
Information Technologies, Mechanics and Optics, 49
Kronverksky Prospect, St-Petersburg, 197101, Russia

Results of weighing of the tight vessel containing a thermo-isolated copper sample heated by a tungstic spiral are submitted. The increase of temperature of a sample with masse of 28 g for about 10^0 C causes a reduction of its apparent weight for 0.7 mg. The basic sources of measurement errors are briefly considered, the expediency of researches of temperature dependence of gravity is recognized.

Key words: gravity force, weight, temperature, gravity mass.

PACS: 04.80-y.

Introduction

The question on influence of temperature of bodies on the force of their gravitational interaction was already raised from the times when the law of gravitation was formulated. The first exact experiments in this area were carried out at the end of XIXth - the beginning of XXth century with the purpose of checking the consequences of various electromagnetic theories of gravitation (Mi, Weber, Morozov) according to which the force of a gravitational attraction of bodies is increased with the growth of their absolute temperature [1-3]. That period of experimental researches was completed in 1923 by the publication of Shaw and Davy's work who concluded that the temperature dependence of gravitation forces does not exceed relative value of 2×10^{-6} K^{-1} and can be is equal to zero [4]. Actually, as shown in [5], those authors confidently registered the negative temperature dependence of gravitation force. Nevertheless, probably in the view of growth of popularity of the general theory of relativity (GR) by Einstein, Shaw and Davy have not dared to insist on their results. According to GR doctrines, the positive relative temperature dependence of gravitation force has the order of $10^{-15}\ K^{-1}$ which means that it can not practically be observed [6].

It is necessary to note that non-relativistic, including ether models of gravitation, as well as separate (sometimes exotic) hypotheses of the nature of gravitation, do not exclude rather "strong" temperature dependence of the force of gravitation [7,8]. Here it is pertinent to note the experiment by A.P. Shchegolev made in 1983 who, following the idea of the "thermodynamic" nature of gravitation, had observed the temperature reduction of weight of the massive steel sphere which was heated up with a beam of a powerful laser [9]; unfortunately, the accuracy of those experiments was rather insignificant.

In the 90s, in the process of researches into the influence of the accelerated movement of a test body on the results of its exact weighing and on the basis of individual analogies of the gravitational and electromagnetic phenomena, the author and his colleagues had executed measurements of apparent weights of samples of non-magnetic metal rods exited by ultrasound [10]. The longitudinal ultrasonic waves in rods, created by the piezoelectric converter, are accompanied by significant accelerations of the rod material microparticles which fact was used as a basis of measurements idea. During the experiments it was found that the results of measurements of rod weights were significantly influenced by the increase of their temperature, owing to both absorption of ultrasound and heat transfer from the piezo-converter. The frequency spectrum of temperature fluctuations of solid body particles lies in the field of hypersound frequencies and essentially exceeds the frequency of ultrasound, therefore such results are natural. The measurements of temperature dependence of weight (apparent mass) of metal samples executed by the specified technique had shown a rather strong negative temperature dependence of their weight with relative value γ in the range from 4.6 $\times 10^{-6}\ K^{-1}$ for a lead sample up to 11.6 $\times 10^{-6}\ K^{-1}$ for duralumin one. The elementary phenomenological theoryo f temperature dependence of samples weight [10,11] had given a satisfactorily explanation of temperature dependence factor γ on density ρ and elastic properties (speed V of longitudinal ultrasonic waves) of material:

$$\gamma \propto -\frac{V}{\sqrt{\rho}} \quad ; \qquad (1)$$

the same model allowed to prove the orientation dependence of weight of some crystals [12].

Though the results of measurements of negative temperature dependence of gravitation are in obvious disagreement with conclusions of GR, they do not contradict the earlier executed experiments or are challenged by anybody. On the contrary, in 2010 the work of Chinese physicists (Liangzao Fan, Jinsong Feng, Wuquing Liu) investigating the temperature dependence of weight of metal samples (including samples from copper, gold and silver) was published in which the sign and value of temperature factor γ for a copper sample closely corresponded to our data [13]. Recently conducted measurements of temperature dependence of weight of the pile of piezoelectric converters excited on resonant frequency had also appreciably shown the reduction of piezo-ceramics weight with the growth of its temperature [14].

Experiment

In the described experiment a tight vessel was weighed inside which there was a thermo-isolated copper sample heated by a tungstic spiral through which the electric current was passed. The design and appearance of the container are shown in Fig. 1. Diameter of the vessel is 63 mm, height - 87.5 mm, mass - 127.4 g.

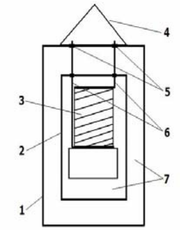


Fig. 1. The design of the container. 1 - external, sealed tin vessel; 2 - an envelope of the internal case (foil); 3 - copper cartridge wrapped up by mica and a tungstic spiral; 4 - a suspension bracket; 5 - «cold welding» (polymeric glue); 6 - copper conductors; 7 – thermo-isolation envelopes (foam plastic).

Weighing was made by the elongation method (with readout of extreme angular positions of oscillating scales beam) on laboratory scales of ADL-200 model. Procedure of weighing consisted of three stages. At the first stage the container with a cold sample was weighed for 5-6 minutes. At the second stage of total duration equal to 2.5 minutes the electrodes of the container heater were connected for 35 seconds to a power supply source; the current in the heater circuit is 0.9A, resistance of the winding - 6.5 Ohm. At the third stage the continuous readout of current values of container weight was made for 8-9 minute. All mentioned manipulations were repeatedly and carefully fulfilled, the resulting error of measurement of weight of the container did not exceed 50 mcg.

During measurements the temperature of walls and bottom of the container was equal to $24.9 \pm 0.1^0\ C$. The temperature of the "hottest" central area of the container cover from the moment of the heater switching ON has grown with speed of less than $0.1^0 / \min$; so, in the first 2 minutes after switching OFF of the heater power supply, the temperature of the container cover had increased by no more than $0.15^0\ K$. Under the specified conditions the influence of the air convection flows caused by difference of temperatures on the surface of the container and air in a closed box of scales was practically insignificant. Absence of a leak (hermetic sealing) in the container was controlled by usual methods. Typical time dependence of container apparent weight is shown in Fig. 2.

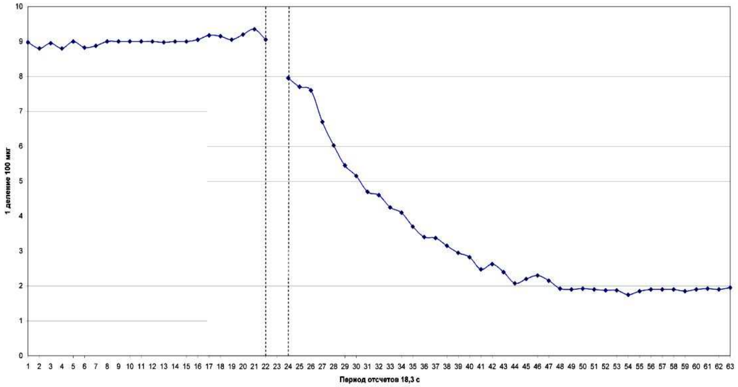


Fig. 2. Time dependence of changes of the container apparent weight. Shaped lines specify the moments of the beginning and the end of the second stage of weighing (the time scale of this stage is reduced). Vertical axis: 1 div 100 mcg; horizontal axis: period of sample 18.3 s.

During the first 2-3 minutes after switching OFF of the heater the reduction of the container weight is maximal, reaching 200 mcg, then during approximately 3 minutes a monotonous reduction of weight down to $\Delta m \approx 700 mcg$ is observed.

Discussion

The calculated amount of heat supplied by the electric heater is approximately equal to 184 J. A part of this heat is dissipated in conductors and heat insulator, but significant, in amount of about 100J, part ΔQ is transferred to copper sample 3 (Fig. 1) which has mass $m \approx 28g$. The respective change ΔT of average temperature of uniformly heated sample ($\Delta T = \Delta Q / mc$, where c = $3.9 \times 10^2\ J / kg \times K$ is a specific thermal capacity of copper) $\Delta T \approx 9^0$. The relative temperature change of sample weight,

$$\gamma = \frac{\Delta m}{m \Delta T} , \qquad (2)$$

is equal to $\gamma = -2.8 \times 10^{-6} K^{-1}$. This value differs by more than 2 times from the result received in ultrasonic heating of a copper sample; nevertheless, the sign and the order of value γ correspond to the previous measurements [10-14]; comparing the specified results it is necessary to consider the difference of physical conditions of heating the sample by ultrasound and in the process of heat transfer.

The general character of apparent weight reduction in Fig. 3 is explained by the process of distribution of heat in a copper sample of complex configuration (the heated part of the copper hollow cartridge makes approximately half of its length; the diameters of heated up and no-load parts of the cartridge differ) and, on the whole, correspond to similar dependence in measurements of weight of a brass core in Dewar's vessel [10]. In both cases the monotonous time dependence of the measured weights is explained by slow distribution of thermal wave in the samples being weighed.

As shown by the special measurements, the temperature change of the top part of the container during the experiment did not exceed 0.5^0 , and the temperature of walls remained constant with accuracy of 0.1^0 . Under these conditions, on the basis of Glaser's theory [15], the changes of apparent weight of the container, caused by air convection, and the change of buoyancy of the sample do not exceed $50 mcg$. So, with a difference of air temperature Δt and temperatures of the cylinder surface of the area $A = 173 cm^2$ and the diameter $d = 6.3 cm$, the change Δm of apparent weight of a cylindrical sample is equal to

$$\Delta m = -9.2 \cdot 10^{-7} A d^{1/4} \Delta t^{3/4} \quad . \qquad (3)$$

With $\Delta t = 0.2^0$ from equation (3) which is obviously overestimated for conditions of the described experiment it follows that $\Delta m \approx 75 mcg$ which is approximately by an order less than the total value of the observed weight change.

It can be shown that the change of buoyancy caused by temperature change of the container volume owing to temperature change of the container case even by 1^0 , causes a measurement error of its apparent weight of less than 10 mcg.

On the whole, the results of the executed experiment will be coordinated with the dates [10-13] received earlier, confirming the fact of rather strong negative temperature dependence of force of the gravitation acting on the heated test body.

***

As a note, we shall mark the following. If during the further experiments it will be shown that the specified temperature dependence has the universal character there probably will be necessary to update some conclusions of the well-known theories and models of gravitation.

In particular, the negative temperature dependence of gravitation force specifies that in the course of (astrophysical) gravitational collapse accompanying by an increase of temperature of collapse-mass, the realization of the so-called condition of "singular point" is impossible. Hence, the popular hypothesis of “black holes” can seem to be rather doubtful.

Conclusions

13. An increase of temperature of thermo-isolated copper sample with mass of 28 g by value of about $10^0 C$ is accompanied by reduction of its apparent weight by more than 0.7 mg.
6. The observed, rather "strong" negative temperature dependence of body physical weight with relative value by the order of $10^{-6} K^{-1}$ does not contradict the known experiments on exact weighing the heated test body.
3. The experimental researches of temperature dependence of weight of bodies of the various structures, conducted in a wide range of temperatures, will promote the development of concepts of physics of gravitational interaction.

References

1. Bogorodsky A. Vsemirnoe Tjagotenie , Кiev. «Naukova dumka», 1971.
2. Roseveare N. Mercury's Perihelion, Oxford, «Clarendon Press»,1982.
3. Gillies G. Rep. Prog. Phys. (1997), Vol. 60, p. 151.
4. Shaw P. & Davy N. Phys. Rev. (1923), Vol. 21, p. 680.
5. Dmitriev A. arXiv, physics/0611173, 20 Nov. 2006.
6. Assis A. & Clemente R. Nuovo Cimento (1993), Vol. 108 B, № 6, p. 713.
7. Sizov R. Magnetic Fundamental Particles in Physics of Magnetic and Electromagnetic Effects, Moscow, 2007.
8. Bukhalov I. Inercia I gravitacia, Moscow, «KomKniga», 2007.
9. Shegolev A. Nugen grazer, SPb, «Anatolia», 2009.
10. Dmitriev A., Nikushchenko E. & Snegov V. Measurement Techniques (2003), Vol. 46, No. 2, p. 115.
11. Dmitriev A. AIP Conf. Proc. 2008, Vol. 969 , p. 1163; 2009, Vol. 1103 , p. 345.
12. Dmitriev A. & Chesnokov N. Measurement Techniques (2004) Vol. 47, No. 9, p. 899.
13. Liangzao Fan, Jinsong Feng & Wuquing Liu Engineering Sciences, China (2010), No.12(2), p. 9.
14. Dmitriev A. & Nikushchenko E. arXiv:1105.266v1 [physics. gen-ph], 16 May 2011.
15. Glaser M. Metrologia (1990), Vol. 27, № 2, p. 95.

№ 19

Инженерная физика, №1, 13 – 17 (2012)

УДК 528.27; 531.51

ЧАСТОТНАЯ ЗАВИСИМОСТЬ УСКОРЕНИЯ СВОБОДНОГО ПАДЕНИЯ РОТОРА

А. Л. Дмитриев, Е. М. Никущенко

Санкт-Петербургский государственный университет Информационных технологий, механики и оптики, СПб, 197101, Кронверкский проспект,49. (812)3154071 alex@dmitriyev.ru

Аннотация. Измерена зависимость кратковременного, с временем измерения менее 0.05 с, ускорения свободного падения (УСП) контейнера с находящимся в нем ротором механического гироскопа от частоты вращения ротора. На отдельных частотах наблюдается значительное, величиной около 2 см/с^2, уменьшение УСП контейнера с вращающимся ротором, по сравнению с УСП контейнера с неподвижным ротором. Рассмотрены источники ошибок измерений и возможные причины наблюдаемой «резонансной» частотной зависимости ускорения свободного падения ротора. Отмечена перспективность развития баллистической гравиметрии высокого временного разрешения с использованием вращающихся либо колеблющихся пробных тел.

Ключевые слова: гравиметрия, ускорение свободного падения, вес, гироскоп, ротор.

Введение

Измерение ускорения свободного падения (УСП) тел издавна является одной из главных методик экспериментальной гравитации и лежит в основе действия баллистических гравиметров [1]. Механический ротор представляет собой систему ускоренно двигающихся по круговой траектории микрочастиц («материальных точек»), жестко связанных между собой силами упругости, и его использование в качестве пробного тела в баллистических экспериментах создает возможности проверки физических принципов, положенных в основу современных концепций гравитации. Сравнение ускорений свободного падения двух роторов с вертикальными осями, с попутной и встречной ориентациями векторов моментов вращения, не дало положительных результатов [2]. Это представляется естественным, ввиду того, что при вертикальной ориентации осей падающих роторов мгновенные центростремительные ускорения составляющих их частиц лежат в плоскости, перпендикулярной вектору силы тяжести, и в этих условиях нет оснований ожидать достаточно заметных отклонений от известных закономерностей свободного падения тел. Наоборот, при горизонтальной ориентации оси ротора его частицы испытывают значительные переменные ускорения вдоль вектора силы тяжести, при этом физические условия взаимодействия частиц ротора с гравитационным полем Земли принципиально отличаются от условий эксперимента [2], и взаимосвязь упругих (электромагнитных по природе) и гравитационных сил [3-5] здесь проявляется наиболее отчетливо. В [6] описан эксперимент по измерению ускорения свободного падения механического ротора с горизонтальной осью вращения, при этом в первые минуты выбега ротора отмечено значительное превышение ускорения свободного падения вращающегося ротора по сравнению таким ускорением для неподвижного ротора. Методика измерений, использованная в [6], не позволяла прямо определить частотную зависимость ускорения свободного падения вращающегося ротора. Цель настоящей работы состоит в попытке решения именно такой задачи.

Эксперимент

В описываемом эксперименте измерялось ускорение свободного падения закрытого контейнера с помещенным в нем ротором вакуумированного механического гироскопа марки

ГМС-2. Для устранения влияния внешних магнитных помех контейнер размерами 82x82x66 мм изготовлен из пермаллоя, для звуко- и теплоизоляции покрыт мягкой тканью и поверх нее слоем алюминиевой фольги. Схема эксперимента приведена на рис.1.

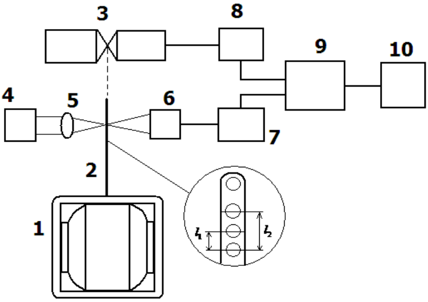


Рис. 1. Принципиальная схема эксперимента. 1 – контейнер; 2 – шкала; 3 – электромеханическое устройство сбрасывания контейнера; 4 – лазер; 5 – микрообъектив; 6 - фотоприемник; 7 – усилитель; 8 – электронная схема включения/выключения электромагнита и регулятор задержки импульса запуска; 9 – цифровой осциллограф «OWON» PDS5022S; 10 – компьютер.

Перед проведением измерений двигатель гироскопа подключался к источнику переменного тока и в течение 3 мин ротор раскручивался до максимальной частоты вращения 400 Гц; полное время выбега ротора 22 мин, временная зависимость частоты вращения ротора измерялась электронным частотомером.

На корпусе контейнера закреплена шкала-держатель в виде тонкой медной пластины с отверстиями, верхнее из которых использовалось для подвески контейнера в механизме сбрасывания. Другие три отверстия перекрывались параллельными медными нитями толщиной 75 мкм, расстояния

l_1, l_2 между которыми измерялись с точностью 0.05 мм. Электромагнит механизма сбрасывания контейнера управлялся сигналом от блока 8, соответствующий сигнал запуска с задержкой по времени подавался к цифровому осциллографу 9. При падении контейнера нити шкалы последовательно пересекали сфокусированный луч лазера 4, форма сигнала на выходе фотоприемника показана на рис. 2. Длина траектории падения контейнера 30 мм, время одного измерения УСП около 40 мс.

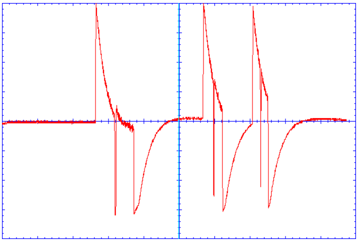


Рис. 2. Осциллограмма выходного сигнала фотоприемника. Одно деление горизонтальной шкалы - 10 мс, вертикальной – 1 В. Моменты t_1, t_2, t_3 перекрытия нитей шкалы соответствуют коротким отрицательным импульсам, считая слева направо.

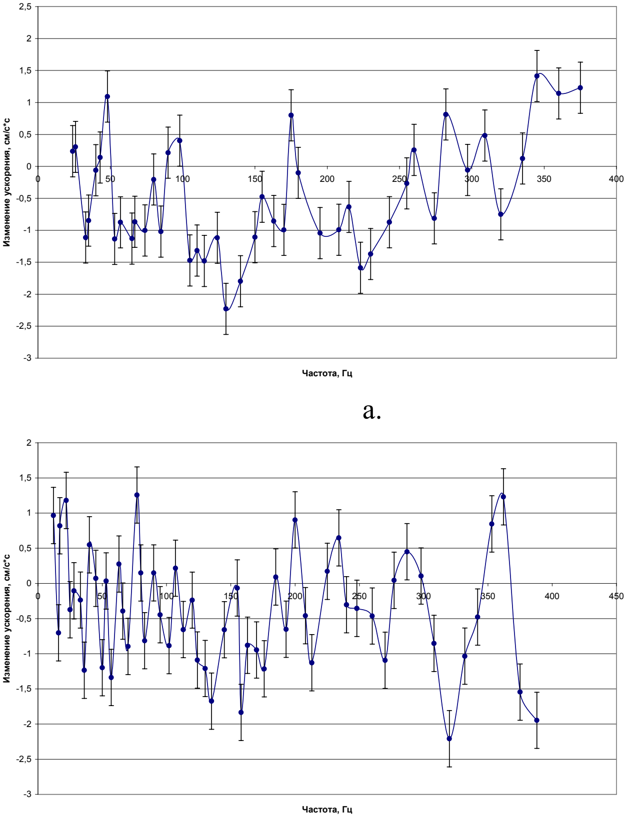
Расчет ускорения свободного падения контейнера, в см/с^2, выполнялся по формуле

$$g = \frac{2 \cdot 10^5 (l_1 - l_2 x / y)}{(x^2 - xy)}, \tag{1}$$

где $l_1 = 12.08$мм, $l_2 = 20.37$мм, $x = (t_2 - t_1)$, $y = (t_3 - t_1)$ и t_1, t_2, t_3 - моменты положений центров импульсов на осциллограмме рис. 2, в мс. При использовании программы «Oscilloscope Software», погрешности отсчетов времен t_1, t_2, t_3 1-2 мкс. Сбрасывания контейнера, фиксация и запоминание осциллограмм выполнялись периодически, примерно через 0.5-1.0 мин, в течение всего времени выбега ротора, а также при неподвижном роторе.

Примеры частотных зависимостей изменения $\Delta g(f)$ УСП контейнера при вертикальной (а) и горизонтальной (б)

ориентациях оси вращения ротора, и погрешности измерений приведены на
рис. 3;



а.

б.

Рис. 3. Частотные зависимости изменения ускорения свободного падения контейнера. а. – ось ротора вертикальна, б. – ось горизонтальна.

значение $\Delta g(0) = 0$ соответствует ускорению свободного падения контейнера с неподвижным ротором (измерения УСП при неподвижном роторе проводились до раскручивания ротора и после времени его выбега, при этом усредненные по результатам 10 измерений значения УСП контейнера с неподвижным ротором совпадали с точностью 0.05 %). Изменения направления вращения ротора и географической ориентации его горизонтальной оси, в пределах указанных погрешностей измерений, не влияло на результаты измерений $\Delta g(f)$.

Обсуждение результатов

Примечательными особенностями частотных зависимостей $\Delta g(f)$ являются их нестационарный характер и сравнительно узкие экстремумы, в том числе, минимумы, наиболее заметные вблизи частот 130 и 320 Гц при вертикальной, и 135 и 320 Гц при горизонтальной ориентации оси ротора. Эти минимумы, величиной свыше 2 см/с^2, регистрировались в десятках серий проводимых измерений и при горизонтальной ориентации оси ротора, как правило, наблюдались в окрестности 320 Гц с разбросом средних значений около 5-10 Гц. Следует отметить, что масса ротора гироскопа ГМС-1 равна 250 г, что составляет 0.32 часть массы всего снаряженного контейнера (770 г), и при вращении ротора контейнер испытывает слабые вибрации, сопровождающиеся как горизонтальными, так и вертикальными колебаниями составляющих его частиц. Поэтому закономерна близость частот экстремумов зависимости $\Delta g(f)$ при горизонтальной и вертикальной ориентациях оси ротора. Как видно из рис. 3, в рассмотренном диапазоне частот вращения ротора, в среднем, преобладают отрицательные значения $\Delta g(f)$, наиболее сильно выраженные при горизонтальной ориентации оси ротора.

Приведенные зависимости не противоречат результатам экспериментов, описанных в [6], в которых в начальные значения времени выбега роторов наблюдалось увеличение ускорения их свободного падения. Измеренное в этих экспериментах увеличение УСП контейнера, содержащего два ротора с горизонтальными осями, отмечалось в первые минуты выбега роторов, что примерно соответствует диапазону частот вращения 350-380 Гц, где и наблюдается рост Δg (рис. 3. б.).

Тенденция уменьшения усредненных за время 1-2 мин значений ускорения свободного падения ротора с горизонтальной осью, в диапазоне частот вращения 90-320 Гц, соответствует подобной зависимости уменьшения веса гироскопа, описанной в [4].

«Резонансный» характер частотной зависимости ускорения свободного падения контейнера можно, например, объяснить акустическими эффектами – изменением силы аэродинамического сопротивления воздуха, обтекающего слабо вибрирующую поверхность контейнера. Но такое влияние нелинейных акустических эффектов (акустических течений [7]) при сравнительно низком (около 40 дБ) уровне звуковых шумов, обусловленных вибрациями контейнера в воздушной среде, незначительно. Это подтверждается соответствием данных измерений $\Delta g(f)$, полученных в экспериментах с контейнером, заключенным в звукоизолирующую оболочку, и без нее.

Ускорение g свободного падения контейнера в воздухе равно

$$g = g_0 - \frac{F_A}{m} - \frac{F_S}{m} \quad , \qquad (2)$$

где g_0 - нормальное ускорение силы тяжести, F_A - сила Архимеда, F_S - сила сопротивления воздуха при движении контейнера и m - масса контейнера. Изменение δg_A ускорения свободного падения, обусловленное плавучестью (силой Архимеда), связано с изменением плотности $\Delta\rho$ воздуха,

$$\delta g_A = \frac{g_0 V}{m} \delta\rho \quad , \qquad (3)$$

где V - объем контейнера (445 см^3). Если изменения $\delta\rho$ сравнительно велики и составляют, например, 0.1 от среднего значения плотности воздуха (около $1.20\cdot10^{-3} г\cdot см^{-3}$ при 20^0С), соответствующее изменение δg_A равно 0.07 см/с^2.

Изменение ускорения свободного падения δg_S, обусловленное силой аэродинамического сопротивления, оценим с использованием формулы Стокса,

$$\delta g_S = \frac{6\pi\eta l u}{m}k \quad , \tag{4}$$

где η - вязкость воздуха ($\eta \approx 18.2\cdot10^{-5}$ пуаз), l - средние размеры контейнера (максимум $l \approx 8$ см), u - средняя скорость падения контейнера (на конечном участке траектории длиной 30 мм максимальная скорость 70 см/с), $k \approx 3.7$ – отношение коэффициентов сопротивления плоского бруска и шара примерно равных размеров [8,9]. Согласно 4, максимальное значение δg_S в условиях эксперимента не превышало 0.02 см/с^2. Сравнительно малое значение δg_S подтверждает незначительность влияния на измерения упомянутых выше нелинейно-акустических эффектов, связанных со слабыми вибрациями поверхности контейнера.

Возможными причинами разброса фиксируемых значений УСП также могут быть случайные колебания массивного основания измерительного стенда и его оптико-механических элементов. Хорошая воспроизводимость основных результатов измерений – тенденция уменьшения УСП контейнера с вращающимся ротором и совпадения «резонансных» частот зависимостей $\Delta g(f)$, измеренных в разных сериях экспериментов, - указывают, что вклад отмеченных артефактов в частотную зависимость УСП, по-видимому, не является определяющим.

Основным источником погрешностей измерения ускорения свободного падения контейнера в описываемых экспериментах были ошибки в отсчетах моментов t_1, t_2, t_3 регистрации импульсов по осциллограмме рис. 2. Полная экспериментальная погрешность выборочных значений ускорений свободного падения составила от 0.3 до 0.6 см/с^2.

Заключение

Описанные результаты не противоречат известным экспериментам по взвешиванию ускоренно двигающихся тел и, по-видимому, обусловлены малоизученными особенностями динамического взвешивания тел [3-6]. Как видно из рис. 3, в экспериментах преобладают отрицательные изменения ускорения свободного падения контейнера, и при горизонтальной ориентации оси ротора такие изменения со средней величиной около 1 см/с^2 наблюдаются в широком диапазоне частот вращения от 20 до 350 Гц. «Резонансный» характер как положительных, так и наиболее заметных отрицательных изменений $\Delta g(f)$, указывает на зависимость ускорения свободного падения контейнера от колебательных, действующих на контейнер (ротор), физических процессов. Являются ли эти процессы собственными резонансными механическими колебаниями корпуса контейнера, или они обусловлены переменными во времени внешними геофизическими, техногенными и другими факторами, предстоит выяснить в будущем. Хотя большой разброс выборочных значений гравиметрических данных обычно объясняют ошибками измерений и влиянием артефактов [1], временной, в диапазоне звуковых частот, и, вообще говоря, случайный характер гравитационного поля Земли естествен и, по-видимому, связан со сложными физическими процессами в ее объеме.

Влияние артефактов (плавучесть, сопротивление воздуха, случайные вибрации установки и др.) в описываемом эксперименте недостаточно для объяснения полученных результатов. Переменный, в диапазоне звуковых частот, характер гравитационного поля Земли наиболее заметно должен проявлять себя при динамических взвешиваниях тел

[3,6] и в экспериментах по измерению ускорений свободного падения вращающихся либо колеблющихся пробных тел. Баллистические гравиметрические измерения, выполненные с использованием вращающихся либо колеблющихся пробных тел, с высоким временным разрешением и при тщательном учете возможных сторонних воздействий, позволят установить причины наблюдаемых частотных зависимостей.

Выводы

1. Ускорение свободного падения контейнера с помещенным в нем ротором механического гироскопа, измеренное за время менее 0.05 с, значительно отличается от нормального ускорения силы тяжести и в диапазоне частот вращения ротора 20-380 Гц различие таких ускорений достигает нескольких единиц см/с^2. Как при вертикальной, так и при горизонтальной ориентациях оси вращения ротора, преобладает уменьшение ускорения свободного падения контейнера с вращающимся ротором.
2. Частотная зависимость изменения ускорения свободного падения контейнера (ротора) носит случайный, а на отдельных частотах вращения ротора, например, вблизи 320 Гц, резонансный характер.
3. Гравиметрические исследования, проводимые с высоким временным разрешением с использованием вращающихся либо колеблющихся пробных тел, информативны при измерениях динамических характеристик гравитационного поля Земли и будут способствовать развитию представлений о физике гравитационного взаимодействия.

Литература

1. В. Торге Гравиметрия, М. «Мир», 1999 г.
2. J. Luo, Y. X. Nie, Y. Z. Zhang, Z. B. Zhou Phys. Rev. D, Vol. 65, 042005 (2002).
3. А. Л. Дмитриев Известия ВУЗ «Физика», № 12, 65-69, 2001.
4. А. Л. Дмитриев, В. С. Снегов Измерительная техника, №8, 33-35, 2001.
5. A. L. Dmitriev AIP Conference Proc., Vol. 969, 1163-1169, 2008.
6. A. L. Dmitriev, E. M. Nikushchenko, S. A. Bulgakova AIP Conference Proc., Vol. 1208, 237-245, 2010.
7. В. А. Красильников, В. В. Крылов Введение в физическую акустику, М., «Наука», 1984 г.
8. Л. Г. Лойцянский Механика жидкости и газа, М. «Наука», 2003 г.
9. Г. Эберт Краткий справочник по физике, М. ГИФМЛ, 1963 г.

№ 20

SciVerse ScienceDirect

Physics Procedia

Physics Procedia 38 (2012) 150 – 163

Space, Propulsion & Energy Sciences International Forum-2012

Physical substantiation of an opportunity of artificial change of body weight

Alexander L. Dmitriev

St- Petersburg State University of Information Technologies, Mechanics and Optics, St- Petersburg, 49 Kronverksky Prospect, 197101, Russia

Abstract

Evangelical legends about «walking on waters» though they are apparently a fruit of imagination, can have a natural physical substantiation. Change of weight of accelerated moving bodies, confirmed with laboratory measurements of temperature dependence of body weight, in combination with an assumption of non-stationary character of the gravitational field of the Earth, directly leads to the conclusion regarding an opportunity of appreciable artificial change of body weight. The simple phenomenological model is described, according to which at the certain phase ratio of vertical oscillations of a trial body and small (with a relative level of amplitude equal to the tenth - 100-th fractions of per cent) own periodic fluctuations of normal acceleration of free falling (AFF) there are possible both a significant increase and a reduction of average weight of such a body. It is shown that at frequencies of the vertical fluctuations essentially exceeding frequency of own fluctuations of AFF the effect of reduction of average body weight prevails. Results of an experiment with "instant" measurements of acceleration of free falling of a mechanical rotor with horizontal axis of rotations which have confirmed the periodic changes of rotor AFF followed from the specified model are given. A good outlook for development of physics of gravitation and development of new principles of movement, set-up of precision experiments with weighing of bodies moving with acceleration, including those oscillating vertically along trial bodies, is noted.

Keywords: gravitation, weight, acceleration, phenomenological model, rotor.

NOMENCLATURE

A_c	coefficient of interaction of elastic and gravity forces by counter of $\vec{a}$ and total vector of gravity force ($m^{-1}\cdot s^{2}$)
A_p	coefficient of interaction of elastic and gravity forces by passing of $\vec{a}$ and total vector of gravity force ($m^{-1}\cdot s^{2}$)
$\vec{a}$	acceleration vector of external force (value of vector, $m\cdot s^{-2}$)
$a(t)$	variable acceleration of the material point ($m\cdot s^{-2}$)
B	amplitude of oscillation (m)
F	frequency (s^{-1})
$f(x)$	frequency function
g_0	normal acceleration of gravity ($m\cdot s^{-2}$)
m	mass (kg)
T	average absolute temperature of air (K)
V	volume of air in the container (cm^{3})
v	velocity of a sound ($m\cdot s^{-1}$)
x	ω/Ω
β	relative amplitude changes of AFF
γ	relative temperature change of piezoelectric ceramics weight by 1 degree (K^{-1})
$\tilde{\gamma}$	calculated factor ($kg^{-1/2}\cdot m^{5/2}\cdot s^{-1}$)
$\Delta\bar{g}$	average change of acceleration of free falling ($m\cdot s^{-2}$)
$\Delta\vec{g}_c, \Delta\vec{g}_p$	increments of acceleration of gravity (value of vectors, $m\cdot s^{-2}$)
$\Delta\tilde{T}$	average change of temperature of air in the container (K)
$\delta\tilde{m}$	change weight of the container (kg)
θ	the phase of changes of AFF (rad)
μ	A_c/A_p
ρ	density ($kg\cdot m^{-3}$)
τ	period of oscillation (s)
Ω	fraquency of changes of AFF ($rad\cdot s^{-1}$)
ω	angular velosity of oscillations of test body – material point ($rad\cdot s^{-1}$)

INTRODUCTION

In [1-3] the gravitational analogy of Faradays' electromagnetic induction phenomenon is considered. Accelerated under action of external (for example, elastic) forces, the movement of a test body downwards causes the increment $\Delta\vec{g}_p$ of acceleration of the gravity, acting on a body and directed from the centre of the Earth. On the contrary, the accelerated movement of a test body upwards is accompanied by a value $\Delta\vec{g}_c$ increase of acceleration of the gravity acting on the body. Change of acceleration of the gravity acting on a body, moving with acceleration $\vec{a}$ under influence of the elastic force, elementary (linear) approximation, is represented as

$$\Delta\vec{g}_{p,c} = -\frac{\vec{g}_0}{|\vec{g}_0|}(\vec{g}_0 \cdot \vec{a})A_{p,c} \quad , \qquad (1)$$

where symbols p,c mean passing (p) and a contrary (c) , in relation to a direction of vector $\vec{g}_0$ of normal acceleration of a gravity, orientation of a vertical projection of vector $\vec{a}$ of acceleration of external forces, and factors A_p and A_c characterize a degree of change of values $\Delta\vec{g}_{p,c}$.

1. WEIGHT OF MECHANICAL OSCILLATOR

If the massive body (for example, a ball) under action of the external, electromagnetic in nature, elastic force makes harmonious oscillations along a vertical with frequency ω and amplitude B , the average for the period $\tau = 2\pi/\omega$ of fluctuations value $\overline{\Delta g}$ of change of acceleration of free falling (AFF) of
such mechanical oscillator is equal to the sum of average changes of AFF in movement of a body passing
and contrary to vector $\vec{g}_0$,

$$\Delta\overline{g} = \Delta\overline{g}_p + \Delta\overline{g}_c \tag{2}$$

and at constant $g_0 = |\vec{g}_0|$ it is equal

$$\Delta\overline{g} = -\frac{g_0 B\omega^2}{\pi}(A_p - A_c) \quad . \tag{3}$$

From 3, it follows that at $A_p \succ A_c$, the average acceleration of free falling of mechanical oscillator, for example, a rotor with a horizontal axis of rotation, is less than value g_0 of normal acceleration of the gravity force. The reduction, averaged on several series of the measurements of the apparent weight of a rotor with horizontal axis, was observed in experiment [4], by results of which for the material of a rotor (stainless steel) it is possible to approximately estimate the order of value of difference $(A_p - A_c) \approx 10^{-7} g_0^{-1}$.

The absolute values of factors A_p and A_c can be measured on the basis of the shock mechanical experiments accompanied by the high, above $10^5 ms^{-2}$ accelerations of interacting bodies. For steel samples the order of values A_p and A_c is approximately equal to $10^{-2} g_0^{-1}$ [1,5].

2. TEMPERATURE DEPENDENCE OF WEIGHT OF BODIES

If to examine, as the considered above test body, a microparticle of a solid state body linked by elastic forces of inter-atomic interaction with other similar particles, then formulas 1-3 allow to explain the influence of temperature on acceleration of free falling (weight) of such a body.

The problem of influence of bodies' temperature on the force of their gravitational interaction has been discussed since long ago and the first precision experiments in this field were already carried out at the beginning of the XXth century [6]. The next stage of experimental studies of the said specified problem fell to the beginning of the current millenium when in Russia there were published the results of laboratory measurements of temperature dependence of weight of metal bars, indicating an appreciable negative temperature dependence of the gravitation forces [2,7,8], recently these results were confirmed in works of Chinese scientists [9].

The physical substantiation of relatively strong influence of temperature on force of gravitation consists in deep interrelation of electromagnetic and gravitational interactions, and their dependence on the accelerated movement of the microparticles forming a massive body, with intensity growing with growth of temperature [1,3]. In experiments [7,9], the weighed samples were heated up to comparatively high temperatures - from ten degrees up to hundreds.

A possible, in such conditions, influence on results of measurements of the thermal air convection, the change of temperature of the scales mechanism, the thermal change of residual magnetization and adsorption of moisture on the surface of samples, and so on – naturally caused caution and even mistrust in estimations of the obtained results. Meanwhile, the results of weighing the heated metal samples were obtained at high enough levels of an effective signal to noise ratio, with the careful account for the influence of the mentioned factors.

In the described experiment, there was carried out the weighing of samples of PZT-piezoelectric ceramics, whose temperature increased by near $2^0 C$ in respect to the normal room temperature ($24^0 C$). In so doing, the influence of temperature factors on accuracy of measurements of weight of samples was reduced to a minimum. The design of the weighed container is shown in Fig. 1.

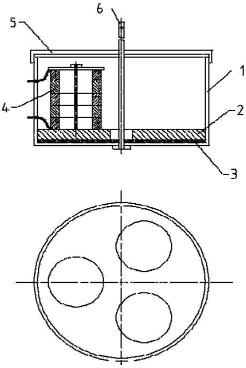


Fig. 1. The arrangement of container. 1- body, 2 – base, 3 – laying, 4 – PZT-pile, 5 – cover, 6 – hanging bar.

The container was placed in the closed box of analytical scales, the high-frequency electric signal was fed to electrodes of piezoelectric ceramics by means of elastic copper conductors $85 \mu m$ in diameter and 150 *mm* in length. The weighed sample is made in form of three "piles" ("sandwiches") of parallel-connected piezoelectric ceramic rings, 5 rings in each "pile", fixed on the massive brass base; the external diameter of rings is 22 *mm* , the internal diameter is 16 *mm* , height is 6 *mm* ; the full weight of 15 rings is equal to 112.9 *g* . In parallel to the power supply terminals of piezoelectric ceramics, there was connected the variable inductance for adjustment of resonance frequency of the supplied signal equal to 389 *kHz* , which allows to achieve the most effective heating of samples; the amplitude of the resonance signal is equal to 40 *V* . The readout of scales was carried out by the elongation method with the period of scale beam oscillations equal to 19.7 *s* . At full weight of the container equal to about 470 *g* , the error in reading out the changes of weight in time did not exceed 30 *mcg* .

An example of typical experimental time dependence of the container weight change is shown in Fig. 2.

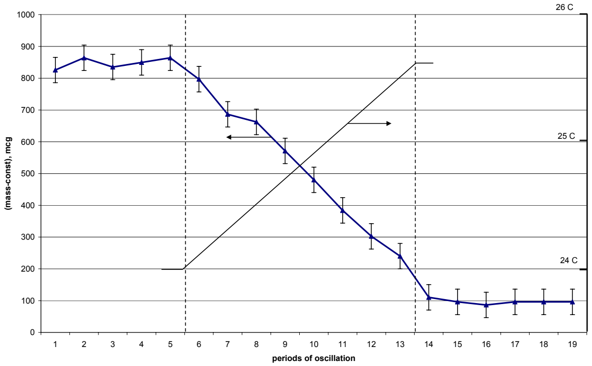


Fig. 2. Experimental time-dependence of container mass by heating PZT-pile from 24.0 till 25.7 ^{0}C. Touch lines is “in” and “out” moments. 1 period = 19.7 *s* .

The temperature of walls of the container remained practically a constant. On Fig. 3 the results of measurements of temperature of PZT-pile and air in the top (most heated) part of volume of the container are given.

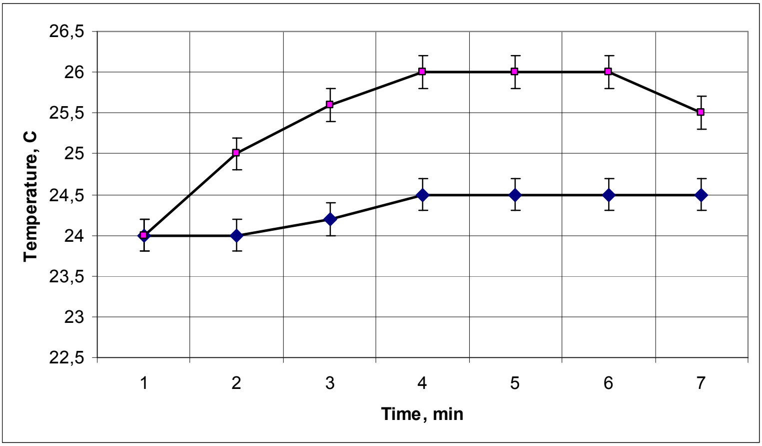


Fig. 3. An example the dependence of temperature of PZT-pile (the upper curve) and temperature of air in the top part of the container (the under curve) from time of heating. The point 1 on time-axis corresponds to the moment "in" of signal, a point 4 – "out".

Change $\delta\widetilde{m}$ of weight of the container, caused by temperature change of density of air taking place in it, equally

$$\delta\widetilde{m} = \rho V \Delta \widetilde{T} / T \qquad (4)$$

where ρ is density of air ($1.19\ kg / m^3$), V - volume of air in the container ($150 cm^3$), T – average absolute temperature of air ($297K$), $\Delta\widetilde{T}$ - average change of temperature of air in the container. It according with Fig 3, for duration of heating near 2.7 min, $\Delta\widetilde{T} \approx 0.25K$ and the corresponding change of weight of the container $\delta\widetilde{m} \approx 150 mcg$, that much less than full temperature change of weight of the container ($700 mcg$, Fig. 2).

According to Fig. 2, for $\Delta T = 1.75K$ and $\Delta m = 550mcg$ the relative temperature change γ of piezoelectric ceramics weight by 1 degree,

$$\gamma = \left(\frac{\Delta m}{m}\right)\frac{1}{\Delta T} \quad , \qquad (5)$$

is equal to $\gamma \approx -2.8 \cdot 10^{-6} K^{-1}$.

In [3,7] it is shown, that, in classical approximation,

$$\gamma \propto \frac{v}{\sqrt{\rho}} = \widetilde{\gamma} \quad , \qquad (6)$$

where v - velocity of a sound in a sample, ρ - density of a material. Experimental values of γ [7] and calculated sizes of factor $\widetilde{\gamma}$ are given in the Table.

Table. Characteristics of Samples and Results of Measurement of γ and Calculate values of $\widetilde{\gamma}$

Sample	**Lead**	**Cooper**	**Brass**	**Titanium**	**Duralumin**	**PZT**
ρ , $\cdot 10^3$ ($kg \cdot m^{-3}$)	11.34	8.89	8.55	4.50	2.79	7.2
v, $\cdot 10^3$ ($m \cdot s^{-1}$)	2.64	3.80	3.45	5.07	5.20	3.5
$\widetilde{\gamma}$, ($kg^{-1/2} \cdot m^{5/2} \cdot s^{-1}$)	0.783	1.275	1.181	2.391	3.114	1.306
γ, $\cdot 10^{-6}$ (K^{-1})	4.56	6.50	4.50	8.70	11.60	2.8

Their magnitudes normalized on the maximal value (for duralumin) are shown in the Fig. 4.

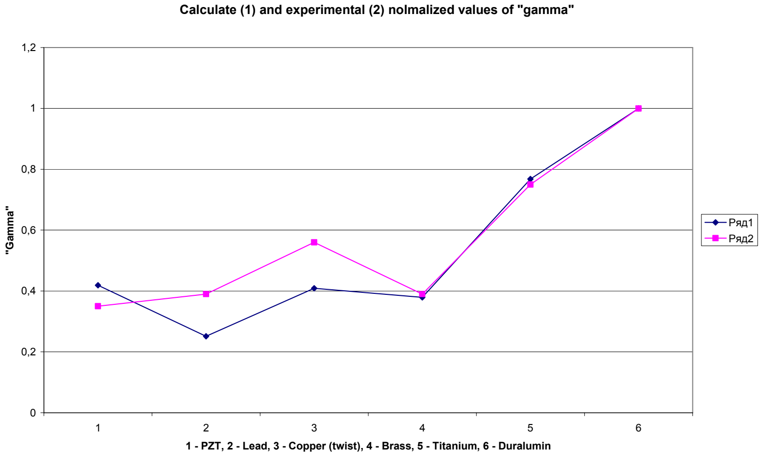


Fig. 4. Calculate (1) and experimental (2) normalized values of "gamma"

Let's note that close conformity of γ measurement results is realized with essentially different dimensions and configurations of the samples and containers which were used.

The satisfactory conformity of calculated and experimental data proves the correctness of physical preconditions put in a basis of elementary classical model of temperature dependence of weight [2,7]. It is necessary to note, that outside of classic approximation 6, by near to absolute zero temperatures of a weighed sample, the temperature dependence of weight of bodies, apparently, has other character and is not so strongly expressed, as at normal temperatures [10].

So, the laboratory experimental data, obtained in heating of piezoelectric ceramic samples for near 2 ^0C, confirm the negative temperature dependence of such sample weights. These data will essentially agree with high-temperature measurements of weight of non-magnetic metal bars.

3. *WEIGHT OF OSCILLATOR IN A VARIABLE FIELD OF GRAVITATION*

The considered above elementary model can be formally generalized, having introduced the time variable $g_0(t)$ value of normal acceleration of the gravity. Modern ballistic gravimeters provide the precision measurements of absolute values of g_0 , thus the best results have been obtained in statistical processing of the thousands of the given selected measurements of acceleration of free falling (AFF) and long access times of measurements (from seconds to days) [11,12]. Obviously, with such measurement techniques, the high-speed, having time of relaxation less than 0.1 s , fluctuations of value g_0 essentially can not be registered. Meanwhile, in view of the complex physical processes occurring in the core and volume of the Earth, and also under influence of external astronomical factors, the presence of rather strongly expressed maxima in a high-frequency (for example, a range of several hundreds – thousands of Hz) spectrum of fluctuations of value g_0 is probable. Following such assumption, we shall present elementary time dependence $g_0(t)$ as

$$g_0(t) = g_0(1 + \beta \sin(\Omega t + \theta)) \tag{7}$$

where Ω – frequency of changes of AFF value, β - their relative amplitude, θ- the phase. Acceleration $a(t)$ of the material point making harmonious oscillations along a vertical with amplitude *B* is equal to

$$a(t) = B\omega^2 \sin \omega t \quad , \qquad (8)$$

where ω - frequency of fluctuations.

The averages for oscillation half-cycle $\tau/2$ of values of changes of accelerations $\Delta\overline{g}_p$ and $\Delta\overline{g}_c$ are eqal to

$$\Delta\overline{g}_p = -A_p g_0 B\omega^2 \frac{2}{\tau}\int_0^{\tau/2} \sin \omega t(1+\beta\sin(\Omega t+\theta))dt \quad , \qquad (9)$$

$$\Delta\overline{g}_c = -A_c g_0 B\omega^2 \frac{2}{\tau}\int_{\tau/2}^{\tau} \sin \omega t(1+\beta\sin(\Omega t+\theta))dt \quad . \qquad (10)$$

The relative change of AFF of the oscillator, in view of 2, shall be presented as

$$\frac{\Delta \bar{g}}{g_0} = 4\pi A_p B F^2 f(x) \qquad , \qquad (11)$$

where $F = \Omega / 2\pi$, $x = \omega / \Omega$ and frequency function $f(x)$ is equal to

$$f(x) = -x^2 \left[\int_0^{\pi} \sin z (1 + \beta \sin(xz + \theta)) dz + \mu \int_{\pi}^{2\pi} \sin z (1 + \beta \sin(xz + \theta)) dz \right]; \ (12)$$

here $\mu = A_c / A_p$ and $z = \omega t$.

Examples of frequency functions $f(x, \mu, \theta, \beta)$ at various parameters μ, θ, γ , and both low (a) and high (b) values of x are shown in Fig. 5, 6.

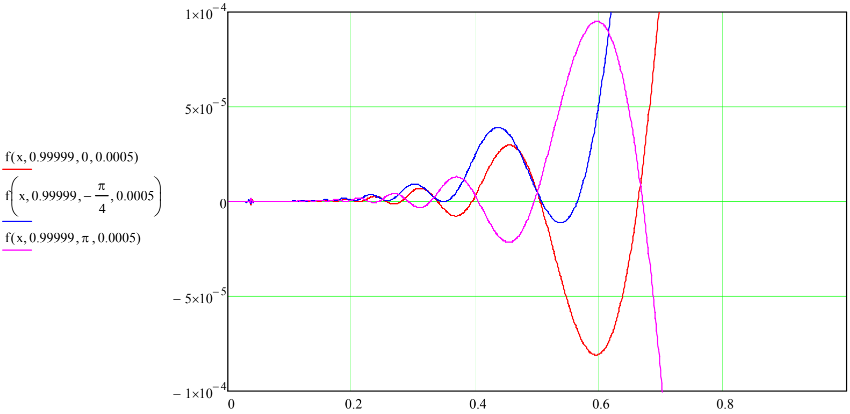


Fig. 5 a

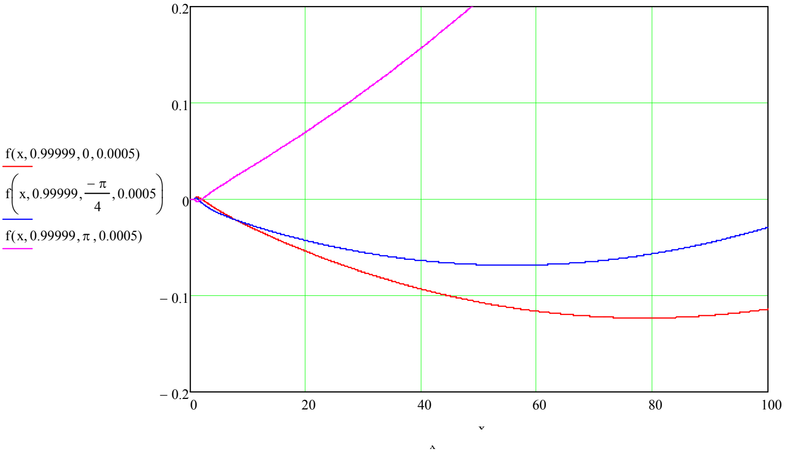


Fig. 5 b

Fig. 5 . Examples of frequency functions $f(x,\mu,\theta,\beta)$ at low (a) and high (b) values of argument x ; relative amplitude of fluctuations AFF $\beta = 0.0005$.

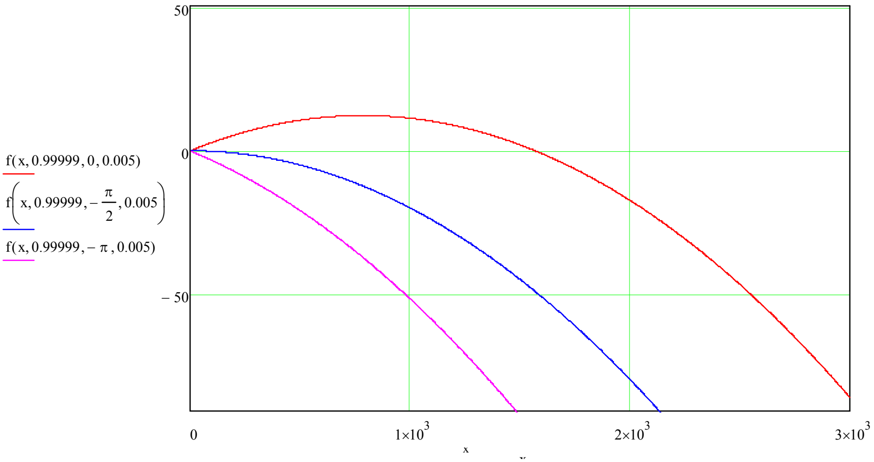


Fig.6a

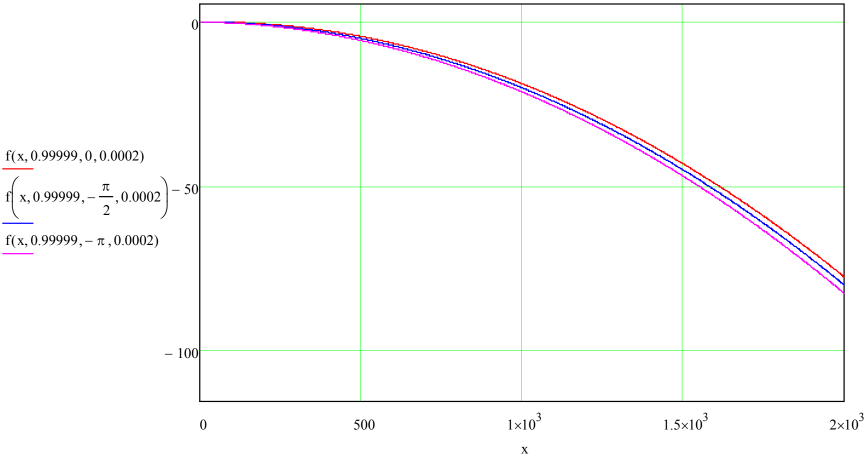


Fig.6b

Fig. 6 . Examples of frequency functions $f(x,\mu,\theta,\beta)$ at the high values of argument x ; a. - relative amplitude of fluctuations AFF $\beta = 0.005$, b - $\beta = 0.0002$.

Obviously, the sign and a general view of functions $f(x)$ essentially depend on parameters μ,θ,β. According to estimations given above, in the calculations, μ = 0.99999 is assumed. The given calculated dependences show that even at small, with relative value of about the 100-th fractions of percent, amplitudes β of fluctuations in value of normal acceleration of the gravity of the Earth, the weight of mechanical oscillator can be changed appreciably.

At frequencies ω of oscillations, with an order of the frequency Ω of own fluctuations of AFF, in area $x \leq 1$, the weight of oscillator is periodically changes with frequency, with sign and values of such changes essentially depending on a difference of phases θ of oscillations and AFF (Fig. 5a). At high $(x \succ\succ 1)$ frequencies of oscillator, the monotonous dependence of average weight of oscillator on frequency of its fluctuations is taking place, with influence of phase θ being insignificant (Fig. 6b). Such reduction of weight of oscillator at high frequencies of fluctuations will agree with temperature dependence of weight of bodies as the frequencies of thermal fluctuations of microparticles of solid state bodies are rather high and lie in the field of the hypersound [13].

4. EXPERIMENTAL DEPENDENCE OF ACCELERATION OF FREE FALLING ROTOR

Experimental check of the dependence of average weight of the above-considered oscillator on frequency of its fluctuations can be executed, measuring the instant values of acceleration of free falling rotor. Mechanical rotor is the system of the accelerated, moving on a circular trajectory microparticles, forming a solid state body, and linked to each other by forces of elasticity. With horizontal orientation of rotor rotation axis, the vertical component of trajectories of movement of particles of the rotor corresponds to the oscillations of such particles considered in
[3]. Measurements of instant values of free falling acceleration of the closed container with the rotor of vacuum mechanical gyroscope fixed inside are described in [14,15]. The rotor (mass is 250 *g*) gathered momentum up to the maximal frequency 400
Hz , then during the run out time (about 22 min) its frequency smoothly decreased, the container was periodically dropped down, and by method of falling scale, the instant values of acceleration of free falling of the container were measured. The example the frequency dependence of change of acceleration of free falling container with a rotor fixed inside it, and with horizontally positioned axis of rotor is shown in Fig. 7.

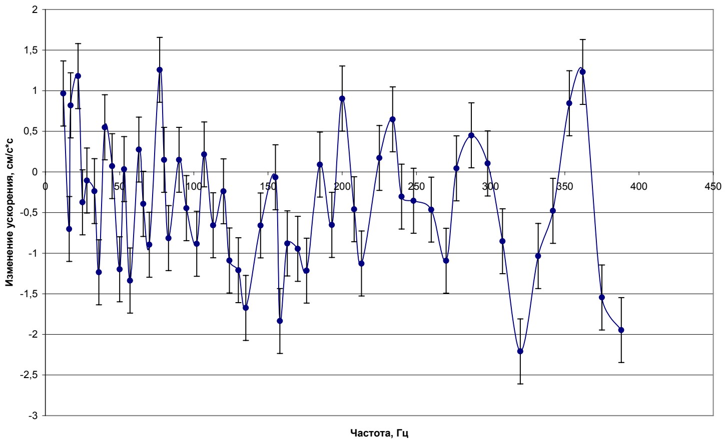


Fig. 7. The frequency dependence of free falling acceleration of the container with horizontally positioned rotor; the changes of AFF (*Gal*) relatively to the value of AFF with the stopped rotor have been shown.

Comparing Fig. 5a and Fig. 7, it can be seen that the area of steady periodic changes of AFF in Fig. 7 in a band of frequencies 200-400 *Hz* approximately corresponds to the area in a vicinity of value $x \approx 0.5$ in Fig. 5a. Having substituted in 11 the experimental value $\Delta g / g_0 \sim 10^{-3}$, assumimg $A_p \sim 10^{-2} g_0{}^{-1}$, $f(x) \sim 10^{-5}$, we obtained an estimation of amplitude $B \sim 1.4$cm of oscillator. The given size almost coincides with radius of the rotor used in experiments. At oscillation frequencies tens times higher than the frequencies F of own fluctuations of normal acceleration of the gravity (according to the given estimations, $F \sim 300$ / 0.5 = 600*Hz*) and following the suggested model, there is observed a monotonous frequency dependence of change $\Delta \overline{g}$ of average value of acceleration of free falling oscillator, with sign $\Delta \overline{g}$ beingis directly determined by the difference of phases θ of fluctuations AFF and oscillator (Fig. 5b, Fig. 6a). Within the limits of applicability of formulas 7,11 there are possible both substantial growth and reduction of the average gravity working on mechanical oscillator on the part of the variable gravitational field of the Earth. Let's note that the independent measurements of high frequency, in the range of hundreds –

thousands of *Hz* , spectra of fluctuations of acceleration of the gravity of the Earth, executed, for example, with use of superconducting gravimeters, will allow to define modes of the matched fluctuations of oscillator at which the changes of its average weight can essentially surpass the ones described by formulas 7-11.

The above-given estimations have the selective, illustrative character. Nevertheless, the considered simple phenomenological model finely explains the experimental dependences and agrees with the known data of measurements of weight of accelerated moving test bodies.

Experimental researches into free falling mechanical oscillators (rotors, vibrators) will allow to bring the necessary specifications into the offered models, to determine the borders of their applicability, and to prove more strictly the size parameters introduced into these models. Such researches will promote obtaining the new data on dynamic characteristics and specific features of the gravitational field of the Earth.

CONCLUSION

The considered above model does not contradict to the known experiments for exact measurements of masse and weight of bodies, and explains the influence of temperature and accelerated (oscillatory or rotary) movements of a body on its average weight. The experimental researches of gravitational analogies of the electrodynamic phenomena should promote the active development of both physics of gravitation and its applications in metrology of weight and gravimetry.

In the immediate prospects, the following directions of researches into features of gravitational interaction of accelerated moving bodies seem to be expedient.

First, the researches into temperature dependence of weight of bodies of various physical and chemical structures, conducted in the wide range of absolute temperatures of test bodies. Second, the exact measurements of weight of bodies in a condition of oscillatory and rotary movements, and also in shock mechanical experiments. Third, the experimental researches into high-frequency ranges up to several hundreds - thousands *Hz* , spectra of fluctuations of normal acceleration of the gravity of the Earth.

The experimental results obtained during such researches will allow to specify and improve the phenomenological models in the description of the "non -classical" gravitational phenomena, breaking the frameworks of the simple Newton approximation, and probably to specify the ways of their effective practical applications.

Acknowledgements

The author brings thanks to E. M. Nikushchenko for help in the experiments.

References

[1] Dmitriev, A. L., On the Influence of External Elastic (Electromagnetic) Forces on the Gravity, *Russian Physics Journal,* 2001; **44** (12), 1323-1327 .

[2] Dmitriev, A. L., Measurements of the Influence of Acceleration and Temperature of Bodies on their Weight, in proceedings of *Space Technology and Application International Forum (STAIF-2008),* edited by M. El-Genk, AIP Conference Proceedings **969**, New York, 2008, pp. 1163-1169.

[3] Dmitriev, A. L. Analogue of Lenz's Rule in Phenomenological Gravitation, in proceedings of *Space, Propulsion & Energy Sciences International Forum (SPESIF-2009)*, edited by G. A. Robertson, AIP Conference Proceedings **1103**, New York, 2009, pp. 345 – 351.

[4] Dmitriev, A. L., and Snegov V. S., Weighing of a Mechanical Gyroscope with Horizontal and Vertical Orientations of the Spin Axis, *Measurement Techniques*, 2001; **44(**8), 831-833.

[5] Dmitriev, A. L., Inequality of the Coefficients of Restitution for Vertical and Horizontal Quasielastic Impacts of a Ball Against a Massive Plate, *International Applied Mechanics*, 2002; **38** (6), 747 – 749.

[6] Shaw P. E. and Davy N. The Effect of Temperature on the Gravitative Attraction, *Phys. Rev.* 1923; **21** (6), 680-691.

[7] Dmitriev, A. L., Nikushchenko, E. M., and Snegov, V. S., Influence of the Temperature of a Body on its Weight, *Measurement Techniques*, 2003; **46** (2), 115 – 120.

[8] Dmitriev A. L. Experimental Study of Gravity Force Temperature Dependence, *18th International Conference on General Relativity and Gravitation (GRG18),* Abstract Book, 2007; 77-78.

[9] Liangzao Fan, Jinsong Feng and Wuqing Liu An Experimental Discovery about Gravitational Force Changes in Materials due to Temperature Variation, *Engineering Sciences*, China, 2010; **12** (2), 9-11.

[10] Tajmar M., Plesescu F. and Seifert B., Measuring the dependence of weight on temperature in the low-temperature regime using a magnetic suspension balance , *Meas. Sci. Technol.* 2010; **21**, 015111 (7pp).

[11] Torge W. *Gravimetry,* Walter de Gruyter, Berlin-New York, 1989.

[12] Jentzsch G. et al. (Editors), Time Varying Gravimetry (Special Issue*),* *Journal of Geodynamics*, **38**(3-5), (2004).

[13] Anselm A. I. *Osnovy statisticheskoj fiziki I termodinamiki* , Nauka, Moskva, 424 p.,1973.

[14] Dmitriev A. L., Nikushchenko E. M. and Bulgakova S. A. Nonzero Result of Measurement of Acceleration of Free Falling Gyroscope with the Horizontal Axis, http://arXiv.org: 0907.2790v1[physics. gen-ph], pdf 2009.

[15] Dmitriev A. L. Frequency Dependence of Rotor's Free Falling Acceleration and Inequality of Inertial and Gravity Masses, http://arXiv.org:1101.4678v1 [physics. gen-ph], pdf 2011.

№21

World Academy of Science, Engineering and Technology Vol. 79, July 2013, pp 1560-1565

Negative Temperature Dependence of a Gravity - A Reality

***Abstract*—Temperature dependence of force of gravitation - one of fundamental problems of physics. This problem has got special value in connection with that the general theory of a relativity, supposing the weakest positive influence of a body temperature on its weight, actually rejects an opportunity of measurement of negative influence of temperature on a gravity in laboratory conditions. Really, the recognition of negative temperature dependence of gravitation, for example, means basic impossibility of achievement of a singularity («a black hole») at a gravitational collapse. Laboratory experiments with exact weighing the heated up metal samples, indicating negative influence temperatures of bodies on their physical weight are described. Influence of mistakes of measurements is analyzed. Calculations of distribution of temperature in volume of the bar, agreed with experimental data of time dependence of weight of samples are executed. The physical substantiation of negative temperature dependence of weight of the bodies, based on correlation of acceleration at thermal movement of micro-particles of a body and its absolute temperature, are given.

***Keywords*—Gravitation, temperature, weight.

I. INTRODUCTION

By the papers in the most authoritative scientific journals, the last experimental work dealing with research of temperature dependence on the force of gravitation was published in 1923 by Shaw and Davy in Phys. Rev. [1]. For the next 80 years interest to this theme had considerably fallen that was promoted much by the statement which

---

Alexander L. Dmitriev is with the National Research University of Information Technologies, Mechanics and Optics, St. Petersburg, 49, Kronverksky Prospect, Russia (phone/fax: +7 812 3154071; e-mail: alex@dmitriyev.ru).

Sophia A. Bulgakova is with the National Research University of Information Technologies, Mechanics and Optics, St. Petersburg, 49, Kronverksky Prospect, Russia (phone/fax: +7 812 3154071; e-mail: lija84@ mail.ru).

had been made within the general theory of relativity regarding the smallest and practically not observable positive temperature dependence of physical weight of bodies. Meanwhile, a careful analysis of experimental data of Shaw and Davy shows that even those authors actually observed appreciable negative temperature dependence of force of gravitation [2].

At the beginning of the 21st century some works of the Russian and Chinese researchers showing rather strong negative influence of temperature on weight of bodies [3-6] became known. Nevertheless, the enormous reputation of the general theory of relativity till now sets barriers to the organization of experimental researches of temperature dependence of gravitation.

Actually, negative temperature dependence of force of gravitation directly contradicts the general theory of relativity and, in particular, puts under doubt a reality of achievement of a singularity condition at a gravitational collapse; hence, it also forces to doubt some popular cosmological theories.

No matter how reasons of pure theorists were convincing, physics is primarily an experimental science and it is just experience that makes basis of adequate physical concepts.

The paper provides the results of recent laboratory experiment s regarding studying the influence of temperature on physical weight of bodies and considers some simple phenomenological models allowing to prove the obtained experimental data.

II. TEMPERATURE «DEFECT OF WEIGHT»

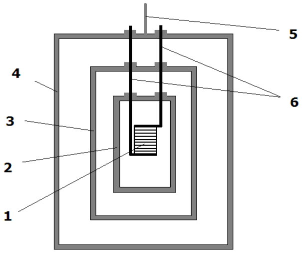
The results of measurements of mass of thermo-isolated containers containing heated up metal elements in which temperature reduction of weight is regularly observed and which can not be explained by the action of artefacts are submitted below.

A. Containers with Electric Heaters

In the first series of measurements a copper sample which is placed inside a three-layer container was heated up before weighing by means of an electric spiral. The design of such container (No 1) is shown in Fig. 1.

Here 1 – a cooper sample with a winding of an electric heater; 2,3 – cylinders from titan; 4 - cylinder from brass; 5 - a wire of suspension bracket of container; 6 – cooper conductors.

Use of container in form of three enclosed tight metal cylinders with thickness of walls of 1.0 *mm*, two of which are made of titan - a material with low factor of heat conductivity, and the external cylinder - from brass, improves thermo-isolation properties of the container. The heated sample is a copper core 10 *mm* in diameter, height of 15 *mm*, weight of 10.3 *g* which is wrapped up with a layer of mica and an incandescence filament - Nichrome wire 0.3 *mm* in diameter.



Tightness of containers is provided by tight fit of cylinders covers and by «cold welding» of all elements of the joint, including electrodes of the heater. Weight of the collected container is 128 *g*, diameter of the external cylinder is 40 *mm*, height is 51 *mm*. Time of heating of a copper sample is 60 *s*, current in the circuit of the heater is 1.5 *A*, electric resistance of the heater is 6 *Ohm*. Under the specified conditions of the experiment the temperature of the external of a calibrated thermo-element.

After heating the container was weighed with laboratory scales of wall of the container was preliminarily measured by means XP2004S Precision trade mark by firm «Mettler-Toledo GmbH» under normal conditions of atmosphere in the working room (temperature of air is 24^0C, humidity - 45 %, pressure - 1000 *hPa*). Results of measurements of the current values of mass of the container and temperatures of its surface are given in Fig. 2. Here, there is also shown calculated according to temperature measurements change of weight of the container, caused by influence of air convection.

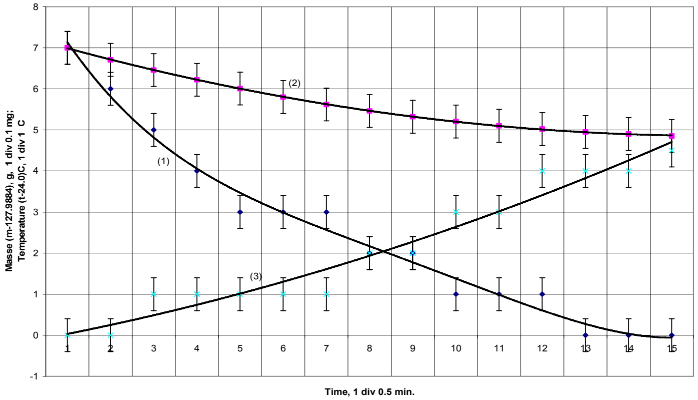


Fig. 2 1 - experimental time dependence of weight of container No 1; 2 - calculated dependence of weight of the container with account for influence of air temperature convection; 3 - change of temperature of surface of the external cylinder

The design of container No 2, with external cylinder made of steel, is shown in Fig. 3.

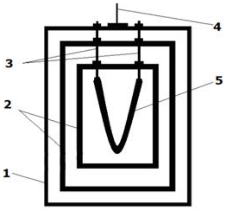


Fig. 3. The design of the container No 2. 1 - a cylinder made of steel, 2 - cylinder made of titan, 3 - copper electrodes, 4 - a suspension bracket, 5 - an electric spiral

Here as a heater, there is used a Nichrome spiral with weight of 540 *mg*, suspended inside the small cylinder. The full weight of the container is 167 *g*, thickness of walls of the external cylinder - 1.5 *mm*, diameter - 40 *mm*, height - 53 *mm*; thickness of walls of internal cylinders from titan - 2.0 *mm*. An electric heater with 10.5 *Ohm* resistance was connected to a power source (voltage 15 *V*, current 1.3 *A*) for 40 *min*, then the container was weighed. Results of measurements of mass of container No 2 and temperatures of the wall of the external cylinder are given in Fig. 4.

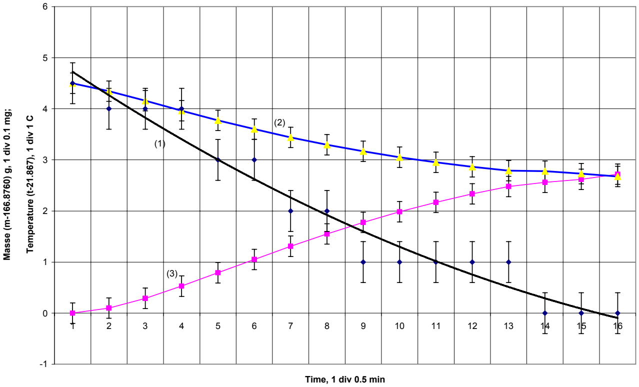


Fig. 4 1 - experimental time dependence of weight of container No 2; 2 - calculated dependence of weight of the container with account for the influence of temperature air convection; 3 - change of temperature of the surface of the external cylinder

B. A Container with a Chemical Heater

The design of container No 3, in which heating of a tight steel cylinder made of stainless steel was carried out by a chemical method, is shown in

Fig. 5.

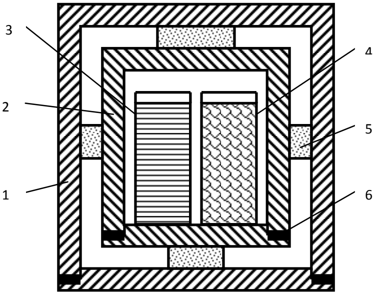


Fig. 5. The design of container No 3 with chemical heating of the internal cylinder. 1 - the external cylinder; 2 - the internal cylinder; 3 - an open vessel with distilled water; 4 - an open vessel with crystals of NaOH; 5 - polyfoam; 6 - vacuum sealing

Diameter of the external brass-cylinder is 60 *mm*, height - 62 *mm*, thickness of walls - 3.5 *mm*, weight - 475 *g*; diameter of the internal cylinder - 45 *mm*, height - 46 *mm*, thickness of walls -4.5 *mm*, weight - 280 *g*. In the condition specified in the figure the temperature of the internal cylinder is constant, the weight of completely equipped container is equal to 773.7651*g*.

Measurements of weight with a margin error readout of 0.1 *mg* were also carried out with laboratory scale of XP2004S mark at temperature of air in a working room equal to 19.8 ^{0}C, humidity - 31.8 %, pressure - 1022 *hPa*.

In the course of measurements the container was overturned, then the current value of its weight was registered. In the overturned condition, inside the small cylinder, there is going a process of partial dissolution of crystals NaOH (masse of 5 *mg*) in distilled water (masse of 6 *mg*) which is accompanied by heat release. The temperature of the mix in the first seconds of reaction grows by 10 ^{0}C, and, as have been shown by special measurements, the average temperature of the internal temperature of the mix in the first seconds of reaction grows by 10 ^{0}C, and, as have been shown by special measurements, the average temperature of the internal cylinder, owing to a heat transfer, is smoothly increased by 3-4 ^{0}C within the first two-three minutes. A specific feature of the given experiment is that, first, the process of dissolution of crystals of alkali is not accompanied by release of gases and, due to reliable sealing of covers of containers, the release of air from small and big cylinders (and the corresponding handicap to weighing) is absent. Second, due to the big weight of the external cylinder, the temperature of its surface, owing to a heat transfer, increases during the first two minutes by no more than by 0.2 ^{0}C. As a result, apparent reduction of weight of the container caused by air convection, which is determined by differences of temperatures of the surface of the container and the ambient air, in the first 2-3 minutes of measurements does not exceed 0.1 *mg*. High durability of the external cylinder also practically excludes influence of its weak temperature deformations on change of buoyancy of the weighed container.

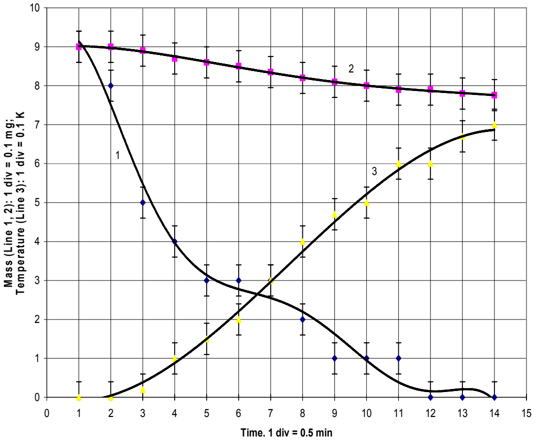


Fig. 6. 1 - experimental time dependence of change of weight of container No 3 in the overturned position; 2 - calculated dependence of change of weight of the container with account for influence of temperature air convection; 3 - experimental dependence of temperature of the surface of the external cylinder

Fig. 6 shows experimental time dependences of weight of container No 3, temperatures of its surface, and the calculated value of weight caused by temperature convection of air close to the walls of the container. Obviously, the paths of curves 1 and 2 essentially differ, accompanied by a typical sharp fall of weight of the container during the first minutes of measurements.

C. Calculation of Influence of the Basic Artefacts

Let's estimate influence of temperature artefacts on the results of measurements of weights of samples [7].

TABLE I

CALCULATED TOTAL ($\Delta m_\Sigma = \Delta m_1 + \Delta m_2 + \Delta m_3$) AND EXPERIMENTAL ($\Delta m$) IS TEMPERATURE REDUCTION OF WEIGHTS OF CONTAINERS № 1-3

№	d, mm	h, mm	δ, mm	$\alpha \cdot 10^6$, K^{-1}	ν	$E \cdot 10^{-10}$, N/m^2	ΔT, K	Δm_1, mcg	Δm_2, mcg	Δm_3, mcg	Δm_Σ, mcg	Δm, mcg
1	40	51	1.5	18.9	0.36	9	1.4	6.0	$\prec 100$	107	$\prec 213$	440
2	40	53	1.3	11.9	0.30	20	1.0	2.8	$\prec 80$	86	$\prec 169$	225
3	60	62	3.5	18.9	0.36	9	0.22	2.6	$\prec 290$	54	$\prec 346$	640

Change Δm_1 of apparent weight of the container, caused by change of volume of the steel cylinder owing to thermal expansion of its material is equal to

$$\Delta m_1 = \frac{3\pi}{4}\rho d^2 h \alpha \Delta T \tag{1}$$

where ρ - density of air, α - factor of linear expansion of material of the cylinder, d - its diameter, h - height. Change Δm_2 of apparent weight of the container, caused by deformations of walls of the cylindrical vessel, owing to temperature change of air pressure ΔP within its volume, as it is possible to show on the basis of the theory of elasticity [8], is equal to:

$$\Delta m_2 = \frac{\pi\rho h d^3 \Delta P}{4\delta E} + \frac{\pi\rho d^3}{16}\sqrt[3]{\frac{3(1-\nu)d\Delta P}{2\delta E}} \tag{2}$$

where δ - thickness of walls, E - the modulus of elasticity and ν - Poisson’s ratio . The size ΔP is connected to change of temperature ΔT of air within the volume of the external cylinder $\Delta P = P\Delta T / T$, where P - normal pressure of atmosphere and T - temperature of air in the cylinder. The given estimate is overestimated, as in the second addend of formula 2, describing deformation of face walls of a vessel, such walls are presented by thin membranes; actually, the deflection of end faces is less than it is supposed in conclusion 2.

The change Δm_3 of apparent weight of the container, caused by air convection due to difference ΔT of temperatures of surface of the external steel cylinder and temperatures of air in the closed box of analytical balance, will be estimated on the basis of [9] according to which

$$\frac{\Delta m_3}{A d^{1/4} \Delta T^{3/4}} = 9.2 \cdot 10^{-7} g cm^{-9/4} K^{-3/4} \tag{3}$$

where the area of lateral surface of the cylinder is $A = \pi dh$.

In Table I the experimental and calculated values of change of weights of containers No 1-3, corresponding to the third minute of measurements are given. In the given calculations the density of air $\rho = 1.19 kg/m^3$, $\Delta T = 3^0 K$ (obviously overestimated value), $\Delta P = 1020 N/m^2$.

Obviously, observable (registered) reduction of weights of containers essentially, with account for errors of measurements, exceeds calculated one.

III. PHENOMENOLOGICAL MODEL OF TEMPERATURE DEPENDENCE OF GRAVITY

A. General Provisions

Let's consider the gravitational analogy of the phenomenon of Faraday electromagnetic induction and Lenz rules - Fig. 7 [10], [11].

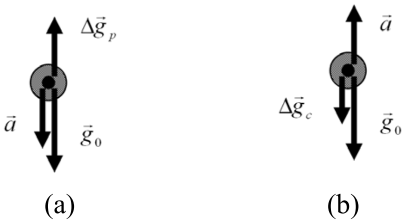


Fig. 7 Gravity analogy of the Faraday induction law and the Lenz rules

Proceeding from the principle of inertness of mechanical system, that is, its tendency to preserve the stable state, accelerated under action of external, for example, elastic force of movement of a test body downwards (Fig. 7 (a)) should cause an increment $\Delta\vec{g}_p$ of acceleration of the gravity applied to a body which is directed from the centre of the Earth. On the contrary, the accelerated movement of a trial body upwards (Fig. 7b) is accompanied by increase of acceleration of the gravity applied to a body by value $\Delta\vec{g}_c$. Values $\Delta\vec{g}_p$ and $\Delta\vec{g}_c$, generally speaking, can be different. Change of acceleration of the gravity acting on a body, moving with acceleration $\vec{a}$ under influence of the elastic force, in the elementary (linear) approximation, is represented as

$$\Delta\vec{g}_{p,c} = -\frac{\vec{g}_0}{|\vec{g}_0|}(\vec{g}_0 \cdot \vec{a})A_{p,c} \qquad (4)$$

where symbols p, c mean passing (p) and a contrary (c), in relation to a direction of vector $\vec{g}_0$ of normal acceleration of a gravity, orientation of a vertical projection of vector $\vec{a}$ of acceleration of external forces, and factors A_p and A_c characterize a degree of change of values $\Delta\vec{g}_{p,c}$. If the massive body (for example, a ball) under action of the external, electromagnetic in nature, elastic force makes harmonious oscillations along a vertical with frequency ω and amplitude b, the average for the period $\tau = 2\pi/\omega$ of fluctuations value $\Delta\bar{g}$ of change of acceleration of free falling (AFF) of such mechanical oscillator is equal to the sum of average changes of AFF in movement of a body passing and contrary to vector $\vec{g}_0$,

$$\Delta\bar{g} = \Delta\bar{g}_p + \Delta\bar{g}_c \qquad (5)$$

and at constant $g_0 = |\vec{g}_0|$ it is equal

$$\Delta\bar{g} = -\frac{g_0 b\omega^2}{\pi}(A_p - A_c) \quad . \quad (6)$$

From (6), it follows that at $A_p \succ A_c$, the average acceleration of free falling of mechanical oscillator, for example, a rotor with a horizontal axis of rotation, is less than value g_0 of normal acceleration of the gravity force. The reduction, averaged on several series of the measurements of the apparent weight of a rotor with horizontal axis, was observed in experiment [12], by results of which for the material of a rotor (stainless steel) it is possible to approximately estimate the order of value of difference $(A_p - A_c) \approx 10^{-7} g_0^{-1}$.

The absolute values of factors A_p and A_c can be measured on the basis of the shock mechanical experiments accompanied by the high, above $10^5 ms^{-2}$ accelerations of interacting bodies. For steel samples the order of values A_p and A_c is approximately equal to $10^{-2} g_0^{-1}$ [13].

If to consider as the mentioned above trial body a microparticle of a solid body bound together by forces of interatomic interaction with other similar particles, formulas 1-3 allow to explain influence of temperature on acceleration of free falling (weight) of such body [4]. Thermal movement of microparticles of a solid body is accompanied by their significant accelerations, in so doing, the average value a_s of a projection of these accelerations on a vertical is proportional to average speed of chaotic movement of microparticles. In a classical approximation, at a body temperature higher than the one of Debye-temperatures, the acceleration a_s is in direct ratio to a square root from an absolute body temperature T,

$$a_s = C\sqrt{T} \qquad (7)$$

where C - the factor dependent on physical properties of a material.

In one-dimensional approximation, we can consider a test body as a chain of microparticles bound by elastic forces, as shown in [3], [10],

$$C \propto \frac{v}{\sqrt{\rho}} \qquad (8)$$

where v - speed of a longitudinal acoustic wave in a solid test body and ρ - its density.

Formally, having replaced in equation (6) the average for the period of fluctuations magnitude of acceleration $b\omega^2/\pi$ with average acceleration of particles a_s, we shall present the temperature dependence $P(T)$ of weight of a body as

$$P(T) = P_0(1 - B\sqrt{T}) \qquad (9)$$

where m - weight of a body, $P_0 = mg_0$, $B = C(A_p - A_c)$.

In a small range of temperatures the linear dependence of changes ΔP of weight and ΔT of a body temperature is satisfied,

$$\Delta P = -P_0 B \frac{\Delta T}{2\sqrt{T}} \quad . \qquad (10)$$

Negative temperature dependence of weight of not-magnetic metal samples at close to normal ($300K$) temperatures of bodies experimentally proves to be true, in so doing, the relative change of weight for a unit of temperature

$$\gamma = \frac{\Delta P}{P_0 \Delta T} = -\frac{B}{2\sqrt{T}} \qquad (11)$$

is equal to several units $10^{-6} K^{-1}$ [4].

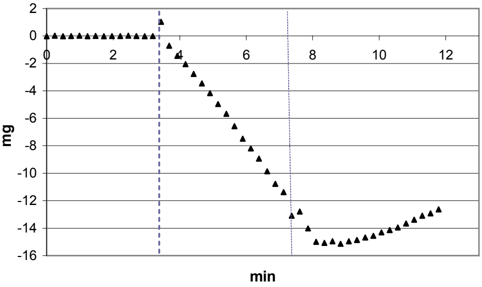


Fig. 8 Change in time of apparent weight of the metal core which is heated up with an ultrasonic radiator

The typical increase of value γ along with reduction of density of a sample material is observed that is in agreement with (8) (see Table II). (We should note that outside the limits of considered classical approximation, for example, at close to zero absolute temperatures of bodies, formulas 7-8 are not satisfied).

TABLE II

CHARACTERISTICS OF SAMPLES AND RESULTS OF MEASUREMENT [4]

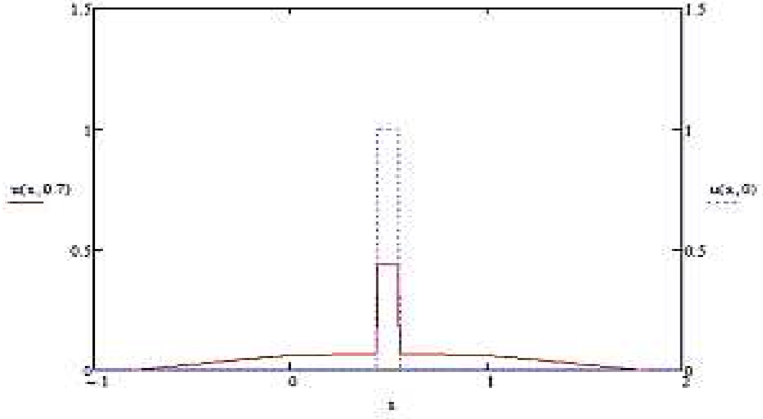
Sample	Lead	Copper	Brass	Titani-um	Dura-lumin
Length, *mm*	80.2	71.6	140.0	140.0	140.0
Diameter, *mm*	8.0	10.5	8.0	8.0	8.0
Mass, *g*	45.6	39.2	58.5	31.2	19.1
Ultra-sound Frequen-cy, *kHz*	135.43	129.70	131.27	136.22	134.90
$\gamma \cdot 10^6\ K^{-1}$ $(\overline{T} = 300K)$	4.56	6.50	4.50	8.70	11.60

The magnitude of factor B for the mentioned above materials is within the limits of $(1.5 \div 2.4) \cdot 10^{-4} K^{-1/2}$.

B. Calculation of Time Change of Weight of a Core

Strong calculation of time change of weight of the container containing a heater, is based on the decision thermo-physical tasks about distribution of heat to elements of its design. Owing to necessity of the account of boundary conditions and various physical properties of materials, the decision of such task is carried out by computing methods. The general tendency of time change of weight of the container at the initial moments of time of weighing

Fig. 9 Distribution of temperature (here - u) on length (x) of a bar in initial (a shaped line) and the subsequent (a continuous line) the moments of time



can be found at the decision of a simple task on distribution of heat in a homogeneous bar. The one-dimensional equation of heat conductivity for thermo-isolated a homogeneous bar looks like

$$\frac{\partial T}{\partial t} = \frac{\chi}{c\rho}\left(\frac{\partial^2 T}{\partial x^2}\right) \qquad (12)$$

where $T(x,t)$ - function of distribution of temperature, χ - factor of heat conductivity, c - a specific thermal capacity of a material of a bar, ρ - density.

The example of temperature distribution on length of a bar in initial $t(0)$ and the subsequent the moments of time are shown on Fig. 9.

With the account (6), time dependence $m(t)$ of weight of a bar in length L is represented by integral

$$m(t) \propto \int_0^L \left(1 - B\sqrt{T(x,t)}\right)dx \ . \qquad (13)$$

The example of settlement dependence $m(t)$ is shown on Fig. 10.

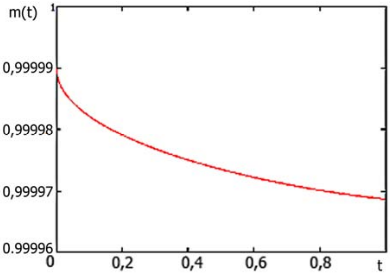


Fig. 10 Time dependence $m(t)$ full weight of a homogeneous bar (in relative units)

Apparently from this figure, for the initial moments of process of distribution of heat typically sharp reduction of weight of a bar. The similar tendency in experiments is observed that is especially appreciable on Fig. 2 and Fig. 6.

IV. CONCLUSION

Temperature dependence of force of gravitation - one of fundamental problems of physics. The negative temperature dependence of weight of bodies is confirmed by laboratory experiments and similar to Faraday phenomenon in electrodynamics is a consequence of natural "conservatism" of physical system, its tendency to preserve a stable condition. Realization of experimental researches of influence of temperature of bodies on their gravitational interaction is timely and, undoubtedly, will promote progress of development of physics of gravitation and its applications. We welcome consolidation of efforts of various groups of researchers, both experimenters and theoreticians for implementation of this important problem.

ACKNOWLEDGMENTS

Authors thank Yu. I. Kamenskih, V. S Snegov and E. M. Nikushchenko for the help in experiments, and Doctor of Chemistry I. B. Dmitrieva for recommendations regarding the choice of a chemical heater.

REFERENCES

[1] P. E Shaw., N. Davy Phys. Rev., 21(6), 680 (1923).
[2] A. L. Dmitriev arXiv:physics/0611173.
[3] A. L. Dmitriev, E. M. Nikushchenko and V. S. Snegov Measurement Techniques, 46 (2), 115 (2003) .
[4] A. L. Dmitriev AIP Conference Proceedings 969, 1163 (2008).
[5] L.Fan, J. Feng and W. Liu Engineering Sciences, China 12 (2), 9 (2010).
[6] A. L. Dmitriev Engineering Physics, No 3, 48 (2012) (in Russian).
[7] A. L. Dmitriev Intellectual Archive, 1(5), 24 (2012).
[8] Yu. Rabotnov Soprotivlenie materialov. GIFML, Moscow, 1962 (in Russian).
[9] M. Glaser Metrologia. 27 (2), 95 (1990).
[10] A. L. Dmitriev. AIP Conference Proceedings 1103, 345 (2009).
[11] A. L. Dmitriev , E. M. Nikushchenko and S. A. Bulgakova AIP Conference Proceedings 1208, 237 (2010).
[12] A. L. Dmitriev and V. S. Snegov Measurement Techniques, 44 (8), 831 (2001).
[13] A. L. Dmitriev *Russian Physics Journal.* **44** (12), 1323 (2001)

№22

Инженерная физика, № 9, 27 – 30 (2014)

CHANGE OF WEIGHT OF AIRTIGHT CONTAINER WITH BUILT-IN ELECTROMECHANICAL VIBRATOR

A. L. Dmitriev, E. M. Nikushchenko, N. N. Chesnokov

St. Petersburg National Research University of Information Technologies, Mechanics and Optics, 49 Kronverksky Prospect, St-Petersburg, 197101, Russia

Abstract. *Weight of airtight container about 1.1 kg with electromechanical vibrator built-in inside, with independent supply and contactless control, has been measured. Decrease of container weight up to 170 μg, basically, is determined by heating of copper wire of vibrator electromagnet and practically is not related to artifacts – change of buoyancy, air convection, electromagnetic interference.*

PACS: 06.30. Dr

Problems referring to the influence of accelerated motion and body temperature on its physical weight have been repeatedly discussed [1-6]. The results concerning weighing of mechanical rotor with horizontal axis of rotation and indicative of dependence of rotor weight being measured on its angular velocity of rotation are given in [3].The results of experiments concerning precise weighing of insulated containers with sample of metal being heated electrically or chemically are described in [7]. Data of these measurements demonstrate relatively strong negative temperature dependence of weight of nonmagnetic metals (brass, titanium, copper etc.) with relative value γ about $10^{-6} K^{-1}$. In the given experiment weighing of massive cylinder container with electromechanical vibrator installed inside with mild steel core oscillating along the vertical has been carried out. Structure of container is given in Fig. 1.

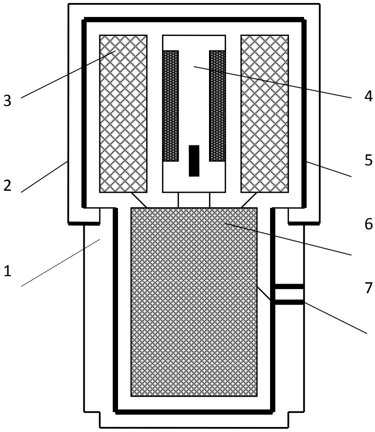


Fig. 1. Structure of container. 1,2 – hermetically connected parts of housing; 3 – batteries; 4 – electromechanical vibrator (contains electromagnet and core supported by springs); 5 – heat seal; 6 – pulse generator; 7 – photodiode generator control.

Parts and details of container were tightly connected and junction points were filled with bi-component polymer adhesive providing almost complete tightness of entire construction. Weight of assembled container - 1104.346 g, batteries - 213 g, vibrator core - 2.36 g. Switching on/off of unipolar pulse generator with amplitude 12 V, duration of 2.9 ms and period of 4.4 ms was carried out by visual signal setting to photodiode 7. Container was weighted using Manual Mass Comparator CCE 1005 ("Sartorius AG") in special metrological room at air temperature 21.8 ^0C, relative humidity 36% and atmospheric pressure 1017 hPa. Error (discreteness) of weight counting didn't exceed the value of 10 μg . Contactless control of the pulse generator connected to vibrator was carried out via glass wall of balance showcase (ordinary laser pointer was used). An external view of the measuring system is shown in Fig. 2.

Fig. 2. An external view of comparator and container

An example of typical time dependence of container weight change is given in Fig. 3.

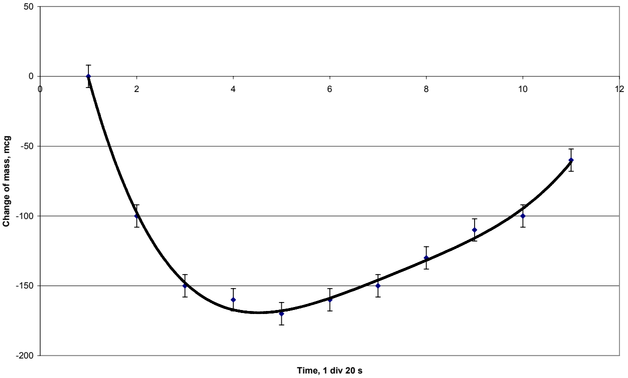


Fig. 3. Time dependence of container weight change

Pulse generator was switched on at time «1» and switched off within 20 sec at time «2»; the readouts of the balance were carried out every 20 sec. The effective value of the amperage within exciting coil was 500 mA.

The internal resistance of the battery is significantly lower than the resistance of the vibrator electric coil with value of 12 Ω, and power loss within the battery as well as within generator circuitry is also much less than on load resistance. Therefore, the heat is being released basically within vibrator electric coil. In this case relatively slow propagation of the heat wave within coil copper wire and as a result of heat exchange within housing of vibrator coil and insulating layers is observed.

Energy Q, dissipated in resistance R of vibrator winding is equal $Q = I^2 R \tau$, where $I \approx 0.5A$ - effective current, $R = 12\ \Omega$ and $\tau = 20$ sec – current duration. Design value Q, equal to 60 J, allows to evaluate the order of ΔT change of temperature of copper wire, $\Delta T = Q / mc$, where $m \approx 80$ g – weight of wire and $c = 0.38 \cdot 10^3 J / kg \cdot K$ - specific heat capacity of copper, therewith $\Delta T \approx 2K$. Actual value of ΔT is about half as much due to heat exchange processes given above. This fact is proved by time dependence (shown in Fig. 4) of surface temperature of vibrator electric coil by passing of direct current with value 500 mA equal to effective current by weighing; the given dependence is measured in adiabatic regime of heating when the thermosensor and coil have been thoroughly thermally insulated. It can be seen that increase of coil surface temperature within first 3 minutes of measurements didn't exceed $1^0 C$.

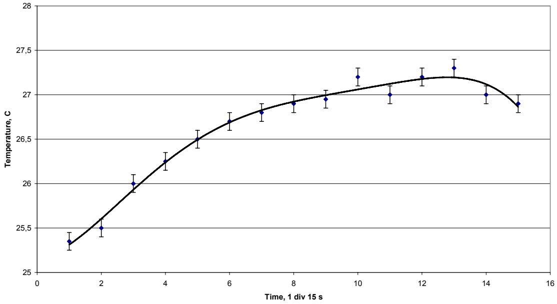


Fig. 4. Surface temperature of thermally insulated coil of vibrator electromagnet by direct current 500 mA (heating time 20 sec, start heating at time «1», one marking of time scale 15 sec)

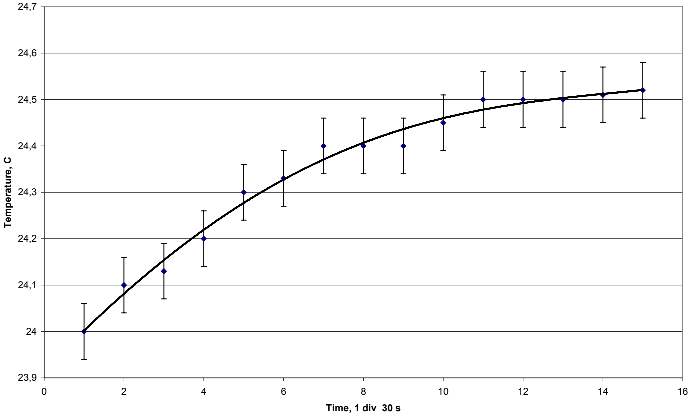


Fig. 5. Time dependence of container lid temperature (one marking of time scale 30 sec).

Fig. 5 gives time dependence of temperature of container upper lid obtained at the same switching on regime of vibrator as by weighing. It follows from the figure that within first 80-100 sec of observations in which the change of container weight achieves maximum value of about $170\,\mu g$, the temperature of container lid monotonically increases not more than by $0.2^0 C$. Thereby, as it can be shown using Glaser theory [8], the apparent decrease of container weight determined by air convection doesn't exceed $12\,\mu g$. Insignificant influence of convection on measurement results is proved as well by the common time course of container weight dependence shown in Fig. 3 and its comparison with Fig. 5.

The reason of container weight change is obviously of thermal nature, i. e. it is related to heating and further, within 1-1.5 minutes after start measurements, slow cooling of vibrator coil, as well as to lesser extent it is related to heating of power supplies and electronic devices of signal generators. Deformation of massive steel container housing caused by insignificant change of air pressure within its volume is practically equal to zero, therefore, change of buoyancy (Archimedes force) affecting the results of weighing is also equal to zero. The extreme nature of time dependence of the container weight change considering monotonic, over the period of more than 5 minutes, dependence of the container lid temperature (Fig. 5) indicates that fundamentally possible insignificant depressurization of the container (leakage) doesn't cause the decrease of weight being observed. The fact that decrease of the container weight occurs within one minute after vibrator switching off confirms that electromagnetic and vibrating (acoustic) interference couldn't cause the observed time dependence of the weight value. Referring to Fig. 3, the container gross weight slowly returns to its initial value as a result of heat dissipation within container, heat transfer from its surface and decrease of temperature of vibrator coil.

Let's calculate relative temperature weight change of the vibrator coil copper wire $\gamma = \Delta m / m \cdot \Delta T$, where $\Delta T \approx 1^0$, therewith $\gamma \approx -2 \cdot 10^{-6} K^{-1}$ ($\Delta m \approx 170 \mu g$, $m \approx 80$ g,). Sign and order of the given magnitude γ are well agreed with values obtained in [4-6].

So, the experimental results displayed in the given article confirm previously noticed relatively strong negative temperature dependence of the copper specimen physical weight. It is expedient to fulfill further experimental studies using precision scales in vacuum to explain the dependence being observed.

The authors express their gratitude to V. A. Korablev for consultation with regard to temperature measurement technique.

References

[1] Quinn T. J., Picard A. // Nature. 1990. Vol. 343. P. 732

[2] Faller J. T. et. al. // Phys. Rev. Lett. 1990. Vol. 64. P. 825

[3] Dmitriev A. L., Snegov V. S // Measurement Techniques. 2001. Vol. 44. No 8. P. 831

[4] Dmitriev A. L, Nikushchenko E. M., Snegov V. S. // Measurement Techniques. 2003. Vol. 46. No 2. P. 115

[5] Dmitriev A. L. // AIP Conference Proc. 2008. Vol. 969. P. 1163; 2009. Vol. 1103. P. 345;
2010. Vol. 1208. P. 237

[6] Dmitriev A. L. // Physics Procedia. 2012. Vol. 38. P. 150

[7] Dmitriev A. L., Bulgakova S. A. // Proc. WASET. 2013. Issue 79. P. 338

[8] Glaser M. // Metrologia. 1990. Vol. 27. P. 95

№ 23

Proc. of the International Conference APSAC 2015, Vienna, Austria, March 15-17, 2015
International Journal of Circuits, Systems and Signal Processing, Vol. 9, pp. 275-280 (2015)

Prospects of high-frequency gravimetry

A. L. Dmitriev

Abstract - The gravitational field of the Earth is assumed to be a stochastic process the wide frequency spectrum of which is conditioned by the influence of various geophysical, astrophysical and anthropogenic factors. The frequency range of fluctuations of gravity field at frequencies over 1 *Hz* has not been significantly studied yet and still remains a peculiar "Terra Incognita" of gravimetry. High-frequency changes of a free fall acceleration data are informative for understanding of the complex physical processes happening in the core and crust of the Earth. They can be used to solve practical problems such as prediction of earthquakes, exploration of minerals, as well as problems of detection and identification of massive underwater or underground artifacts. The principles of new types of high-frequency gravimeters – the holographic ballistic gravimeter with the short length of a trajectory of a trial body and the ballistic gravimeter on the basis of freely falling mechanical rotor are considered.

Keywords - ballistic gravimeters, free fall acceleration, gravitational field of the Earth, hologram, rotor

I. INTRODUCTION

The gravitational field of the Earth is assumed to be a stochastic process the wide frequency spectrum of which is conditioned by the influence of various geophysical, astrophysical and anthropogenic factors. High sensitivity of the best modern gravimeters is achieved primarily through proper stabilization of temperature and mechanical characteristic of the equipment used and long integration time of registered signals – from tens of seconds to 24 hours [1]. Obviously, at large times of signal integration, the information about high-frequency variations of a gravitational field is lost. The frequency range of fluctuations $g_0(t)$ at frequencies over 1 *Hz* has not been significantly studied yet and still remains a peculiar "Terra Incognita" of gravimetry [2].

Meanwhile, high-frequency changes of a free fall acceleration (FFA) data are informative for understanding of the complex physical processes happening in the core and crust of the Earth.

They can be used to solve practical problems such as prediction of earthquakes, exploration of minerals, as well as problems of detection and identification of massive dynamic underwater or underground artifacts. High-frequency (HF) gravimetry data is of a great scientific and practical importance and the development of HF-gravimetry as a new research area is inevitable. Such gravimeters should provide an accurate measurement of the "instantaneous" value of FFA in the frequency range from few *Hz* to thousands (and probably more) *Hz*.

For data acquisition about high-frequency fluctuations of the FFA the following experimental methods can be used

- spectral analysis of output signals of known types of ballistic and static gravimeters;
- data processing of superconducting gravimeters with the minimum mass of a trial body;
- data processing of ballistic gravimeters with very small, an order of units of mm, length of a trajectory of falling of a trial body;
- data processing of ballistic gravimeters on the basis of freely falling mechanical rotor with a horizontal axis of rotation.

The convenient modern tools of HF-gravimetry include superconducting gravimeters (SCG). Owing to a rather big proof mass, the highest frequency of variations in the gravity acceleration value registered by SCG does not exceed a few tens of *Hz*, although the frequency range of such measurements can be essentially extended after the improvement of these devices. Among HF-gravimetry measurement methods we should also mention the application of ballistic gravimeters with extremely small, for example, less than 1 mm, length of the proof mass fall trajectory.

II. A BALLISTIC GRAVIMETER WITH FALLED HOLOGRAPHIC GRATING

In a ‘standard’ ballistic laser gravimeter a corner reflector mounted on a free-falling trial body acts as a part of the two-beam Michelson interferometer [1]. The absolute value of the FFA is measured by counting the number of interference fringes passing in the photodetector out-plane within a present time interval. A small error of measurement in these gravimeters is achieved by using a single-frequency laser, atomic clocks, high vacuum, and with large (from several dozen seconds up the about a day) time of accumulation and averaging of measured signal. The large, several dozen centimeters, length of the falling trajectory restricts the possibility of using these laser gravimeters for measurement of high-frequency fluctuations of gravitational field in a frequency range of several hundred Hz and above.

Principle of holographic ballistic gravimeter is based on variation of the frequency of light diffracted on a moving holographic grating. Geometry of light-beam diffraction on the holographic transmission grating is shown in Fig.1.

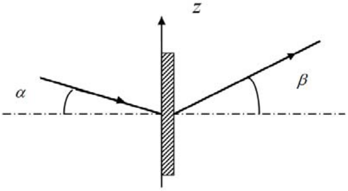
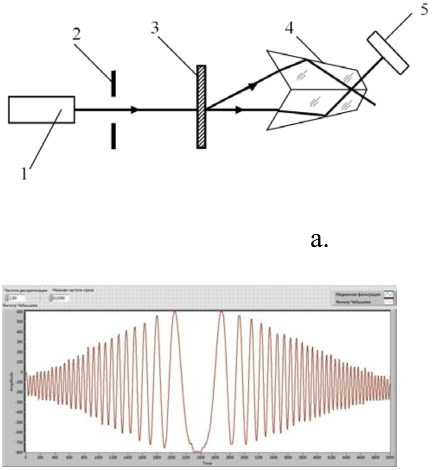


Fig.1. Light diffraction on the transmission hologram.

At the movement of the hologram the frequency of the diffracted light changes**.** As shown in [3], size of the acceleration g of free falling hologram is equal

$$g = \frac{\lambda}{\sin\alpha + \sin\beta}\left(\frac{\partial f}{\partial t}\right) \qquad (1)$$

and proportional to the grade of variation of the frequency f of output beam signal of hologram interferometer; here λ - wavelength and angles α, β shown in Fig. 1. The optical device of the holographic gravimeter and typical form of the registered frequency-modulated signal of beats are shown in Fig. 2 a,b.



a.

b.

Fig. 2. a. Basic optical device of the holographic gravimeter; 1 - laser, 2 – diaphragm, 3 – hologram, 4 – optical multiplexer, 5 – photo-detector.
b. Frequency-modulated output signal of beats.

In our experiments a hologram with 37% diffraction efficiency had an angular selectivity 10^0, $\alpha = 0, \beta = 37.8^0, \lambda = 632.8nm$. The hologram was mounted in the special holder (catapult).

Temporal resolution of measuring is $10^{-2}s$, error of separate (single) measurement of FAA is near 10 mGal. Using the modern methods of statistical filtration and processing of the linear frequency-modulated beat signals, it is possible to obtain the mobility and high precision of gravimetric measurements. Specific features of the holographic gravimeter is simple optics-mechanical design and very small (below 1 mm) length of the trajectory of the free-falling body.

III. WEIGHT OF OSCILLATOR IN A VARIABLE FIELD OF GRAVITATION

Ballistic gravimeters with the test body executed in the form of a mechanical rotor with a horizontal axis of rotation should also be considered as new and perspective means of HF-gravimetry. Rotary motion corresponds to two oscillatory motions of the rotor particles along the orthogonal axis of coordinates. The accelerated harmonic motion of the rotor particles on a vertical is characterized by an infinite set of time derivates. In these condition the interaction of such rotor with a non-stationary gravitational field of the Earth can have a specific, not trivial character. Such researches will promote obtaining the new data on dynamic characteristics and specific features of the gravitational field of the Earth.

Let's consider interaction of a mechanical rotor with an alternating gravitational field which is based on the gravitational analogy of the phenomenon of Faraday and Lenz's Law in electrodynamics [4-6]. According to [5,6] the change of acceleration of the gravity acting on a body, moving with acceleration $\vec{a}$ under influence of the elastic force, in the elementary (linear) approximation, is represented as

$$\Delta\vec{g}_{p,c} = -\frac{\vec{g}_0}{|\vec{g}_0|}(\vec{g}_0 \cdot \vec{a})A_{p,c} \tag{2}$$

where symbols p, c mean passing (p) and a contrary (c), in relation to a direction of vector $\vec{g}_0$ of normal acceleration of a gravity, orientation of a vertical projection of vector $\vec{a}$ of acceleration of external forces, and factors A_p and A_c characterize a degree of change of values $\Delta\vec{g}_{p,c}$. If the massive body under action of the external, electromagnetic in nature, elastic force makes harmonious oscillations along a vertical with frequency ω and amplitude B, the average for the period $\tau = 2\pi/\omega$ of fluctuations value $\Delta\overline{g}$ of change of FFA of such mechanical oscillator is equal to the sum of average changes of FFA in movement of a body passing and contrary to vector $\vec{g}_0$,

$$\Delta\overline{g} = \Delta\overline{g}_p + \Delta\overline{g}_c \tag{3}$$

and at constant $g_0 = |\vec{g}_0|$ it is equal

$$\Delta\overline{g} = -\frac{g_0 B\omega^2}{\pi}(A_p - A_c). \tag{4}$$

We will note that square dependence $\Delta\overline{g} \propto \omega^2$ shows that changes of weight of the oscillator will be considerable owing to thermal fluctuations of particles of material of the oscillator which frequency is in hyper-sound area. Is shown that temperature dependence of physical weight $P(T)$ of the oscillator is represented by a formula

$$P(T) = P_0\left[1 - \frac{C(A_p - A_c)}{\pi}\sqrt{T}\right] \tag{5}$$

where T - absolute temperature and C - the coefficient depending on elastic characteristics of material of the oscillator [4,6].

The effect of negative temperature dependence of body weight was repeatedly observed in experiments [7,8] that confirms justice of formulas (1,5).

Some interesting and deserving attention results turn out at calculations of change of weight of the mechanical oscillator which is freely falling in a variation field of gravitation.

We shall present elementary time dependence $g_0(t)$ as

$$g_0(t) = g_0(1 + \beta\sin(\Omega t + \theta)) \quad , \tag{6}$$

where Ω – frequency of changes of FFA value, β - their relative amplitude, θ - the phase. Acceleration $a(t)$ of the material point making harmonious oscillations along a vertical with amplitude B is equal to

$$a(t) = B\omega^2 \sin\omega t \tag{7}$$

where ω - frequency of oscillations.

The averages for oscillation half-cycle $\tau/2$ of values of changes of accelerations $\Delta\overline{g}_p$ and $\Delta\overline{g}_c$ are equal to

$$\Delta\overline{g}_p = -A_p g_0 B\omega^2 \frac{2}{\tau}\int_0^{\tau/2} \sin\omega t(1 + \beta\sin(\Omega t + \theta))dt \tag{8}$$

$$\Delta\overline{g}_c = -A_c g_0 B\omega^2 \frac{2}{\tau}\int_{\tau/2}^{\tau} \sin\omega t(1 + \beta\sin(\Omega t + \theta))dt \tag{9}$$

The relative change of FFA of the oscillator, in view of 3, shall be presented as

$$\frac{\Delta \bar{g}}{g_0} = 4\pi A_p B F^2 f(x) \qquad (10)$$

where $F = \Omega / 2\pi$, $x = \omega / \Omega$ and frequency function $f(x)$ is equal t

$$f(x) = -x^2 \left[\int_0^{\pi} \sin z (1 + \beta \sin(xz + \theta)) dz + \mu \int_{\pi}^{2\pi} \sin z (1 + \beta \sin(xz + \theta)) dz \right]$$

(11)

here $\mu = A_c / A_p$ and $z = \omega t$.

Examples of frequency functions $f(x, \mu, \theta, \beta)$ at various parameters μ, θ, β, and both low values of x are shown in Fig. 3.

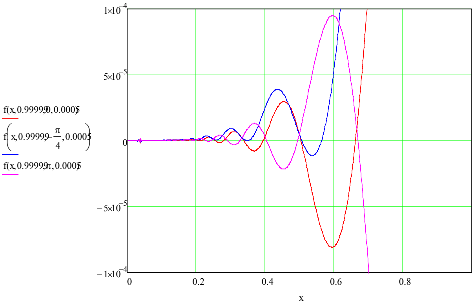


Fig. 3. Frequency functions $f(x, \mu, \theta, \beta)$ at low values of argument x; relative amplitude of fluctuations of FFA $\beta = 0.0005$.

Examples of frequency functions $f(x, \mu, \theta, \beta)$ at various parameters μ, θ, β, and both low (a) and high (b) values of x are shown in Fig. 4 and Fig. 5 a,b.

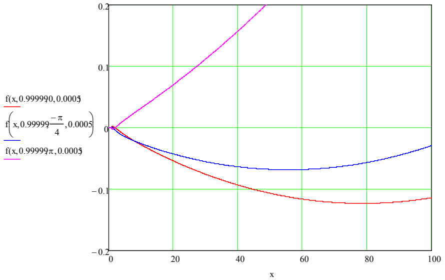
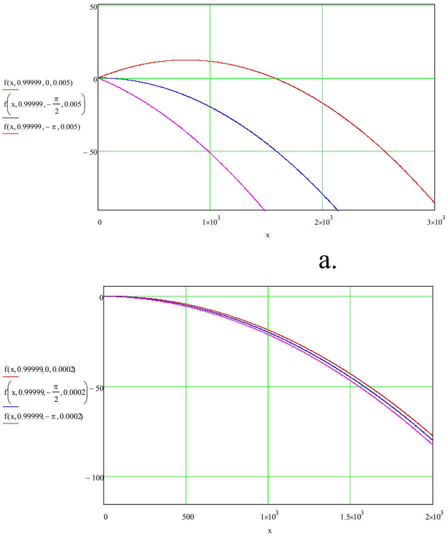


Fig. 4. Examples of frequency functions $f(x,\mu,\theta,\beta)$ at high values of argument x; relative amplitude of fluctuations of FFA $\beta = 0.0005$.



a.

b.

Fig. 5. Examples of frequency functions $f(x,\mu,\theta,\beta)$ at the high values of argument x; a. - relative amplitude of FFA fluctuations $\beta = 0.005$, b. - $\beta = 0.0002$.

Obviously, the sign and a general view of functions $f(x)$ essentially depend on parameters μ,θ,β. According to estimations given above, in the calculations, $\mu = 0.99999$ is assumed. The given

calculated dependences show that even at small, with relative value of about the 100-th fractions of percent, amplitudes β of fluctuations in value of normal acceleration of the gravity of the Earth, the weight of mechanical oscillator can be changed appreciably.
At frequencies ω of oscillations, with an order of the frequency Ω of own FFA fluctuations, in area $x \leq 1$, the weight of oscillator periodically changes with frequency, and sign and values of such changes essentially depend on a difference of phases θ of oscillations (see Fig. 3). At high ($x \succ\succ 1$) frequencies of oscillator, the monotonous dependence of average weight of oscillator on frequency of its fluctuations is taking place, with influence of phase θ being insignificant (Fig. 5. b). Such reduction of weight of oscillator at high frequencies of fluctuations will agree with negative temperature dependence of weight of bodies as the frequencies of thermal fluctuations of microparticles of solid state bodies are rather high and lie in the field of the hypersound [9].

Obviously, the sign and a general view of functions $f(x)$ essentially depend on parameters μ, θ, β. According to estimations [4,5], in the calculations, $\mu = 0.99999$ is assumed. The given calculated dependences show that even at small, for example, with relative value of about the 100-th fractions of percent, amplitudes β of fluctuations in value of normal acceleration of the gravity of the Earth, the weight of mechanical oscillator can be changed appreciably.
At frequencies ω of oscillations, with an order of the frequency Ω of own fluctuations of FFA, in area $x \leq 1$, the weight of oscillator periodically changes with sign and values of such changes essentially depending on a difference of phases θ of oscillations and FFA (Fig. 3).

III. EXPERIMENTAL FREQUENCY DEPENDENCE OF FREE FALLING ACCELERATION OF ROTOR

In our experiment the free falling acceleration of the magnetically-, thermally- and sound-isolated container with a vacuumed aviation rotor inside it was measured [10,11]. Appearance of a rotor is shown in Fig. 6.

Fig. 6. Rotor of aviation gyroscope.

The maximal rotation frequency of a rotor is 400 *Hz*, the run out time of rotor is 22 min. Fall path length of the container is 30 mm, readout time of sample value of gravity acceleration is near 40 ms, the period of sampling is from 0.5 up to 1.0 minutes. The principle of measurements is based on photo registration of movement of the scale in form of three horizontal strings fixed on the container (Fig.7.).

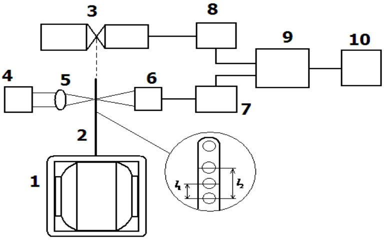


Fig. 7. Basic device of experiment. 1-falled container, 2 – scale, 3 – driver, 4 – laser, 5 – lens, 6 – photodiode, 7 – amplifier, 8 – timer, 9 – oscillograph, 10 – computer.

At the maximal falling velocity of the container equal to 60 cm/s and its dimensions of 82x82x66 mm, the joint influence of buoyancy and resistance force of air in FFA measurements did not exceed 0.1 cm/s^2. The error of some measurements of the FFA container was within the limits of 0.3-0.6 cm/s^2 and was basically determined by accuracy of readout times of registration of pulse signals in movement of the scale (near 1 microsecond). The example of experimental frequency dependence of FFA changes $\Delta g(f)$ of the container, containing a rotor with a horizontal rotation axis, is shown (in the Fig. 8. – in Fig.8.

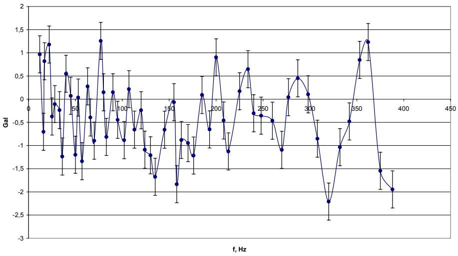


Fig.8. The frequency dependence of free falling acceleration of the container with horizontally positioned rotor; the changes of FFA (*Gal*) relatively to the value of FFA with the stopped **r**otor have been shown.

The value $\Delta g(0) = 0$ corresponds to acceleration of free falling of the container with a motionless rotor; FFA measurements of the container with a motionless rotor were carried out till the moment when rotor got going and after its run out time, in so doing the FFA values of the container, averaged by results of 10 measurements with a motionless rotor, coincided to the accuracy of 0.05%.

Comparing Fig. 3 and Fig. 8, it can be seen that the area of steady periodic changes of FFA in Fig. 8 in a band of frequencies 200-400 *Hz* approximately corresponds to the area in a vicinity of value $x \approx 0.5$ in Fig. 3. Having substituted in (10) the experimental value $\Delta g / g_0 \sim 10^{-3}$, and assume then $A_p \sim 10^{-2} g_0^{-1}$, $f(x) \sim 10^{-5}$, we obtained an estimation of amplitude $B \sim 1.4\text{cm}$ of oscillator. The given size almost coincides with radius of the rotor used in experiments. At oscillation frequencies tens times higher than the frequencies F of own fluctuations of normal acceleration of the gravity (according to the given estimations, $F \sim 300/0.5 = 600 Hz$) and following the suggested model, there is observed a monotonous frequency dependence of change $\Delta\overline{g}$ of average value of acceleration of free falling oscillator, with sign $\Delta\overline{g}$ being is directly determined by the difference of phases θ of fluctuations FFA and oscillator. Within the limits of applicability of formulas 6,10 there are possible both substantial growth and reduction of the average gravity working on mechanical oscillator on the part of the variable gravitational field of the Earth. Let's note that the independent measurements of high-frequency, in the range of hundreds – thousands of Hz, spectra of fluctuations of acceleration of the gravity of the Earth, executed, for example, with use of SCG, will allow to define modes of the matched fluctuations of oscillator at which the changes of its average weight can essentially surpass the ones described by formulas 6-10.

The above calculated and experimental estimations given above have an illustrative character. Nevertheless, the considered simple phenomenological model finely explains the experimental dependences and agrees with the known data of measurements of weight of accelerated moving test bodies. Experimental researches into free falling mechanical oscillators (rotors, vibrators) will allow to bring the necessary specifications into the offered models, to determine the borders of their applicability, and to prove more strictly the size parameters introduced into these models. Such researches will promote obtaining the new data on dynamic characteristics and specific features of the gravitational field of the Earth.

IV. CONCLUSIONS

1. High-frequency gravimetry – the new direction in gravitation measurements. Its purpose is research into high-frequency fluctuations of natural gravitation field of Earth
in the range of tens-hundreds Hz and more.
2. Technical approach of HF-gravimetry:
- spectral and correlation analysis of output signals and noise of known types of gravimeters;
- creation of broadband gravimeters with the minimum mass of a trial body;
- development of ballistic gravimeters with very short, about 1 mm, length of a trajectory of falling of a trial body (for example, hologram gravimeter);
- development of gravimeters with a trial body in the form of a mechanical rotor with horizontal axis of rotation and the speed of rotations about hundreds Hz;
3. Data of HF-gravimetry will allow to improve techniques of investigation of minerals, and techniques of the prevention of natural disasters (earthquakes, a tsunami and others).

Development of HF-gravimetry techniques and exploration of above-mentioned "Terra Incognita" carries significant scientific and applied values.

REFERENCES

[1] W. Torge, *Gravimetry*, New York: Walter de Gruyter, 2008.

[2] A. L. Dmitriev, E. M. Nikushchenko, "Prospects and Methods of High-Frequency Gravimetry", *IAG Symposium on Terrestrial Gravimetry (TG-SMM 3013), Paper Abstracts, 73-74,* Sept.2013.

[3] A. L. Dmitriev, E. I. Kotova et al. "A Ballistic Gravimeter with Dropping Holographic Grating", *Optics and Spectroscopy*, vol. 117, pp. 799-780, Nov. 2014.

[4] A. L. Dmitriev, "Analogue of Lenz's Rule in Phenomenological Gravitation" in *AIP Conference Proceedings, vol. 1103, pp. 345-351, NY 2009.*

[5] A. L. Dmitriev, E. M. Nikushchenko and S. A. Bulgakova, “Dynamic Weighing Experiments – the Way to the New Physics of Gravitation”, in *AIP Conference Proceedings, vol. 1208, pp. 237-246, NY 2010.*

[6] A. L. Dmitriev, “Physical Substantiation of an Opportunity of Artificial Change of Body Weight”, *Physics Procedia, vol. 38, pp.150-163, 2012.*

[7] A. L. Dmitriev, E. M. Nikushchenko and V. S. Snegov “Influence of the Temperature of a Body on this Weight”, *Measurement Techniques, Vol. 46, No 2, pp. 115-120, 2003.*

[8] A. L. Dmitriev, S. A. Bulgakova, “Negative Temperature Dependence of Gravity – A Reality”, *Proc. World Academy of Science, Engineering and Technology, Issue 79, pp. 1560-1565, July 2013.*

[9] A. I. Anselm, “Fundamentals of statistical physics and thermodynamics”, *Nauka, Moscow, 1973 (in Russian).*

[10] A. L. Dmitriev and E. M. Nikushchenko, “Frequency Dependence of Rotor’s Free Fall Acceleration”, *Engineering Physics, No 1, 13-17, 2012 (In Russian)*

[11] A. L. Dmitriev “Frequency Dependence of Rotor's Free Falling Acceleration and Inequality of Inertial and Gravity Masses”, arXiv:1101.4678 (physics.gen-ph)

№24

Applied Physics Research, Vol. 7, No 6, pp 43-48, 2015

Thermogravimetry and the negative temperature dependence of gravity

A. L. Dmitriev

St. Petersburg National Research University of Information Technologies,
Mechanics and Optics, St. Petersburg, 49 Kronverksky Prospect, 197101, Russia

Abstract. *It is shown that data of thermogravimetric measurements confirm the negative temperature dependence of gravity. The accounting of this dependence is necessary for increase of accuracy of the thermogravimetric analysis. Physical prerequisites of the phenomenon are briefly considered. Possible influence of the observed effect of weight reduction by a form of the electric arc discharge is noted.*

PACS 07.20.-n; 04.80.-y.
Keywords: temperature, gravitation, thermogravimetric analysis, mass, plasma

Introduction

The thermogravimetric analysis based on exact weighing of the heated sample is widely applied in researches of physical and chemical properties of materials [1-3]. The first stage of thermogravimetric measurements is receiving a basic curve – temperature dependence of weight of the empty holder of a sample, for example, of a crucible. At data processing of temperature measurements the basic curve is subtracted from experimental temperature dependence of weight. Out of areas of change of phase structure of substance in which there are sharp changes of its weight, the main reason for the monotonous increasing temperature dependence of weight is considered action of forces of buoyancy. Meanwhile, physical temperature dependence of weight of bodies [4-8] has essential impact on measurements of weight and has to be taken into account in the exact thermogravimetric analysis; this circumstance was noted by M. Grumazesku [9].

1. Temperature dependence of gravity force

Negative temperature dependence of physical weight of bodies – the experimental fact confirmed by a set of measurements. The majority of these measurements were taken in a normal laboratory conditions, thus influence of artifacts – buoyancy (buoyancy force of pushing out in the atmosphere), temperature change of the sizes of a sample, thermal air convection, action of electric and magnetic fields were carefully considered. Various types of high-precision scales, various designs of the weighed containers, various materials of samples and various methods of their heating were used (ultrasound, a heat transfer from the electric heater and a chemical way) [5-7]. One of the recent experiments showing negative temperature dependence of weight is described in [8].

1.1.Experiment

The design of container, in which heating of a tight steel cylinder made of stainless steel was carried out by a chemical method, is shown in Fig. 1.

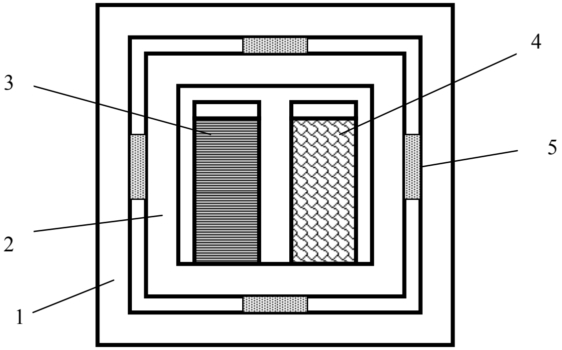


Fig. 1. The design of container with chemical heating of the internal cylinder. 1 - the external cylinder; 2 - the internal cylinder; 3 - an open vessel with distilled water; 4 - an open vessel with crystals of NaOH; 5 - polyfoam

Diameter of the external brass-cylinder is 60 *mm*, height - 62 *mm*, thickness of walls - 3.5 *mm*, weight - 475 *g*; diameter of the internal cylinder - 45 *mm*, height - 46 *mm*, thickness of walls - 4.5 *mm*, weight - 280 *g*. In the condition specified in the figure the temperature of the internal cylinder is constant, the weight of completely equipped container is equal to 773.7651*g*.

Measurements of weight with a margin error readout of 0.1 *mg* were also carried out with laboratory scale of XP2004S mark at temperature of air in a working room equal to 19.8 ^{0}C, humidity - 31.8 %, pressure - 1022 *hPa*.

In the course of measurements the container was overturned, then the current value of its weight was registered. In the overturned condition, inside the small cylinder, there is going a process of partial dissolution of crystals NaOH (masse of 5 *mg*) in distilled water (masse of 6 *mg*) which is accompanied by heat release. The temperature of the mix in the first seconds of reaction grows by 10 ^{0}C, and, as have been shown by special measurements, the average temperature of the internal temperature of the mix in the first seconds of reaction grows by 10 ^{0}C, and, as have been shown by special measurements, the average temperature of the internal cylinder, owing to a heat transfer, is smoothly increased by 3-4 ^{0}C within the first two-three minutes. A specific feature of the given experiment is that, first, the process of dissolution of crystals of alkali is not accompanied by release of gases and, due to reliable sealing of covers of containers, the release of air from small and big cylinders (and the corresponding handicap to weighing) is absent. Second, due to the big weight of the external cylinder, the temperature of its surface, owing to a heat transfer, increases during the first two minutes by no more than by 0.2 ^{0}C. As a result, apparent reduction of weight of the container caused by air convection, which is determined by differences of temperatures of the surface of the container and the ambient air, in the first 2-3 minutes of measurements does not exceed 0.1 *mg*. High durability of the external cylinder also practically excludes influence of its weak temperature deformations on change of buoyancy of the weighed container.

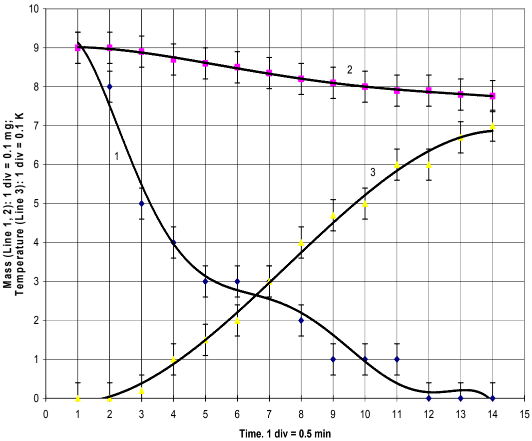


Fig. 2. 1 - experimental time dependence of change of weight of container in the overturned position; 2 - calculated dependence of change of weight of the container with account for influence of temperature air convection; 3 - experimental dependence of temperature of the surface of the external cylinder

Fig. 2 shows experimental time dependences of weight of container, temperatures of its surface, and the calculated value of weight caused by temperature convection of air close to the walls of the container. Obviously, the paths of curves 1 and 2 essentially differ, accompanied by a typical sharp fall of weight of the container during the first minutes of measurements.

Let's estimate influence of temperature artefacts on the results of measurements of weights of samples. Change Δm_1 of apparent weight of the container, caused by change of volume of the steel cylinder owing to thermal expansion of its material is equal to

$$\Delta m_1 = \frac{3\pi}{4} \rho d^2 h \alpha \Delta T \quad , \qquad (1)$$

where ρ - density of air, α - factor of linear expansion of material of the cylinder, d - its diameter, h - height. Change Δm_2 of apparent weight of the container, caused by deformations of walls of the cylindrical vessel, owing to temperature change of air pressure ΔP within its volume, as it is possible to show on the basis of the theory of elasticity [8], is equal to:

$$\Delta m_2 = \frac{\pi\rho h d^3 \Delta P}{4\delta E} + \frac{\pi\rho d^3}{16}\sqrt[3]{\frac{3(1-\nu)d\Delta P}{2\delta E}} \tag{2}$$

where δ - thickness of walls, E - the modulus of elasticity and ν - Poisson's ratio . The size ΔP is connected to change of temperature ΔT of air within the volume of the external cylinder $\Delta P = P\Delta T/T$, where P- normal pressure of atmosphere and T- temperature of air in the cylinder. The given estimate is overestimated, as in the second addend of formula 2, describing deformation of face walls of a vessel, such walls are presented by thin membranes; actually, the deflection of end faces is less than it is supposed in conclusion 2.

The change Δm_3 of apparent weight of the container, caused by air convection due to difference ΔT of temperatures of surface of the external steel cylinder and temperatures of air in the closed box of analytical balance, will be estimated on the basis of [10] according to which

$$\frac{\Delta m_3}{Ad^{1/4}\Delta T^{3/4}} = 9.2\cdot 10^{-7}\, gcm^{-9/4}K^{-3/4} \tag{3}$$

where the area of lateral surface of the cylinder is $A = \pi dh$.
In TABLE the experimental and calculated values of change of weight of container, corresponding to the third minute of measurements are given. In the given calculations the density of air $\rho = 1.19 kg/m^3$, $\Delta T = 3^0 K$ (obviously overestimated value), $\Delta P = 1020 N/m^2$.

CALCULATED TOTAL ($\Delta m_\Sigma = \Delta m_1 + \Delta m_2 + \Delta m_3$) AND
EXPERIMENTAL (Δm) TEMPERATURE
REDUCTION OF WEIGHT OF CONTAINER

d, mm	h, mm	δ, mm	$\alpha \cdot 10^6$, K^{-1}	ν	$E \cdot 10^{-10}$, N/m^2	ΔT, K	Δm_1, mcg	Δm_2, mcg	Δm_3, mcg	Δm_Σ, mcg	Δm, mcg
60	62	3.5	18.9	0.36	9	0.22	2.6	$\prec 290$	54	$\prec 346$	640

Obviously, observable (registered) reduction of weights of containers essentially, with account for errors of measurements, exceeds calculated one.

1.2. Simple phenomenological model

Proceeding from the principle of inertness of mechanical system, that is, its tendency to preserve the stable state, accelerated under action of external, for example, elastic force of movement of a test body downwards should cause an increment $\Delta\vec{g}_p$ of acceleration of the gravity applied to a body which is directed from the centre of the Earth. On the contrary, the accelerated movement of a trial body upwards is accompanied by increase of acceleration of the gravity applied to a body by value $\Delta\vec{g}_c$. Values $\Delta\vec{g}_p$ and $\Delta\vec{g}_c$, generally speaking, can be different. Change of acceleration of the gravity acting on a body, moving with acceleration $\vec{a}$ under influence of the elastic force, in the elementary (linear) approximation, is represented as

$$\Delta\vec{g}_{p,c} = -\frac{\vec{g}_0}{|\vec{g}_0|}(\vec{g}_0 \cdot \vec{a})A_{p,c} \quad , \qquad (4)$$

where symbols p,c mean passing (p) and a contrary (c), in relation to a direction of vector $\vec{g}_0$ of normal acceleration of a gravity, orientation of a vertical projection of vector $\vec{a}$ of acceleration of external forces, and factors A_p and A_c characterize a degree of change of values $\Delta\vec{g}_{p,c}$. If the body under action of the external, electromagnetic in nature, elastic force makes harmonious oscillations along a vertical with frequency ω and amplitude b, the average for the period $\tau = 2\pi / \omega$ of fluctuations value $\Delta\overline{g}$ of change of acceleration of free falling (AFF) of such mechanical oscillator is equal to the sum of average changes of AFF in movement of a body passing and contrary to vector $\vec{g}_0$,

$$\Delta\overline{g} = \Delta\overline{g}_p + \Delta\overline{g}_c \quad , \tag{5}$$

and at constant $g_0 = |\vec{g}_0|$ it is equal

$$\Delta\overline{g} = -\frac{g_0 b\omega^2}{\pi}(A_p - A_c) \quad . \tag{6}$$

From 6, it follows that at $A_p \succ A_c$, the average acceleration of free falling of mechanical oscillator, for example, a rotor with a horizontal axis of rotation, is less than value g_0 of normal acceleration of the gravity force. The reduction, averaged on several series of the measurements of the apparent weight of a rotor with horizontal axis, was observed in experiment [8], by results of which for the material of a rotor (stainless steel) it is possible to approximately estimate the order of value of difference $(A_p - A_c) \approx 10^{-7} g_0^{-1}$.

The absolute values of factors A_p and A_c can be measured on the basis of the shock mechanical experiments accompanied by the high, above $10^5 ms^{-2}$ accelerations of interacting bodies. For steel samples the order of values A_p and A_c is approximately equal to $10^{-2} g_0^{-1}$.

If to consider as the mentioned above trial body a microparticle of a solid body bound together by forces of interatomic interaction with other similar particles, formulas 1-3 allow to explain influence of temperature on acceleration of free falling (weight) of such body [4]. Thermal movement of microparticles of a solid body is accompanied by their significant accelerations, in so doing, the average value a_s of a projection of these accelerations on a vertical is proportional to average speed of chaotic movement of microparticles. In a classical approximation, at a body temperature higher than the one of Debye-temperatures, the acceleration a_s is in direct ratio to a square root from an absolute body temperature T,

$$a_s = C\sqrt{T} \quad , \tag{7}$$

where C - the factor dependent on physical properties of a material.

In one-dimensional approximation, we can consider a test body as a chain of microparticles bound by elastic forces, as shown in [4, 8],

$$C \propto \frac{v}{\sqrt{\mu}} \quad , \tag{8}$$

where v - speed of a longitudinal acoustic wave in a solid test body and μ - its density.

Formally, having replaced in equation (6) the average for the period of fluctuations magnitude of acceleration $b\omega^2/\pi$ with average acceleration of particles a_s, we shall present the temperature dependence $P(T)$ of weight of a body as

$$P(T) = P_0(1 - B\sqrt{T}) \quad , \tag{9}$$

where m - weight of a body, $P_0 = mg_0$, $B = C(A_p - A_c)$.

In a small range of temperatures the linear dependence of changes ΔP of weight and ΔT of a body temperature is satisfied,

$$\Delta P = -P_0 B \frac{\Delta T}{2\sqrt{T}} \quad . \tag{10}$$

Negative temperature dependence of weight of not-magnetic metal samples at close to normal ($300K$) temperatures of bodies experimentally proves to be true, in so doing, the relative change of weight for a unit of temperature

$$\gamma = \frac{\Delta P}{P_0 \Delta T} = -\frac{B}{2\sqrt{T}} \quad , \tag{11}$$

is equal to several units $10^{-6} K^{-1}$ [4,8].

The typical increase of value γ along with reduction of density of a sample material is observed that is in agreement with (8) [4] (we should note that outside the limits of considered classical approximation, for example, at close to zero absolute temperatures of bodies, formulas 7-8 are not satisfied).

2. Thermogravimety

At creation of a basic curve the seeming mass M of the holder (crucible) in air is equal $M = m - \rho V$, where m - the mass of a crucible, V - its volume and ρ - air density. Temperature change of the seeming weight

$$\frac{dM}{dt} = \frac{dm}{dt} - \rho \frac{dV}{dt} - V \frac{d\rho}{dt} \quad ,$$

(12)

where $V = V_0(1 + \beta t)$, β - volume expansion coefficient of material of a crucible.

Temperature dependence of $\rho(t)$ is represented by known expression

$$\rho(t) = \frac{A}{1 + Bt} \cdot \frac{p}{760} \quad ,$$

(13)

where $A = 0.0012932 g/cm^3$, $B = 0.00367K^{-1}$, p - air pressure in mm Hg [11].

By normal ($p = 760$) air pressure Eq. 12 my be represent as

$$\rho(t) = \frac{A}{1+Bt} \cdot \frac{p}{760}$$,

(14)

where $C_1 = -V_0 \beta A (1+Bt)^{-1}$ and $C_2 = V_0 (1+\beta t) AB$.

For numerical estimates we will use results of work [2] according to which the seeming change of mass of a porcelain crucible with the weight $m = 4g$ and volume $1.5cm^3$ measured on Shevenar's thermoscales in the temperatures range $200-1000^0C$ is equal $4.0 \cdot 10^{-6} gK^{-1}$. Volume coefficient of expansion of porcelain $\beta = 9 \cdot 10^{-6} K^{-1}$ [11] and, for example, at $t = 200^0 C$, the values of coefficients $C_{1,2}$ are equal $C_1 = -1.0 \cdot 10^{-8} gK^{-1}$ and $C_2 = 7.1 \cdot 10^{-6} gK^{-1}$. As the absolute values $C_1 \prec\prec C_2$, the main contribution to the seeming change of mass of a crucible is made by the effects of buoyancy described by coefficient C_2. Obviously, the consent of the experimental and provided settlement data is possible only at $\frac{dm}{dt} = -3.1 \cdot 10^{-6} gK^{-1}$. This fact directly confirms the negative temperature dependence of weight of bodies. Temperature change of weight of the holder, it is generally connected with change of temperature of a porcelain crucible, the assessment of size of relative temperature change of the weight of porcelain from where follows the $\gamma = \frac{dm}{mdt} \approx -0.8 \cdot 10^{-6} K^{-1}$. Sign and an order of the specified size correspond to data of measurements of physical temperature dependence of weight of various metals [4-6], and also PZT-ceramic [12].

3. About possible "pushing out" of plasma by a gravitational field

As appears from 8,9, the greatest loss of weight as a result of its physical negative temperature dependence is reached in materials with a small density μ, a high speed of a sound V and at high absolute temperatures. It is interesting to note that it follows from formula 9 that at very high temperatures T exceeding value of $B^{-1/2}$, the weight value P of a sample changes a sign, i.e. such sample has to be pushed out by a gravitational field. Today the highest temperatures are achievable in nuclear reactions, and also in plasma of an arc electric discharge. For example, in the typical arc discharge in the air, temperature of plasma reaches 12 000 K [13,14]. The shape of the arc discharge is defined by action of an electric and magnetic fields, and also forces of convection and buoyancy (Archimedes).

Nevertheless, in certain experimental conditions, for example, in vacuum, in the absence of Archimedes force, gravitation forces, including, the effects of loss of weight described by formula 9, have to influence a shape of the arc discharge considerably. It is remarkable that though the shape of the electric arc discovered by the Russian scientist Petrov in 1802 is explained by action of forces of buoyancy, the electric discharge in "vacuum" (at very low pressure) also often has a shape of the arc with its top up.

Special research has to show whether the characteristic shape of an electric arc in vacuum confirms the phenomenon of temperature dependence of weight. This result is also interesting for interpretation of dynamics of nuclear explosions in the atmosphere.

Conclusion

For more exact quantitative estimates of influence of temperature dependence of weight on results of thermogravimetric measurements, the accounting of the sizes, forms, masses, physical and thermodynamic characteristics as holder, and the studied sample is necessary. Temperature dependence of physical weight of bodies will allow to establish the reasons of anomalies of thermogravimetric dependences with bigger degree of reliability and to increase the accuracy of the gravimetric analysis.

References

1. Wendlandt, W. *Thermal Methods of Analysis*, John Wiley & Sons, New York, 1974.
2. Simons, E. L., Newkirk, A. E., Aliferis I. *Analytical Chemistry*, Jan. 1957, Vol. 29, No 1, pp. 48-54.
3. Sestak, J. *Thermophysical Properties of Solids*, Academia Prague, 1984.
4. Dmitriev, A. L., Nikushchenko, E. M., Snegov, V. S. Influence of the Temperature of a Body on its Weight, Measurement Techniques, 2003, Vol. 46, No. 2, pp.115-120.
5. Dmitriev, A. L. Experimental Study of Gravity Force Temperature Dependence, 18 th International Conference on General Relativity and Gravitation (GRG18), Sydney, Abstract Book, 2007, pp. 77-78.
6. Dmitriev A. L. AIP Conference Proceeding, 2008, Vol. 969, pp 1163-1169.
7. Dmitriev, A. L. Simple Experiment Confirming the Negative Temperature Dependence of Gravity, *Ingenernaja Fizika*, 2012, No 3, pp. 48-51 (in Russian).
8. Dmitriev, A. L., Bulgakova, S. A. Negative Temperature Dependence of Gravity – A Reality, Proc. WASET, 2013, Issue 79, pp. 1560-1565.
9. Grumazescu, M. On Thermogravity, http://www.researchgate.net/publication/275354540.
10. Glaser M. *Metrologia*, 1990, Vol. 27 (2), 95-98.
11. Ebert, H. *Physikalisches Taschenbuch*, Friedr.Vieweg & Sohn, 1957.
12. Dmitriev, A. L. Physical substantiation of an opportunity of artificial change of body weight, *Physics Procedia*, 2012, Vol. 38, pp. 150-163.
13. Raizer Yu. P. *Gas Discharge Physics*, “Springer”, Berlin-Heidelberg, 1991.
14. Lafferty J. M. (Editor), *Vacuum Arcs. Theory and Application*, John Wiley & Sons, New York, 1980.

№25

Applied Physics Research; Vol. 8, No 2, pp 38-39, 2016

EXPULSION OF PLASMA IN A GRAVITATIONAL FIELD

A. L. Dmitriev, E. M. Nikushchenko

National Research University of Information Technologies, Mechanics and Optics, St- Petersburg, 49 Kronverksky Prospect, 197101, Russia

Abstract. *It is shown that a characteristic shape of the arc discharge in the air with a pressure of 0.1 atm is mostly caused not by action of forces of buoyancy, but expulsion of plasma in a gravitational field.*

Keywords: gravitation, temperature, plasma, electric arc
PACS: 04.80.-y; 52.90.+z

The electric arch has been known for more than 200 years. Effects of buoyancy, convection, air currents, influence of external electric and magnetic fields [1] traditionally explain its characteristic shape. Experimentally proven influence of body temperature on its weight [2-5] gives the grounds to consider a question of extent of impact of a gravitational field of the Earth on a shape of an electric discharge. High temperatures, till tens of thousands K, in the channel of a free electric discharge at low pressure of about 0.1 atm support it. Earlier, a little attention was paid to the matter and research of physical properties of "an arch" was, as a rule, conducted in discharge tubes or in special chambers.

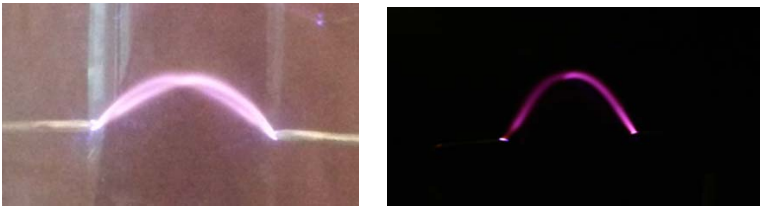
The elementary theory of influence of absolute body temperature T on its physical weight $P(T)$, not connected with action of buoyancy, convection, thermal expansion and other artifacts, leads to expression

$$P(T) = P_0(1 - A\sqrt{T}) \qquad (1)$$

where A is the coefficient which depends on physical characteristics (density and sound velocity) of material of the weighed body and temperature T is more than temperature of Debye [2-4]. From this formula, it is concluded that at rather high temperatures, exceeding

$T_0 = 1/A^2$, the body weight is negative. This may be interpreted as “pushing away” (“expulsion”) a body from the center of gravity (the center of the Earth). It is possible to estimate to what degree the specified effect influences the shape of the glow discharge by considering features of an electric arch in an alternating current.

The example of a photo glow discharge with air pressure of 0.1 atm, amperage range of 30-70 mA, voltage across the electrodes of 0.6-1.0 kV, frequency of current of 50 Hz, is shown in Fig. 1.



a. b.

Fig. 1. Arc discharge in alternating current in the air with the pressure of 0.1 atm. Exposition: a. – 33 ms, b. – 2.5 ms.

During an exposition of 33 ms the two spatially divided discharges are recorded. Specific current direction lasting 10 ms (the half of period of fluctuations) corresponds to each discharge. Relative shift of trajectories of discharges is possibly caused by action of Lorentz force in a magnetic field of the Earth. Obviously, formation of an arch happens in time less or about a half-cycle of current fluctuations.

Assuming that the buoyancy force of ejection is the main reason for an arch shape of the discharge, we will estimate time of "emerging" of the hot channel of such discharge. The temperature and gasdynamic processes accompanying formation of an electric arch in the atmosphere are very complex. Nevertheless, the order of amount of time of emerging of an arch can be estimated approximately by the following elementary calculations.

Electric discharge will be presented as chains of the spheres of radius R filled with plasma with a density ρ_p. Force of ejection of such chain is counterbalanced by its weight and friction force. Stokes formula will be used to assess its value,

$$\frac{4}{3}\pi R^3(\rho_a - \rho_p)g = 6\pi \nu R u \quad , \qquad (2)$$

where ρ_a - air density, g - acceleration of gravity, ν - viscosity of air, u - the average speed of emerging of a chain. Believing $\rho_a \succ\succ \rho_p$, time $t = h/u$ of emerging of a chain to a height h, equals

$$t = \frac{9}{2}\frac{\nu h}{gR^2(\rho_a - \rho_p)} \succ 4.5\frac{\nu h}{gR^2\rho_a}. \qquad (3)$$

Substituting the numerical values which closely correspond to experimental conditions in the right part (3) ($h \approx 1.6cm, R \approx 1mm, \rho_a \approx 0.1 \cdot 1.3kg/m^3$, $\nu \sim 2 \cdot 10^{-5}kg/m \cdot s, g \approx 9.8m/s^2$), we will obtain $t \succ 1s$; 1 atm corresponds approximately to 1.3 kg/m^3, and for viscosity which value increases with a temperature, the specified minimum value is chosen [6]. The specified value t significantly exceeds time of establishment of the arc discharge (about 10 ms). Therefore, buoyancy (Archimedes force) is not the main reason of a peculiar shape of an arch. Since in the presented experimental conditions the influence of slow convection streams of the rarefied air is insignificant, the given estimates provide the grounds to assume that the expulsion of plasma by a gravitational field of the Earth described by formula 1 is the main reason for a shape of an electric arch.

References

1. Yu. P. Raizer. *Gas Discharge Physics*. Springer, Berlin, New York, 1991.
2. A. L. Dmitriev, E. M. Nikushchenko, V. S. Snegov V. S., *Measurement Techniques*, 46(2), pp. 115 – 120, (2003).
3. A. L. Dmitriev *AIP Conf. Proc,* Vol. 969, pp. 1163-1169, N. Y. 2008.
4. A. L. Dmitriev, S. A. Bulgakova *Proc. WASET*, Issue 79, pp. 1560-1565, 2013.
5. A. L. Dmitriev *Applied Physics Research*, Vol. 7, No 6, pp. 43-48, (2015)
6. A. P. Babichev, N. A. Babushkina, A. M. Bratkovski et al. *Physical values. Handbook*, Energoatomizdat, Moscow, 1991.

№26

Applied Physics Research, Vol. 9, No 5, pp 87 – 89 (2017)

Gravitational Induction as Analog of Amplification of Light in Active Medium

Alexander L. Dmitriev

Baltic state technical University, St. Petersburg, Russia

Abstract. Concept of gravitational induction the essence of which is in the change of gravitation force affecting test mass due to influence of gravitational field on this mass by other masses has been considered. Evaluation of coefficient of induced increase of the gravity in the titanium sample has been shown based on the measurement of weight of nonmagnetic metal rod by its vertical and horizontal orientation.

PACS 04.80.−y ; 06.30.Dr

Term “induction” means “pointing, excitation” and in electromagnetic theory, generally, associates with appearance of electromotive force (electric field) in the conductor during change of magnetic flux through the surface limited by this conductor. Following traditional phenomenological approach while describing physical processes it is natural to assume that gravitational interaction of the bodies (masses) is connected to propagation of some disturbances – particles (gravitons etc.) within the space between interacting bodies or waves within etheric environment similar to acoustic and electromagnetic waves. Depending on approved gravitation model velocity of these waves (particles) is within wide range – from single cm/s to the values much more exceeding the velocity of light. At the same time gravitational disturbances produced by interacting masses propagate along the line of mass interaction directed towards each other. Similar to ordinary waves they involve the end space area and in principle should influence the other bodies or particles within the propagation area. Such influence may result in change of the force of gravitational interaction of the bodies analogues to optical phenomena of absorption and amplification of light within absorbing or active (inversion, excited) medium.

As shown in [1-3], acceleration caused by external, for example, elastic forces (electromagnetic in nature), body movement is accompanied by change of the force of its gravitational interaction with massive body (the Earth). The result of this is dependence of the weight of mechanical rotor with horizontal axis on speed of its rotation as well as orientation dependence of coefficients of restitution during elastic impact of the ball on massive plate [4]. Influence of accelerations of micro-particles on the gravity due to their chaotic thermal motion allows to confirm observed negative temperature dependence of the physical body weight [5, 6]. Gravitational effect described below may be called the effect of "gravitational induction". Its essence lies in change of the gravity affecting the test body due to gravitational interaction of this body with other foreign bodies.

Let's consider the rod with mass *m* and length l_1, being placed within homogeneous gravitational field of great mass *M*, for example the Earth mass, Fig. 1.

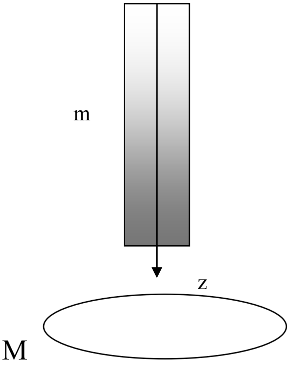


Fig. 1. Explanation of the effect of gravitational induction. "Active" zone of increased value of acceleration of the gravity inside the rod is being primed. $z = 0$ corresponds to the upper end of the rod.

Let's consider the normal acceleration of the gravity along the rod to be constant and equal to g_0. Intensity of gravitational disturbances around point z of the rod volume, caused by interaction of the particles within upper area $(0, z)$ of the rod with great mass *M* equally increases from upper towards lower end of the rod. Due to proportionality of the induced changes *dg* to value *g* of the gravity inside the rod along the length *dz,*

$$dg = \alpha g dz \quad , \tag{1}$$

dependence *g(z)* of the acceleration of the gravity inside the rode is exponential,

$$g(z) = g_0 e^{\alpha z} \quad , \qquad (2)$$

where α - coefficient of induced increase of the acceleration of the gravity.

Weight of the rod P_1 in the shape of parallelepiped with sides l_1, l_2, l_3 with vertical orientation of side l_1 is equal

$$P_1 = \rho g_0 l_2 l_3 \int_0^{l_1} e^{\alpha z} dz \approx m g_0 (1 + \frac{\alpha l_1}{2}) \quad , \qquad (3)$$

where ρ - density of the rod material, $m = \rho l_1 l_2 l_3$ - rod mass.

According to 3, dimensions of the rod directly influence its weight even within homogeneous external gravitational field. In horizontal position the weight P_2 of the rod is described according to the formula 3 with substitution l_1 for l_2 (l_3).

Relative difference δ of the weights (masses) of the rod measured by its vertical and horizontal orientation equals to

$$\delta = \frac{P_1 - P_2}{m g_0} = \frac{\alpha (l_1 - l_2)}{2} \quad . \qquad (4)$$

It is obvious that with $l_1 \succ l_2$ and positive strengthening coefficient α the value δ is also positive.

Dependence of the weight of non-magnetic titanium rod of BT1 model from its orientation taking into account influence on the change of some external physical factors has been studied in [7].

Average relative value δ of mass difference of the rod 150 mm in length, 30 mm diameter and mass of about 476 g measured by vertical and horizontal orientation of the rod is $1.1 \cdot 10^{-7}$ with error 10-15%. Corresponding measurement data of the absolute value of the mass difference are given at Fig. 2.

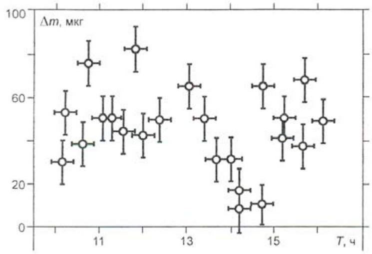


Fig. 2. Mass difference Δm (mcg) of the cylindrical titanium rod measured in day-time in its vertical and horizontal orientations.

Rod weight in vertical position systematically exceeds its weight in horizontal position within measurement errors. It should be noted that decrease of the value of mass (weight) difference during hours close to astronomical noon (about 2.00 p.m. of the standard time at the longitude of Saint Petersburg).

Taking into account the influence on the measurement of the rod weight by acceleration caused by the Sun of value g_s around noon, formula 3 is as follows

$$P_1' = mg_0'(1+\frac{\alpha l_1}{2}) - mg_s(1+\frac{\beta l_1}{2}) \qquad (5)$$

where g_0' - acceleration of gravity towards the Earth center taking into account tidal accelerations caused by the Sun, ($g_0' < g_0$), β - coefficient of induced change of the gravity due to the Sun influence which value may differ from α. It is obvious that $P_1' \prec P_1$, that is the cause of decrease of Δm on Fig. 2 in noon hours.

Fluctuations and decrease of value δ are explained by action of gravitational field from the Sun, Moon, and other planets on the test mass, including change of g_0 determined by tidal accelerations [8]. Accelerations of the gravity produced by these masses are significantly lower than value g_0 and coefficient β of gravitation amplification may, in principle, exceed value α due to the Sun impact.

On the basis of the given experimental data, according to (4), the calculated value of the coefficient α of the induced gravity amplification for titanium within the Earth gravitational field is $\alpha \approx 1.8 \cdot 10^{-4} m^{-1}$. More detailed data on the value of the coefficient of the gravitational amplification within different materials and its possible dependence on the oscillation frequency of the masses being weighted will be gained in further research. Perspective and closest in physical substance of researched problems is experimental research with regard to the weight of oscillating specimens of the test bodies within variable gravitational field of the Earth [9-11].

Thus, the effect of gravitational induction similar to the phenomenon of optical amplification in active medium has been proved experimentally. Thorough study of this effect conducted with the use of the test bodies of different dimensions and compositions, including by accelerated (oscillating) motion of the test bodies [12] will provide deeper understanding of nontrivial properties of the gravity.

References

1. A. L. Dmitriev On the Influence of External Elastic (Electromagnetic) Forces on the Gravity. Russian Physics Journal, Vol. 44, No 12, pp 1323 – 1327 (2001)
2. A. L. Dmitriev, V. S. Snegov The Weighing of a Mechanical Gyroscope with Horizontal and Vertical Orientation of the Spin Axis. Measurement Techniques, Vol. 44, No 8, pp 831 - 833 (2001).
3. A. L. Dmitriev Frequency Dependence of Rotor's Free Falling Acceleration and Inequality of Inertial and Gravity Masses. arXiv:1101.4678 (General Physics, 2011)
4. A. L. Dmitriev Inequality of the Coefficients of Restitution for Vertical and Horizontal Quasielastic Impacts of a Ball Against a Massive Plate. International Applied Mechanics. Vol. 3, No 6, pp 747 - 749 (2002).
5. A. L. Dmitriev, E. M. Nikushchenko, V. S. Snegov Influence of the Temperature of a Body on its Weight. Measurement Techniques. Vol. 46, No 2, pp 115 - 120 (2003).
6. A. L. Dmitriev Measurements of the Influence of Acceleration and Temperature of Bodies on their Weight. Proceedings of *Space Technology and Application International Forum (STAIF-2008),* edited by M. El-Genk, AIP Conference Proceedings, Vol. 969, NY, 2008, pp. 1163-1169.
7. A. L. Dmitriev, V. S. Snegov Influence of orientation of bar on its mass. Measurement Techniques, Vol.41, No 5, pp 425 - 429 (1998).
8. W. Torge Gravimetry Walter de Gruyter, Berlin, NY , 1989.
9. A. L. Dmitriev, E. M. Nikushchenko and S. A. Bulgakova, Dynamic Weighing Experiments – the Way to New Physics of Gravitation. AIP Conference Proc., Vol. 1208, pp 237 – 246 (2010)

10. A. L. Dmitriev Physical Substantiation of an Opportunity of Artifical Change of Body Weight. (SPESIF-2012). Physics Procedia, Vol. 38, pp 150 – 163 (2012).

11. A. L. Dmitriev, S. A. Bulgakova Negative Temperature Dependence of Gravity – A Reality. World Academy of Science, Engineering and Technology. Issue 79, pp 1560 – 1565 (2013).

12. A. L. Dmitriev Prospects of high-frequency gravimetry. Proc. Of the International Conference APSAC 2015, Vienna, Austria, March 15-17, 2015. pp 237 – 240. International Journal of Circuits, Systems and Signal Processing. Vol. 9. pp. 275-280 (2015).

№ 27

СБОРНИК НАУЧНЫХ ТРУДОВ VII МЕЖДУНАРОДНОЙ КОНФЕРЕНЦИИ ПО ФОТОНИКЕ И ИНФОРМАЦИОННОЙ ОПТИКЕ (МОСКВА, 2018 Г., СТР. 204-205)

УМЕНЬШЕНИЕ ВЕСА ВОЛОКОННОГО СВЕТОВОДА ПРИ РАСПРОСТРАНЕНИИ В НЕМ ЛАЗЕРНОГО ИЗЛУЧЕНИЯ

А. Л. ДМИТРИЕВ, Н. Н. ЧЕСНОКОВ*

Балтийский государственный технический университет,
Санкт-Петербург, Россия

**ООО «Сартогосм», Санкт-Петербург, Россия*

Экспериментально показано уменьшение веса волоконного световода (волоконного жгута) при распространении в нем излучения полупроводникового лазера с длиной волны 650 нм. При мощности вводимого в световод излучения 70 мВт и экспозиции 20 с уменьшение массы световода равно 6 мкг с погрешностью измерений 1 мкг. Отмечена инерционность наблюдаемого эффекта, свидетельствующая о его, по-видимому, тепловой природе.

A. L. DMITRIEV, N. N. CHESNOKOV*

*Baltic state technical University, Saint-Petersburg, Russia, *Ltd "Sartogosm", Saint-Petersburg, Russia*

REDUCTION OF THE WEIGHT OF OPTICAL FIBER DURING DISTRIBUTION OF LASER RADIATION

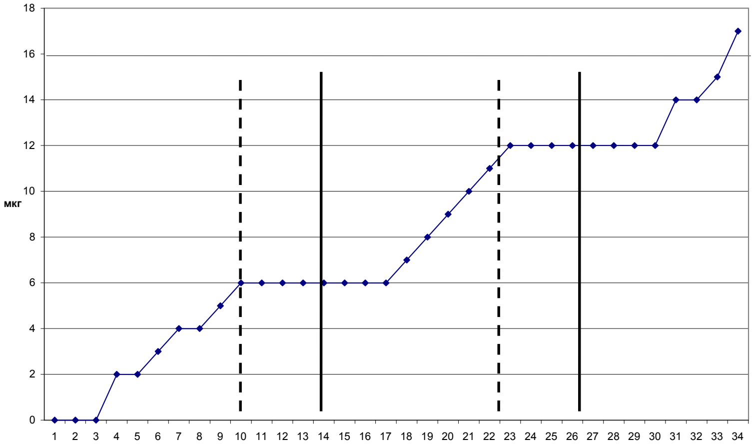
The reduction of the weight of an optical fiber (fiber bundle) during distribution of semiconductor laser radiation with a wavelength of 650 nm is shown experimentally. With the power of radiation input into light guide of 70 mW and exposure of 20 sec., reduction of the weight of the fiber is equal to 6 μg with a measuring accuracy error of 1 μg. Inertia of the observed effect, indicating its possible thermal nature, has been detected.

Влияние гравитации на распространение света – одна из старейших проблем физики. Еще в 1801 году Дж. Зольдер на основе корпускулярной модели излучения оценил угловое отклонение светового луча при его прохождении вблизи Солнца. Исследованиям действия гравитации на свет посвящено множество теоретических работ. Также известны теоретические исследования гравитационных свойств света [1]. Между тем, публикаций экспериментальных работ, предпринятых с целью «взвесить свет», в научной литературе не встречается. Это объяснимо исключительной малостью ожидаемого релятивистского эффекта гравитационного влияния света, практически недоступного современным средствам измерений.

Высокие плотности мощности лазерного излучения и возможность его локализации посредством волоконных световодов создают предпосылки проведения экспериментов по исследованию гравитационных свойств света с использованием современных высокоточных весов. В настоящей работе выполнено взвешивание герметичного контейнера с находящейся в нем катушке волоконного световода (волоконным жгутом) длиной 4.6 м при вводе в световод излучения полупроводникового лазера. Мощность лазера 70 мВт, длина волны излучения 650 нм. Входной и выходной торцы световода, в виде трех соединенных отрезков волоконного жгута, заключены в цилиндрические оправы диаметром 2.5 мм и закреплены на стенках дюралюминиевого контейнера диаметром 33 мм и длиной 49 мм. Световой диаметр торца волоконного жгута производства Лыткаринского завода оптического стекла - 1.5 мм. Излучение лазера вводится в световод через прозрачную стенку витрины весов (компаратора) марки SARTORIUS CC50, находящихся в гермозоне при нормальных температуре и атмосферном давлении.

Лазер периодически включался на время 20 с, после чего следовала пауза длительностью от 40 до 50 с. Отсчеты показаний весов производились с периодом 5 с. Дискретность отсчетов массы контейнера величиной около 37.4 г равна 1 мкг. Стабильный температурный дрейф показаний весов + 0.2 мкг/с.

Измерения массы цилиндрического контейнера выполнялись при горизонтальной и вертикальной ориентациях его оси, что практически не влияло на полученные результаты.



Пример типичной временной зависимости изменений массы контейнера приведен на рисунке. Вертикальными линиями отмечены моменты включения (штриховая линия) и выключения (сплошная линия) лазера. Уменьшение веса контейнера, вызванное действием лазера, соответствует горизонтальным участкам зависимости, при которых происходит компенсация положительного дрейфа показаний компаратора. Обращает на себя внимание инерционность наблюдаемого эффекта: уменьшение веса контейнера происходит не только во время экспозиции, но и в течение примерно 20 с после выключения лазера. Как видно из графика, уменьшение веса контейнера вследствие действия лазера составляет 6 мкг с погрешностью измерений 1 мкг.

Конструкция контейнера и теплозащита сердцевины волоконного жгута практически исключали заметное нагревание корпуса контейнера в первые секунды после включения лазера. Поэтому причина изменения веса контейнера, по-видимому, не связана с влиянием на него сил плавучести, а вызвана нагревом световода вследствие поглощения в нем излучения лазера. Такое уменьшение веса световода согласуется с ранее установленной отрицательной температурной зависимостью веса тел [2,3].

Исследования особенностей изменения веса волоконного световода при распространении в нем лазерного излучения представляют большой интерес для физической и волоконной оптики, а также для метрологии массы, и должны стать предметом специальных исследований.

Литература

1. D. Rätzel et al. Gravitational properties of light—the gravitational field of a laser pulse 2016 New J. Phys. 18 023009.

2. А. Л. Дмитриев, Е. М. Никущенко, В. С. Снегов Влияние температуры тела на его вес. Измерительная техника, № 2, 8 - 11 (2003).

3. A. L. Dmitriev, S. A. Bulgakova Negative Temperature Dependence of Gravity – A Reality. World Academy of Science, Engineering and Technology. Issue 79, pp 1560 – 1565 (2013).

№28

International Journal of Advanced Research in Physical Science (IJARPS)
Volume 5, Issue 4, 2018, PP 1-4

Change of the weight of optical fiber under the impact of laser radiation

A. L. Dmitriev, V. S. Snegov[1], Yu. I. Kamenskih[1], N. N. Chesnokov[2]

Baltic state technical University «VOENMEH» named after D.F.Ustinov, Saint- Petersburg, Russia, [1]D.I.Mendeleyev Institute for Metrology VNIIM, Saint-Petersburg, Russia, [2]Ltd "Sartogosm", Saint-Petersburg, Russia

Abstract: Authors present results of high-precision weighing of sealed containers holding coils of fiber optics bundles (plaits) while stimulating these fibers by radiation of helium-neon and semiconductor lasers. Weight decrease of fiber has been observed during dissemination of laser light. The weight reduction remains for a few seconds after the laser is turned off. The article offers qualitative physical explanation of this effect.

Contemporary physical theories exclude noticeable impact of radiation disseminating in the optical fiber on its weight [1]. With energy E of the current of photons, for example with the value of 1 J, increase $\Delta m = E / c^2$ of gravitational mass of the fiber equals about 10^{-8} mcg which is practically impossible to measure. Light might implicitly impact the weight of the fiber, i.e. as a result of heating of optical fiber during absorption of radiation which causes the change of the dimensions of the fiber and therefore the change of buoyancy of weighed sample (during laboratory weighing in the atmosphere). Experimental data of high-precision measurements of the weight of optical fiber stimulated by laser radiation are highly important both in physics and mass metrology. The article presents the results of weighing of sealed containers holding coils of optical fiber (plaits) during input of helium-neon (wavelength 633 nm) and semiconductor (wavelength 650 nm) lasers into fiber.

Appearance of container №1 is presented on Fig. 1.

Fig. 1 Container №1.

Input tip of fiber optic bundle 2m long with light diameter of 4mm (produced by Lytkarinskiy Factory of Optical Glass – LZOS) is attached to the wall of cylindrical container. Output tip is covered by the end mirror which enhanced concentration of radiation in the fiber. Container with diameter of 60mm and height of 100mm is placed in comparator CC1000SL SARTORIUS. Laser radiation was introduced to the end of the fiber optic bundle through transparent wall of comparator which was located in the tight area with atmospheric pressure of 1007 hPa and relative humidity of 38%. During weighing the temperature inside comparator was 22.38^0C - 22.16^0C. Power of radiation of helium-neon laser introduced to the fiber optics bundle was 16 mW. Weight of appointed container was about 350 g. Measurements of comparator were taken every 5 sec., discontinuity of measurements of the weight was 1 mcg.

Example of experimental time dependence of the change of weight measurements of container №1 is shown on Fig. 2. Vertical lines on Fig. 2 and further down on Fig. 3 and 4 indicate moments when the laser was turned on (cross-hatching line) and turned off (solid line).

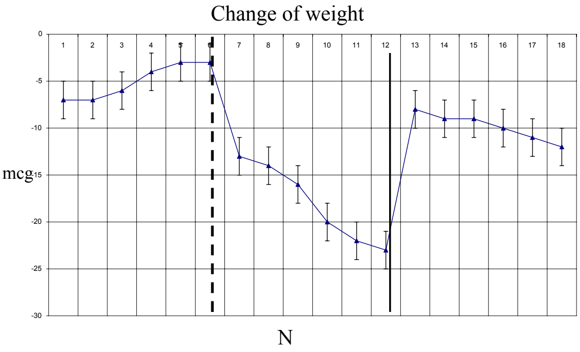


Fig. 2. Temporary change of the weight of container №1. N – number of measurement.

As shown on Fig.2, reduction of the weight of container caused by the laser reaches 15-20 mcg with drifting of weight measurements less than 1 mcg/sec.

Results of weighing of container №2 holding the coil consisting of three successively connected fibers (also produced by LZOS) with light diameter of 1.5mm and length of 4.6m [2] are presented on Fig. 3. Measurements were taken on comparator CC50 SARTORIUS. Power of

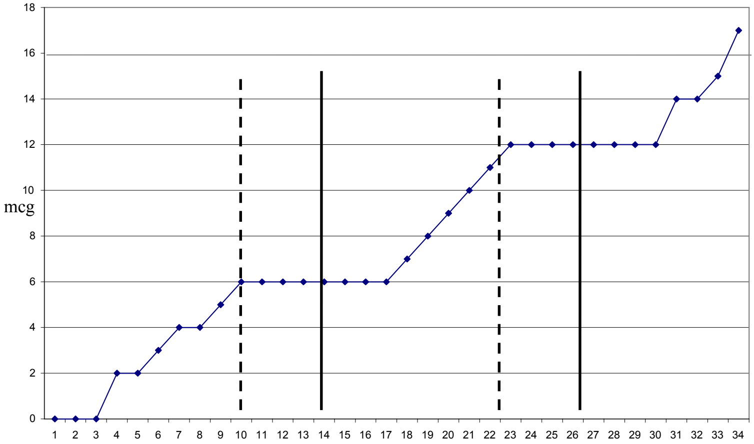


Fig. 3. Temporary change of the weight of container №2. Horizontal scale - number of measurement

semiconductor laser with the wavelength of 650 nm introduced to a optic fiber was 55 mW. Input and output tips of fiber optic bundle are attached to the wall of cylindrical container with the weight of 37.4 g, the diameter of 33mm, and the height of 49mm.

On Fig.3 decrease of the weight of container affected by the laser corresponds to the horizontal parts of presented correlation which represents compensation of positive drift of measurements of comparator with the value of 0.2 mcg/sec. It is interesting to emphasize the inertia of observed effect: decrease of the weight of container happens not only during exposure, but also for the duration of 20 sec after the laser was turned off. As seen on the graph, reduction of the weight of the container affected by laser is 6 mcg with the error of 1 mcg.

On Fig. 4 we showed results of the measurements of the weight of container №2, taken on comparator CC1000SL SARTORIUS. Here, radiation of semiconductor laser with the wavelength of 650nm and power of about 50 mW was introduced into the fiber optic bundle with the help of focusing lens, which made input of radiation more effective.

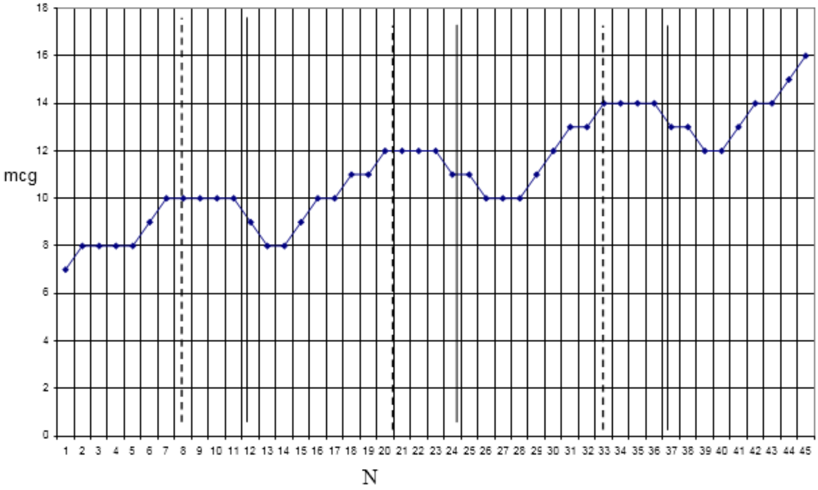


Fig. 4. Changes in the weight of container №2 during input of focused radiation of semiconductor laser into the optical fiber bundle. N – number of measurement.

Fig. 2, 3, and 4 demonstrate general, well recreated tendency of weight decrease of fiber optic bundle during input of laser radiation into them. Questions about why the decrease of weight of the optic fiber continues for a few seconds after turning off of the semiconductor laser and how this effect is being affected by coherency of the source of the light, are still open. Possible causes of the temporary dependency of the weight on Fig. 3 and 4 are particular qualities of processes of distribution of the heat inside optical fiber, analogous to qualities earlier observed during precise weighing of nonmagnetic metal samples heated by ultrasound [3].

Structure of the container and thermal insulation of the center of the optical fiber bundle made heating of the container itself almost impossible, especially during the first seconds after the laser was turned on. Therefore, the cause of the changing of the weight of containers is not related to the impact of the forces of buoyance on them, but probably is related to the heating of fiber optic bundle placed in the containers due to absorption of laser radiation in them. Such decrease in weight of the fiber optic bundle is consistent with negative temperature dependency of their weight [3] observed during precise measurement of non-magnetic samples. 5.

Presented “thermal” interpretation of produced dependencies is not an only explanation of the effect of decrease of weight of optical fiber. Optical radiation even in ideally transparent mediums affects high frequency, with optical frequency of Hz, change of polarization of the medium, therefore vibration and accelerated movement of its particles. Presented in [3-5] a simple phenomenological theory shows that such vibrations may be accompanied by the change of medium weight of a sample. 14 10

Experimental and theoretical research of the effect of radiation spreading in the optical fiber on its weight, are forward-looking both in physical optics and metrology of the weight.

Authors thank E. M. Nikushchenko and A. A. Sergeev for technical assistance.

References

1. D. Ratzel et al. Gravitational properties of light – the gravitational field of laser pulse. 2016 New. J. Phys. 18 023009.

2. A. L. Dmitriev, N. N. Chesnokov Reduction of the weight of optical fiber during distribution of laser radiation. Proc. VII International conference Photonics and Information Optics 2018, Moscow, 2018, pp. 204-205.

3. A. L. Dmitriev, E. M. Nikushchenko, V. S. Snegov Influence of the Temperature of a
Body on its Weight. Measurement Techniques. 2003, Vol. 46, No. 2, pp 115 – 120.

4. A. L. Dmitriev On the Influence of External Elastic (electromagnetic) Forces on the Gravity, Russian Physics Journal, 2001, Vol. 44, No. 12, pp 1323-1327.

5. A. L. Dmitriev, S. A. Bulgakova Negative Temperature Dependence of Gravity – A Reality. World Academy of Science, Engineering and Technology. 2013, Issue 79, pp 1560 – 1565.

Заключение

К актуальным направлениям исследований в области экспериментальной гравитации следует отнести

- высокоточные измерения температурной зависимости физического веса твердых тел различных структуры и химического состава;
- измерения влияния ускорений (в том числе, вызванных механическими и акустическими колебаниями) тел на силу их гравитационного взаимодействия, сравнение результатов статического и динамического режимов взвешиваний;
- исследования влияния размеров и ориентации изотропных и кристаллических тел на их физический вес;
- высокочастотная гравиметрия, исследование естественных колебаний напряженности гравитационного поля Земли.

В отношении популярной идеи преодоления силы тяжести без использования реактивной силы отдачи можно заметить следующее. Скорее всего, эта «лженаучная» (в терминологии релятивистов) проблема будет решена в ходе тщательных экспериментальных (и теоретических) исследований динамических гравитационных эффектов. Как показано в разделах 20 (С.149-168) и 23 (С.190-203), получение отрицательной гравитационной силы «тяги», действующей на осциллятор, находящийся в переменном гравитационном поле, принципиально возможно. Материальные затраты на проведение таких исследований, были бы намного меньше, например, стоимости экспериментов по поиску мнимых «гравитационных волн» или стоимости сверхмощных коллайдеров. Освободившись от надуманной релятивистской схоластики (многомерные «кривые пространства», сингулярности, «черные дыры» и тому подобные математические фантазии), подлинная физика гравитации еще вернется и станет основой практически значимых открытий и технических достижений.

A. L. Dmitriev

Physical Gravity

In the last century mathematic theory of gravitation has gained great popularity due to active promotion of relativistic methods in interpretation of universal gravitation. Abstract “mathematical gravitation”, positivistic in its basis, is not able to describe all gravitation phenomena. Creation of physical model which describes properties of gravitation and unveils new ways of its progressive development is possible only on the basis of experimental data with the limited set of speculative hypotheses. Realistic physical gravitation similar to the experimental data is an alternative to the “mathematical” one. Collection includes texts of author’s articles and reports published during 1998-2018. They deal with electrodynamic analogies and “non-classic” experimental effects in gravitation.

ОГЛАВЛЕНИЕ