The Cavendish Experiment

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The object of this experiment is to measure the Gravitational Constant G.

1. INTRODUCTION

Gravitation is one of few classes of interaction found in nature. Newton discovered in the 17^{th} century that the same interaction that makes an apple fall from a tree is the same one that keeps the planets in orbit around the sun. Newton published the law of gravitation in 1687, which states that:

Every particle of matter in the universe attracts every other particle with a force that is directly proportional to the product of the masses and inversely proportional to the square of the distance between them.

This is represented mathematically by:

$$F = \frac{Gm_1m_2}{r^2}$$

In the above equation G refers to the universal gravitation constant which has units of $kg^{-1}s^{-2}$.However, more than a century elapsed before the magnitude of this constant was measured because the force is very small between any masses which could fit in a laboratory. It can be measured using a *Torsion Balance*, which was used in 1798 by Cavendish to measure vale of G.

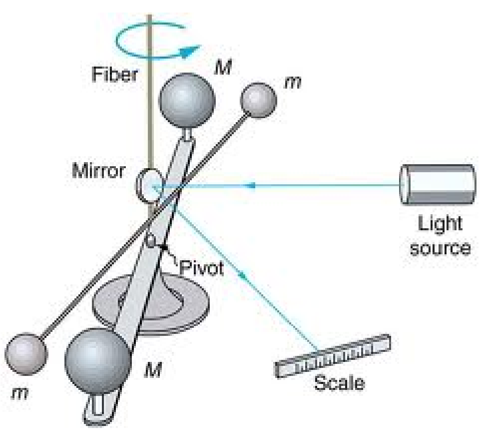

FIG. 1: Experimental Setup

Due to gravitational force between the one pair of small and large masses, there exists a net torque:

$$\tau = 2Fd$$

At the end this net torque and naturally opposing torque produced by the will result in a damped oscillation of the dumbbell. The equation of this oscillation is

$$I\frac{d^2\theta}{dt^2} + k\theta = 0$$

where I is the moment of inertia of the dumbbell system and k is the torsion constant of the wire used. Observing the oscillations through the displacement of a laser beam which is reflected off the small mirror spotted in the middle of the dumbbell and falls on a scale at a distance L, the universal gravitation constant can be determined as

$$G = \frac{\pi^2b^2dS}{MT^2L}$$

where b is the distance between the adjacent small and large massesi M is the large mass, $2d$ is the length of the dumbbell, and S is the difference between the initial and the final equilibrium positions of the laser beam on the scale. T is the period of the oscillation determined by requiring time for one successive wavelength.

2. EXPERIMENTAL SETUP

Initial setted data for $M = 1.498\ kg$, $d = 0.050\ m$ and $b = 0.0465\ m$

- Low Power Laser
- Scale
- Cavendish Torsion Balance With Large Masses
- Ruler

3. DATA ANALYSIS

Initially, we are some experiemtal data as in document *cavendish RP2111.doc*

- $L = 2\ m$
- $\Delta x = 0.03\ m$
- $M = 1.038\ kg$
- $m = 0.014\ kg$

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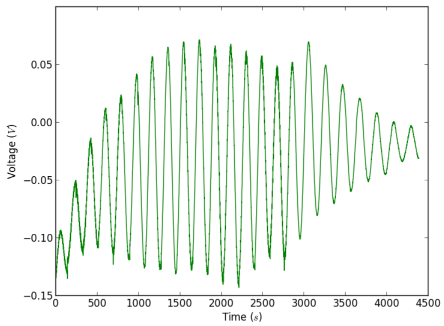

FIG. 2: Output of graph from Computer Cavendish Simulation Program

- $d = 0.05\ m$
- $R = 0.05\ m$
- $r = 0,0071\ kg$
- $l_{boom} = 0,145\ m$
- $m_{boom} = 0.0071\ kg$
- $w_b = 0,0127\ m$

We are going to find T, the period of oscillation of the boom about the wire from Figure 2 as 381 *sec*.

In calculation parts,from the behaviours of the oscillation, we can calculate k from

$$k = \left(\frac{4\pi^2}{T^2} + b^2\right) I$$

where I is the sum of the moments of inertia of the two small spheres $I_s = 2\left(md^2 + \frac{2}{5}mr^2\right)$ and the boom $I_b = \frac{m({l_{boom}}^2 + {w_{boom}}^2)}{12}$ where w_{boom} is the width of the boom.

The displacement angle of a damped oscillator as a function of time is given by:

$$\theta_t(t) = \theta_e + Ae^{-bt}cos(\omega t + \phi)$$

By using derivations in References 3. we are going to have going to have corrected value G.

4. CONCLUSIONS

5. REFERENCES

- E. Gulmez, Advanced Physics Experiment, Istanbul, Bogazici University Publication, 1999
- http://web.mit.edu/8.13/www/experiments.shtml
- http://www.physics.uoguelph.ca/orbax/phys2440/GravitationalConstant.pdf

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