Measuring the Mass of Earth Without the Use of the Universal Constant G

This handout outlines a hypothetical experiment to measure the mass of Earth. The experiment and data collection has already been performed. It is your job to interpret the results of the experiment. Feel free to write on this hand out.

Two massive identical perfect spheres of Iridium, a very dense metal were manufactured. Each has a radius of 1 meter. The two spheres are attached to a structure above (not pictured) by immensely strong cables that are both exactly 10 meters in length. The distance from the floor below and the ceiling where the two spheres are attached is exactly 22 meters from the floor. A laser is attached perfectly below one of the spheres. A detector below measures where the laser pointer reaches the floor. It was first calibrated when only that sphere was in its position. Once the two spheres are placed in their current position shown in Figure 1 the gravitational attraction between the two spheres is large enough to be measured.

The force of gravity between the two massive spheres causes them both to move toward one another, but very quickly the force of gravity and the tension in the cable balances that small force and brings the two sphere to rest, but now the distance between the centers of each sphere is very slightly less than original seperation of 2.5 meters. The detector below has measured the laser being deflected a distance of 2.242 micrometers (μm) ($2.242 \times 10^{-6} meters$). [1]

Given

1. The experimental setup Figure 1.
2. The laser deflection: $d_l = 2.242 \times 10^{-6} m$
3. Density of Iridium: $\rho = 22560 \, \frac{kg}{m^3}$
4. Volume of a sphere: $V = \frac{4\pi r^3}{3}$
5. Radius of Earth: $R = 6.371 \times 10^6 m$

Find

1. The mass of Earth: $M_E = ?$

Relevant Equations

[2]

$$F = G\frac{m_1 m_2}{R^2} \tag{1}$$

$$tan\theta = \frac{length\,of\,the\,opposite\,side}{length\,of\,the\,adjacent\,side} \tag{2}$$

[1] A human hair is about 22 micrometers in width.
[2] The Universal Constant G is not necessary for a solution.

Assessment

The point of this exercise is to practice you problem solving skills and to work with Newton's Universal Law of Gravitation in a more advanced setting. I am more interested as to how you reach an answer than anything else. You will be expected to show your work on a seperate sheet of paper and turn it in at the end of class. Your work will be assessed on the following

1. Student correctly draws and labels a free body diagram for one of the spheres. (*5 points*)
2. Student correctly draws and labels a diagram for the geometry involved in the problem. (*5 points)*
3. Student shows work and all calculations and leaves brief comments throughout his or her work justifying the steps taken.[3] (*8 points*)
4. Correct answer is given in correct units. (*2 points*)

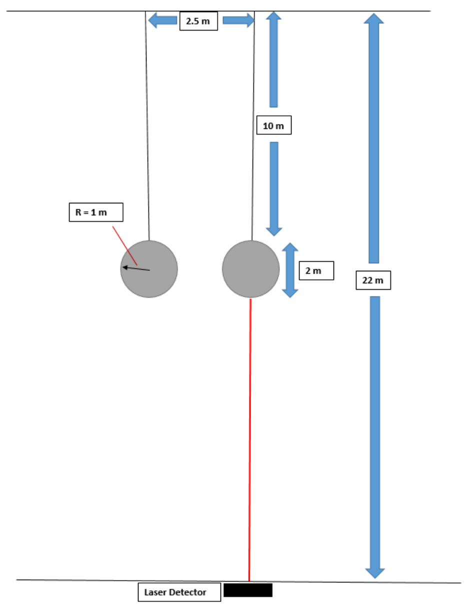

Figure 1: Experimental setup

[3]This is a precise experiment avoid rounding when possible