Name: ________________

Date: ________________

Section: ________________

Astron 104 Laboratory #Extra Credit
The Mass of the Earth
More Precisely 1.1, Section 6.1

Instructions: This is a special extra-credit lab. It can be to replace any missing or low grades. It is to be completed **on your own**, not during a lab period. You cannot copy other's work: what you turn in must be your own. Make sure you are clear about the process you use to solve the problems: partial credit will be awarded. If you have questions, you can email:

- Professor Kaplan (kaplan@uwm.edu): office hours are Monday 2pm-3pm; Wednesday 2pm-3pm
- Daniel Murray (dwmurray@uwm.edu): sections 801 and 803
- Kevin Ross (rdwmurray@uwm.edu): sections 802 and 804

Or attend office hours. Emails for assistance must be received before 12pm on Wednesday, December 12.

Due: Wednesday, December 12, at 4pm in the mailbox of Professor Kaplan (Physics Building, 4th floor). Make sure you include your name and section number/time.

Although the size of the Earth has been known since ancient times, an accurate measurement of the mass of the Earth was possible only relatively recently. We will investigate two methods to calculate the mass of the Earth.

1. A crude estimate of the mass of the Earth can be made by estimating the density of the Earth. Density, d, measures how much mass is in a volume of space. The density of an object of mass M and volume V is:

$$d = \frac{M}{V}$$

   The volume of a sphere of radius R is:

$$V = \frac{4}{3}\pi R^3$$

To calculate the volume, we can use the radius of the Earth that Eratosthenes found, which was about 6,366 km= 6.36×10^6 m.

Compute the volume of the Earth in m^3 [**10 points**]:

The typical density of a rock on the Earth's crust is $d_{\mathrm{rock}} = 2700\,\mathrm{kg/m}^3$. If we assume that the overall density of the Earth is the same as rock, compute the mass of the Earth using this value and the volume you found above. Call this number M_1 [**10 points**]:

2. We can estimate the mass of the Earth by measuring the amount of gravitation the Earth's mass produces. To do so, we need (1) measurements of the Earth's radius (6.36×10^6 m) and of the gravitational acceleration at its surface, g, which measures how quickly objects accelerate when they fall (use $g = 10\,\mathrm{m/s}^2$); and (2) a formula for the Earth's gravitational acceleration g given the mass and radius. We use Isaac Newton's work. He was the first person to describe how gravity operated, and he showed how a body's mass and radius determined its gravitational acceleration. He found that the acceleration at the surface of the Earth could be expressed as:

$$g = \frac{GM}{R^2}$$

where G is Newton's constant, M is the mass of the Earth, and R is the radius of the Earth. Use this equation to solve for the mass of the Earth (call is M_2 to distinguish it from the result we got before; you don't need to plug in values but leave it in terms of G, g, and R) [**10 points**]:

3. In 1798 Henry Cavendish made an accurate measurement of G, getting 6.1×10^{-11} m^3/kg/s^2. Using his value of G and the expression for mass, Cavendish was able to compute a better estimate of the mass of the Earth. Following this procedure, compute the mass of the Earth M_2 [**10 points**].

4. Why is this result M_2 different from the previous result M_1? Hint: what assumptions were required to get M_1? [**10 points**]

5. Using the new mass of the Earth M_2 compute the average density of the Earth. [**10 points**]

6. Is the average density of the Earth the same as the density of rock? What does that tell you about the composition of the Earth? [**10 points**]