

MEASURE THE MEAN DENSITY OF THE EARTH

Objective: Measure the mean density of the earth, ρ , using Newton's gravitation law and the previously measured value of the gravitational constant, $G = 6.67 \times 10^{-11}$ ($\text{m}^3 / \text{kg s}^2$). From this measurement determine which elements could not constitute the major portion of the earth.

Commentary: If we were just beginning to try to determine what material is in the deep interior of the earth, a first step might be to determine its density. We expect that the very high pressure near the center of the earth will compress most materials to higher density than they have at the surface; but the differences between the densities of some of the elements are so great that we could at least eliminate some of them from consideration. For example the density of Iron is $\rho = 7.874$ g/cc, Lead is $\rho = 11.35$ g/cc, Mercury is $\rho = 13.546$ g/cc, Osmium is $\rho = 22.57$ g/cc. The mean density of the crust of the earth (rocks) is about $\rho = 2.7$ g/cc. Much detail is now known about the inner layers of the earth from measurements of the propagation of seismic waves, but this experiment is intended to present you with the problem as it existed before seismic measurements were possible.

In this experiment, the "proposal" that you will be asked to write in subsequent experiments has been (partially) written for you to provide an example¹. It describes what the experiment is to measure and how it will be done. A design for the experiment is given, and some computations are presented to estimate the magnitudes of quantities to be measured and the precision that can be anticipated for these measurements. However, the proposal does not describe the required quantitative propagation of measurement errors to yield the uncertainty in the final result.

The proposed "time of sunset versus observer elevation" method for measuring the radius of the earth was used by the ancient Greeks. Unless the method provides sufficient accuracy so that the final answer for the density of the earth will be known well enough to eliminate some of the elements, the experiment will not be successful. Thus you must estimate the accuracy expected for the proposed methods in order to decide which to use.

¹ You are to read chapters 1, 2, and 3 in Taylor and you are to write a 1 page supplement to the "proposal" that describes how you expect to estimate the error in the final result of your experiment.

Reference: Halliday, Resnick, and Walker, 5th edition. Chapter 14, Gravity. Chapter 16, Oscillations (the simple pendulum section 16.6)

Realization: We recommend that you attempt to measure the time of sunset in groups so that you can avoid a big mistake. You may not get the time measurement right the first time.

Safely. Do not go too near the cliffs. Do not drop or kick objects onto (unseen) people below on the beach. Do not stare directly at the sun for this measurement until the top edge is about to disappear. Sunglasses or darkened film can be used as an aid, as damage to your eyes may result from excessive exposure to direct sunlight.