UNIVERSIDADE da MADEIRA

Experimental Science
P6: Indirect measurement of physical quantities

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1. Purpose

- Indirect measurement of physical quantities: volume, specific mass and density.
- Specific mass measurement of various substances by 3 different methods.

2. Introduction

The specific mass, ρ, is a physical quantity that is characteristic for each substance and is defined as the mass, *m*, that that substance contains in a unit volume, *V*:

$$\rho = \frac{m}{V}$$

The derivation of a specific mass requires therefore the measurement of mass and volume.

Specific density should not be confused with density. In fact, density (*d*) is an dimensionless physical quantity. It compares the substance's specific mass to that of water:

$$d = \frac{\rho_{substância}}{\rho_{H_2O}}$$

4. Experimental activity

4.1 Material

Graduated cylinder (50 or 100 ml), calliper, 3 scales, water, cylinder, sphere and a 4 cylinders set made of the same material and different volumes.

4.2 Experiment plan

Our aim is to determine experimentally the specific mass of 3 different substances by 3 distinct methods.

The first 2 methods will be applied to a sphere and a cylinder. The third method will be applied to the 4 cylinders set.

In all methods it is necessary to measure the mass and volume of the object.

The object's mass is measured indirectly from its weight. The measurements are made using scales. A scale has a sensor that deforms proportionally with the object's weight, *P*. This weight is directly proportional to the object's mass, *m*. That is, $P = mg$, where g is the earth's gravitational acceleration.

Sometimes it is difficult to immobilize an object at the scale's plate centre. On such cases a second stabilizing object should be used (e.g., a recipient, a washer). Before starting the measurement you must tare the scale. This means to adjust the device's zero so that it has a zero reading when subject only to the stabilizer's weight. In order to do so, just push the tare/zero button. The device's zero should be checked always before and after a measurement.

The volume measurements will depend on the method. In one method the volume is estimated from the fluid displacement when the object is submerged. In the other two methods the volumes are derived from object's dimensions.

4.3 Procedure

Organize your data into tables. These tables should contain each measurement's error as well as the corresponding units.

Method 1:

a) Mass measurement

Measure the sphere's mass with the 10 g^{-1} resolution scale.

b) Volume measurement

Fill the graduated cylinder half way with tap water. Record the water's initial volume while the cylinder is placed on a horizontal surface. Avoid the parallax error. Due to the water meniscus's curvature use the maximum device error written on the cylinder (instead of half of the smallest division).

Place the object into the cylinder so that it becomes totally submerged. Record the observed volume in the graduated cylinder. The increase in volume is solely due to the object's volume.

Repeat method 1 for the cylinder with just one modification: instead of the 10 g^{-1} resolution scale use the smallest resolution scale (1 g^{-1}).

Method 2:

a) Mass measurement

Measure the sphere's mass with the 10^3 g^{-1} resolution scale.

b) Volume measurement

Use a calliper to measure the sphere length(s) needed to calculate its volume.

Repeat method 2 for the cylinder.

Method 3:

a) Mass measurement

Measure the mass of each of the cylinders from the 4 cylinder set using a scale with a resolution higher than 1 g^{-1}.

b) Volume measurement

Use a calliper to measure the cylinder length(s) needed to calculate its volume.

Extra activity:

Propose a method to measure the specific mass of water. Perform the necessary measurements.

What is the water’s specific mass standard value at room temperature?