NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 210 – Mechanics & Heat Fall 2022

Lab #10

Lab Writeup Due: Tue/Wed/Thu, Nov. 8/9/10, 2022
Read OpenStax: Chapter 11.1-11.4, 11.7, Lecture Notes #9

Specific Gravity

Apparatus

Specific gravity is a measure of the density of a material compared to water. The apparatus to do this consists of a metal overflow cup with a side spigot and a beaker. If the overflow cup is filled to its limit, then an object lowered into the water will cause some of the water to spill out the side spigot. This water can be collected in the beaker and weighed.

The objects in this laboratory will be weighed by a spring scale. The spring scale measures the weight of an object in Newtons (N). There are two spring scales available, one with a maximum reading of 2.5 N and one with a maximum reading of 20 N. An object with a weight of more than 2.5 N must be read with the 20 N scale. If the weight is below 2.5 N, switch to the 2.5 N scale to get a more accurate reading.

Theory

Though they are often treated interchangeably, weight and mass are different physical properties. Mass m is a fundamental measure of the amount of matter. Weight is a measure of the force exerted by a mass. On the surface of the earth the conversion factor is the acceleration of gravity $(g = 9.8\,\mathrm{m/sec^2})$. Thus, an object on earth has a weight related to its mass:

$$W = mg \tag{1}$$

Density ρ (the Greek letter "rho") is defined as the mass m of an object divided by the volume V of the object [see Eq. (2)]. The density of a material depends on its phase and temperature. For instance, the density of liquids and gases is very temperature dependent. Water in the liquid state has a density ρ_w of about $1\,\mathrm{g/cm^2} = 1000\,\mathrm{kg/m^3}$.

$$\rho = \frac{m}{V} \tag{2}$$

The density of an object can be used to identify the material of the object, and to predict its behavior when placed in a fluid, either liquid or gas. If the density of an object is greater than the fluid it will sink, and if it is less than the density of the fluid it will rise. Water is the most commonly used fluid to compare material for density measurement.

The specific gravity SG is the ratio of a material's density compared to water [see Eq. (3)]. The official specific gravity is defined using water at 4°C. Because it is the ratio of two densities with the same units (g/cm^3), it has no units. Note that since water has a density of 1 g/cm^3, the specific gravity is equivalent to the density of the material.

$$SG = \frac{\rho}{\rho_w} \tag{3}$$

When an object is in a fluid there is a buoyant force acting on the object due to the pressure of the fluid. The buoyant force is equal to

$$F_{buoyant} = \rho_w g V \tag{4}$$

Since $\rho_w V$ is equal to the mass of the water displaced by the object, this quantity is also exactly equal to the weight of the water. This is called the buoyancy (or Archimedes) principle: *the buoyant force on a body immersed in a fluid is equal to the weight of the fluid displaced by the object*.

The buoyant force is also equal to the difference in weight of an object in and out of the fluid:

$$F_{buoyant} = W_{out} - W_{in} \tag{5}$$

If the numerator and denominator of Eq. (3) is multiplied by gV, using Eqs. (1)-(4) gives

$$SG = \frac{\rho g V}{\rho_w g V} = \frac{W_{out}}{W_{out} - W_{in}} \tag{6}$$

The last step in the equation used the buoyancy principle for the denominator. Here W_{out} is the weight of the object out of the water, and W_{in} is the weight in water.

Data Collection

Part A—Heavier than water

(1) Weigh the beaker used to catch water from the overflow can, and record the value of the mass m_0 in grams. Also take a closeup cellphone picture of your wooden block. Do a **Google search** for: "types of wood", look at *images*, and try to determine what type of wood is your wooden block. Record this in your notebook. Also take a *separate* picture of each your four metal cubes for future use (in answering questions in the **Data Analysis** section).

(2) Record the weight W_{out} (in Newtons) of one of the metal cubes with a spring scale.

(3) Fill the overflow can with water so that water just begins to spill out.

(4) Use the spring scale to lower the metal cube into the water in the overflow can until it is completely submerged. The water should be collected in the beaker.

(5) Record the weight W_{in} (in Newtons) of the cube while it is submerged.

(6) Weigh the beaker including the water m_1 and record the mass difference due to the water $m_w = m_1 - m_0$ in grams.

(7) Repeat steps 3 through 6 for each of the other metal cubes.

Part B—Lighter than water

(8) Weigh and record the wood block W_b using a *balance scale*.

(9) Weigh and record the weight of the sinkers using a *balance scale*.

(10) Use a *spring scale* to measure the weight of both the block and sinkers tied together. Make certain this weight is consistent with your results using the *balance scale*.

(11) Use the *spring scale* to lower the sinkers, but not the block, into the water. The water should be collected in the beaker.

(12) Record the weight of the block and sinkers while just the sinkers are submerged W_1.

(13) Record the weight of the block and sinkers when they are entirely submerged W_2.

Analysis

(14) Use the weight of the object in air W_{out} and Eq. (1) to find the mass m of each of the four metal cubes in Step (2).

(15) Use the mass of the water m_w and density (1.0 g/cm^3) to find the volume V of water displaced for each of the four cubes measured in **Part A**, Step (6) using Eq.(2).

(16) Use the mass from Step (14) and the volume from Step (15), and Eq. (2), to find the density of the four cubes.

(17) Use the weights from Steps (2) & (5), and Eq. (6), to find the specific gravity of the four cubes.

(18) Place all the data from **Part A** and Steps (14) through (17) in a single data table.

(19) Find the specific gravity of the wood in **Part B** using the following equation

$$SG = \frac{W_b}{W_1 - W_2} \tag{7}$$

(20) Find the specific gravity of the sinkers in **Part B**.

Data Analysis

(21) How does the density of the cubes in Step (16) compare to the specific gravity in Step (17)?

(22) What experimental effects might account for the differences?

(23) Based on experimental errors, is the calculation of Step (16) or Step (17) better? Cite specific sources of error to support your conclusion.

(24) If there were no sinkers would the wood block sink or float? If it would float how much of the block would be below the surface?

(25) What does the denominator in Eq. (7) represent? Why is Eq. (7) [instead of Eqs.(1)-(6)] needed to find the specific gravity of wood?

(26) Iron has a $SG = 7.9$. Why does a ship with an iron hull float?

(27) Go to the Wikipedia page: https://en.wikipedia.org/wiki/Specific_gravity, and determine the composition of the 4 metal cubes and the sinkers. In your written report, show a picture of each metal cube, the specific gravity you calculated, the specific gravity given in the literature, your percent error, and a comment on the accuracy of your measurement.

(28) Go to the Webpage: http://www.bellforestproducts.com/info/specific-gravity/ (or any other similar website you can find), and try to determine the composition of your wooden block. Why might your result be incorrect? From your cellphone picture, what type of wood do you believe your wooden block actually was? (do a Google search for: "types of wood" and look at *images*)