Physical Science 303 – Homework 2 Rubric

Unit III Problems and Exercises 1 - 12

In this solution set, I will use the formula

$$\rho = \frac{m}{V}, \tag{1}$$

where ρ is density, m is mass, and V is volume. I will refer to it as (1).

1. One liter is 1000 milliliters. One milliliter is equal to one cubic centimeter. One centimeter is equal to ten millimeters. With this information, we can convert liters into cubic centimeters and cubic millimeters.

$$1\,\mathrm{L}\frac{1000\,\mathrm{mL}}{1\,\mathrm{L}}\frac{1\,\mathrm{cm}^3}{1\,\mathrm{mL}} = 1000\,\mathrm{cm}^3 \tag{2}$$

$$1\,\mathrm{L}\frac{1000\,\mathrm{mL}}{1\,\mathrm{L}}\frac{1\,\mathrm{cm}^3}{1\,\mathrm{mL}}\frac{(10\,\mathrm{mm})^3}{(1\,\mathrm{cm})^3} = 10^6\,\mathrm{mm}^3 \tag{3}$$

2. Rearranging the variables in (1), we arrive at

$$m = \rho V. \tag{4}$$

Plugging in our values for this problem, we see that the sample has a mass of

$$40\,\mathrm{mL}\frac{13.6\,\mathrm{g}}{1\,\mathrm{mL}}\frac{1\,\mathrm{kg}}{1000\,\mathrm{g}} = 0.5\,\mathrm{kg}. \tag{5}$$

3. First, we convert the density

$$7.86\,\frac{\mathrm{g}}{\mathrm{cm}^3}\frac{1\,\mathrm{kg}}{1000\,\mathrm{g}}\frac{(100\,\mathrm{cm})^3}{(1\,\mathrm{m})^3} = 7860\frac{\mathrm{kg}}{\mathrm{m}^3}. \tag{6}$$

From page III-11 in the lab manual, iron has this density.

4. Let's approximate the Moon as a sphere. The volume of a sphere is $V = 4\pi r^3/3$, where r is its radius. We can now calculate the volume of the earth as $4\pi(1.74 \times 10^6\,\mathrm{m})^3/3 = 2.21 \times 10^{19}\,\mathrm{m}^3$. Since we know the mass and volume of the Moon, we can calculate the density of the Moon using (1). As we saw in Problem 3, the conversion from g/cm^3 to kg/m^3 is to multiply by 1000. So we find

$$\rho_{Moon} = \frac{m}{V} = \frac{7.35 \times 10^{22}\,\mathrm{kg}}{2.21 \times 10^{19}\,\mathrm{m}^3} = 3330\,\mathrm{kg/m}^3, \qquad (7)$$

which is 3.33 g/cm^3.

5. Using (1), the density of silver is 1.05 kg/100 cm^3. Using (4), 57 cm^3 of silver has a mass of

$$57\,\mathrm{cm}^3 \frac{1.05\,\mathrm{kg}}{100\,\mathrm{cm}^3} = 0.6kg. \qquad (8)$$

6. Using (1), the density of gold is

$$\rho = \frac{m}{V} = \frac{10\,\mathrm{kg}}{518\,\mathrm{cm}^3}\frac{1000\,\mathrm{g}}{1\,\mathrm{kg}} = 20\,\mathrm{g/cm}^3. \qquad (9)$$

Water has a density of 1 g/cm^3. So the ratio of the density of gold to the density of water is

$$\frac{\rho_{gold}}{\rho_{water}} = \frac{20\,\mathrm{g/cm}^3}{1\,\mathrm{g/cm}^3} = 20. \qquad (10)$$

7. Water has a density of 1 g/cm^3. Using (4), the mass of 317 mL of water is

$$317\,\mathrm{mL}\frac{1\,\mathrm{cm}^3}{1\,\mathrm{mL}}\frac{1\,\mathrm{g}}{1\,\mathrm{cm}^3}\frac{1\,\mathrm{kg}}{1000\,\mathrm{g}} = 0.317\,\mathrm{kg}. \qquad (11)$$

To convert mass into weight, we use that the weight density is 9.8 times the mass density (pg. 232 of Hewitt). So the weight of 317 mL of water is 3.1 N.

8. The mass of my body is 2.0×10^2 lb, that is

$$2.0 \times 10^2\,\mathrm{lb}\frac{1\,\mathrm{kg}}{2.2\,\mathrm{lb}}\frac{1000\,\mathrm{g}}{1\,\mathrm{kg}} = 9.1 \times 10^4\,\mathrm{g}. \qquad (12)$$

Since we know the density of water, my body volume is about

$$V = \frac{m}{\rho} = \frac{9.1 \times 10^4 g}{1.0\,\mathrm{g/cm^3}} = 9.1 \times 10^4\,\mathrm{cm^3} \tag{13}$$

If my lungs have a volume of 5.0 L, then inhaling completely will increase my volume by this amount. Five liters is 5000 mL, which is 5000 $\mathrm{cm^3}$. My average density without my lungs full of air is the same as water, 1.0 $\mathrm{g/cm^3}$. With my lungs inflated, my average density is [using (1)]

$$\rho = \frac{m}{V} = \frac{9.1 \times 10^4\,\mathrm{g}}{9.1 \times 10^4\,\mathrm{cm^3} + 5.0 \times 10^3\,\mathrm{cm^3}} = 0.95\,\mathrm{g/cm^3}. \tag{14}$$

So my average density decreases by about 5%. With lungs inflated, I am less dense than water, so I should float. Although I shouldn't trust my life to this calculation! I know the assumption is incorrect that my average body density is that of water, because I sink in a swimming pool when I exhale most of the air in my lungs.

9. If the top layer of the earth is less dense than the average density, then something more dense than the average density must be inside the earth to compensate for this. Many materials more dense than 5.52×10^3 $\mathrm{kg/m^3}$ are metals. My model of the earth has an outer layer of rock and an inner core of metal.

10. Assuming that his foot had a density of water and using (4), the mass of his foot would be

$$m = \rho V = 120\,\mathrm{in^3} \frac{(2.54\,\mathrm{cm})^3}{(1\,\mathrm{in})^3} \frac{1.0\,\mathrm{g}}{1.0\,\mathrm{cm^3}} = 2.0 \times 10^3\,\mathrm{g} = 2.0\,\mathrm{kg}. \tag{15}$$

11. Using an electronic balance, I measured the mass of a nickel to be 4.95 $\pm$ 0.03 g. Using the volume displacement method with a graduated cylinder, I measured the volume of a nickel to be 0.5 $\pm$ 0.1 $\mathrm{cm^3}$. Using (1), the density of a five cent piece is

$$\rho = \frac{m}{V} = \frac{4.95 \pm 0.03\,\mathrm{g}}{0.5 \pm 0.1\,\mathrm{cm^3}} = 10 \pm 2\,\mathrm{g/cm^3}. \tag{16}$$

In this problem, I combined uncertainties by adding their relative uncertainties together and rounding (0.6 % + 20% = 20 %). We haven't learned this method yet in class. I used it to point out how uncertain my measurement is. The mass measurement is very precise, but the volume measurement is not!

12. An exact 1/16 scale model would have each dimension smaller by a factor of 16. The length would be 1/16 of the original, the width would be 1/16 of the original, and the depth would be 1/16 of the original. Assuming the scale model and the real railroad car are made of materials with the same density, the weight of the scale model would be 40,000 lb / 16^3 = 10 lb.