Density lab- explanations for activities

Density ($\rho$) is defined as mass divided by volume ($\rho = \frac{m[M]}{V[L^3]}$). The SI unit of density is kg/m³ and the cgs unit is g/cm³.

Density is central to the understanding of many oceanic processes: from the formation of ocean basins, through ocean circulation to the transport of carbon from ocean surface to depth. As a property of matter, density is a central topic in secondary school physical science. While most adults have heard about the concept of density both school-age students and adults hold a number of misconceptions about density.

Examples of misconceptions include (the list was compiled by the Operation Physics Elementary/middle school physics education outreach project of the American Institute of Physics):

- Large objects sink and small object floats
- Objects float in water because they are lighter than water.
- Objects sink in water because they are heavier than water.
- Wood floats and metal sinks.
- All objects containing air float.
- Mass/volume/weight/heaviness/size/density may be perceived as equivalent.

Note: while weight is commonly used as an equivalent to mass, in physics it is used to describe a particular force arising from the gravitational pull between objects (e.g. the Earth and the mass).

**Station 1: Will it float?**

This activity can be used to address some of the misconceptions stated above (e.g., large object sinks, small object floats, wood floats, metal sinks).

There is a wide range in the densities of wood found throughout the world. The range of density extends from **balsa (0.1-0.17 g/cm³)** to some tropical hardwoods that have density that exceeds that of water (1.04-1.37 g/cm³) **Lignum vitae has a density of 1.17-1.29 g/cm³**.

The volume of the metal ball is 1023 cm³ and its mass is 144g. Its density is therefore $144/12.5= 0.14$ g/cm³.
The volume of the Delrin ball is 1.15 cm³ cm and its mass is 1.5 g. Its density is therefore $1.5/1.15= 1.3$ g/cm³.
Given that the density of water is ~1 g/cm³ (depends on temperature, see reading material) the balsa and large metal ball will float and the Lignum vitae cube and Delrin ball will sink.

**Station 2: Density rods**

The table below summarizes the mass, volume and density for each of the rods

<table>
<thead>
<tr>
<th>Length of rod (cm)</th>
<th>Volume (cm³)</th>
<th>Mass (g)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>3.2</td>
<td>3.7</td>
<td>1.16</td>
</tr>
<tr>
<td>3</td>
<td>3.8</td>
<td>5.4</td>
<td>1.42</td>
</tr>
<tr>
<td>3.5</td>
<td>4.4</td>
<td>5.2</td>
<td>1.17</td>
</tr>
<tr>
<td>4</td>
<td>5.1</td>
<td>7.2</td>
<td>1.42</td>
</tr>
<tr>
<td>4.5</td>
<td>5.7</td>
<td>6.6</td>
<td>1.15</td>
</tr>
<tr>
<td>5</td>
<td>6.4</td>
<td>8.9</td>
<td>1.40</td>
</tr>
<tr>
<td>5.5</td>
<td>7.0</td>
<td>9.8</td>
<td>1.40</td>
</tr>
<tr>
<td>6</td>
<td>7.6</td>
<td>10.7</td>
<td>1.40</td>
</tr>
<tr>
<td>6.5</td>
<td>8.3</td>
<td>11.6</td>
<td>1.40</td>
</tr>
<tr>
<td>7</td>
<td>8.9</td>
<td>12.5</td>
<td>1.41</td>
</tr>
<tr>
<td>7.5</td>
<td>9.5</td>
<td>11</td>
<td>1.15</td>
</tr>
<tr>
<td>8</td>
<td>10.2</td>
<td>14.3</td>
<td>1.41</td>
</tr>
</tbody>
</table>

The data points are arranged along two linear lines, where the slope of each line provides the density (1.4 and 1.15 g/cm³). Compare the slopes with the range of calculated densities.
in the table. While the derived densities are not identical the small difference within each group are not significant given the uncertainties in the measurements). The data suggest that the rods are made of two different materials. (Caution: if two items have the same density it does not necessarily mean that they are made of the exact same material, however, density can be used as a method to distinguish between different materials).

Station 3: Effects of temperature on density

In this activity, the rods are used to demonstrate the effect of temperature on density of liquids and solids and the activity can be used as a discrepant event. One rod is made out of aluminum and the other is made out of PVC. When you place the rods in cold water both rods initially float because their density is lower than that of the cold water. Over time, as the PVC rod gets colder it contracts and as a result its density changes (volume shrinks but its mass remains the same). When the density of the rod exceeds that of the water the PVC rod begins to sink. Aluminum has a much lower temperature expansion coefficient and hence its density is less affected by temperature and it remains floating. When you place the rods in hot water, the density of the water is now lower than that of the aluminum rod and it will sink. The PVC rod is initially denser than the water and sinks but as it warms up it begins to expand. As a results its density changes (again, the mass remains constant) and when its density becomes lower than that of the water in begins to float.

Station 4: Coca-Cola

Density of Coke- 1.01 g/cm³ (volume=376 ml (1 ml= 1 cm³), mass=380.8 g.)
Density of Diet Coke- 0.97 g/cm³ (volume=376 ml (1 ml= 1 cm³), mass=366.6 g.)

The two cans have the same volume but they differ in their sugar content and hence in their mass. There are 39 grams of sugar in a 12 oz Coke can (see label) vs. approximately 100 mg of Nutra sweet in a 12 oz diet Coke can.

Station 5: density of rocks

Density of basalt sample- 2.8 g/cm³ (volume=45 ml (1 ml= 1 cm³), mass=125.5 g.)
Density of granite sample- 2.6 g/cm³ (volume=53 ml (1 ml= 1 cm³), mass=136.9 g.)

The Earth crust is made of two types of crusts: continental and oceanic. Continental crust is composed mostly of granite while oceanic crust is mostly composed of basalt. Oceanic crust is thinner and denser than continental crust (textbook values: 2.9-3.0 vs. 2.7-2.8 g/cm³, respectively; remember that you have measured the density of only one sample of each type of rock). Both overlie the earth’s mantle which is denser (3.3 g/cm³), with the continental crust “floating” higher. Understanding the differences between oceanic and continental crust is crucial for understanding plate tectonics and the formation of ocean basins. We will discuss this in more details on February 14.
On average, earth’s density is 5.5 \( g/cm^3 \). That implies that the earth must be composed of additional layer/s of higher density then the rocks within its crust. In fact, the crust is the least dense layer. The estimated density of the core mantle is 5.5 \( g/cm^3 \), the estimated density of the outer core is 10-12 \( g/cm^3 \) and the estimated density of the core is 12-13 \( g/cm^3 \).

The density of the Earth can be computed using Newton’s laws:
(1) Two bodies attract each other with a force \( F \) that is directly proportional to the product of their masses \( (m_1,m_2) \) and inversely proportional to the square of the distance between them \( (r) \)
\[ F = \frac{Gm_1m_2}{r^2} \]
where \( G \) is the gravitational constant. \( G = 6.7 \times 10^{-11} \text{N m}^2 \text{kg}^{-2} \)
(2) The force attracting a body to earth if its weight (not to confuse with mass) - \( mg \), where \( g \) is the gravitational acceleration \( (g = 980 \text{ cm/s}^2) \):
\[ F = mg \]

Thus, \( Gm_e/r^2 = g \)
\[ m_e = g*r^2/G \approx 6 \times 10^{24} \text{Kg} \]
Dividing by the volume of the Earth \( (4/3\pi R^3) \) we obtain the Earth’s density \( (5461 \text{Kg/m}^3) \)

Station 6: density of fluids

Fluids arrange into layers according to their density. When the divider is removed the denser water (salt water or cold water) sink to the bottom of the container and the less dense water (fresh water or warm water) float above. See reading material.