ARCHIMEDES’ PRINCIPLE

**Purpose:** To verify Archimedes’ Principle. To apply Archimedes’ Principle to the experimental determination of densities and specific gravities of solids and liquids.

**Apparatus:** Triple beam balance; vernier calipers; one metal cylinder with copper wire suspension; one hollow block; tap water; liquid X.

**Theory:** Archimedes’ Principle states that any object completely or partially submerged in a fluid is buoyed up by a force with magnitude equal to the weight of the weight of the fluid displaced by the object:

\[ B = \rho_{\text{fluid}} V_{\text{fluid}} g, \]

where \( \rho_{\text{fluid}} \) is the density of the fluid and \( V_{\text{fluid}} \) is the volume of the displaced fluid. *In this lab, all the forces and weights are measured in the unit of grams using the triple beam balance*, then the above equation becomes:

\[ B = \rho_{\text{fluid}} V_{\text{fluid}}. \]

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Figure 1

When measuring the weight of an object completely submerged in a fluid, as shown in Fig. 1, the volume of the displaced fluid is equal to the volume of the object, and the reading on the balance (\( W_{\text{in-fluid}} \)), the
buoyant force, and its weight in air \( (W_{\text{in-air}}) \) should satisfy the following equation:

\[
B = W_{\text{in-air}} - W_{\text{in-fluid}} = \rho_{\text{fluid}} V_{\text{object}}.
\]

Thus, the volume of the object can be determined as:

\[
V_{\text{object}} = \frac{(W_{\text{in-air}} - W_{\text{in-fluid}})}{\rho_{\text{fluid}}},
\]

and the density and the specific gravity of the object are, respectively:

\[
\rho_{\text{object}} = \frac{W_{\text{in-air}}}{V_{\text{object}}}, \quad \text{s.g.} = \frac{\rho_{\text{object}}}{\rho_{\text{water}}},
\]

**Procedures:**

1. Measure the diameter \((D)\) and height \((h)\) of the cylinder with the vernier caliper.
2. Suspend the metal cylinder by the fine wire from the hook of the balance, over the scale pan. (Do not remove the pan.) Weigh the cylinder in air.
3. Place a beaker of water on the adjustable circular platform over the scale pan, and immerse the cylinder completely. Weigh as before. Remove the beaker and carefully dry the cylinder.
4. Repeat Step 3, using liquid X instead of water.
5. Weigh the hollow block in air. Slip the lower end of the cylinder into the hole in the block. Weigh the suspended block and cylinder in the liquid X, being sure that both block and cylinder are completely submerged. Again remove the beaker and dry the block and cylinder.

**Computation:**

1. **Verify Archimedes’ Principle:** (a) Directly compute the volume of the cylinder using the geometrical data measured by the caliper: \(V_{\text{cylinder}} = \pi D^2 h / 4\). Neglect the volume of the knob. (b) Calculate the weight of the water displaced by the cylinder based on the cylinder’s volume and the density of water. (c) Determine the buoyant force, which is the apparent loss of weight of the cylinder when it is suspended in water. (d) Compare the results from (b) and (c). The agreement between these two values shows how well you have verified Archimedes’ Principle. Enter these results in Table 1.
2. **Apply Archimedes’ Principle:** Compute the densities and the specific gravities of the cylinder, the liquid X, and the block. Compute the volume of the block. Show your works. Enter your results in the Table 2. Indicate clearly the units for each quantity.

**Questions:**

1. By how many grams was the force on the bottom of the beaker increased when the cylinder was immersed in water?
2. Show algebraically that for an object floating in water, the fraction of the volume under water is equal to its specific gravity.
3. Where in this exercise is error introduced by neglecting the volume of the knob? Explain. What is the magnitude of the error in your case?
Table 1: Verification of Archimedes' Principle. Items in bold indicate direct measurements.

<table>
<thead>
<tr>
<th>Diameter of cylinder</th>
<th>Height of cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of cylinder</td>
<td></td>
</tr>
<tr>
<td>Weight of water displaced by cylinder</td>
<td></td>
</tr>
</tbody>
</table>

**Weight of cylinder in air**

**Weight of cylinder in water**

Buoyant force (loss of weight of cylinder in water)

Percent error

Table 2: Application of Archimedes' Principle. Items in bold indicate direct measurements.

<table>
<thead>
<tr>
<th>Weight of cylinder in air</th>
<th>Weight of cylinder in water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of cylinder in liquid X</td>
<td>Weight of hollow block in air</td>
</tr>
<tr>
<td>Weight of block and cylinder in liquid X</td>
<td>Density of cylinder</td>
</tr>
<tr>
<td>Density of cylinder</td>
<td>Specific gravity of cylinder</td>
</tr>
<tr>
<td>Density of Liquid X</td>
<td>Specific gravity of Liquid X</td>
</tr>
<tr>
<td>Density of block</td>
<td>Specific gravity of block</td>
</tr>
<tr>
<td>Volume of block</td>
<td></td>
</tr>
</tbody>
</table>

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