• **Project #1**: Show that the buoyant force \( (F_B) \) equals \( \rho_{\text{fluid}} g V_{\text{object}} \) by first calculating \( \rho_{\text{fluid}} g V_{\text{object}} \), and then by measuring \( F_B \) (indirectly) using the force probe.

• **Project #2**: How does the buoyant force depend on the density of the fluid?

**Project #1**: How does \( F_B \) depend on \( V_{\text{object}} \)?

1. For the aluminum (Al) and lead (Pb) cylinders, measure the length, diameter, and mass, and calculate the volume and density.

<table>
<thead>
<tr>
<th></th>
<th>Al</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>length (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>diameter (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume ((m^3))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mass (kg)</td>
<td></td>
<td></td>
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<tr>
<td>density ((kg/m^3))</td>
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Q: The density of water is \( 1.0 \times 10^3 \text{ kg/m}^3 \). Are the densities of Al and Pb greater than or less than the density of water?

2. Calculate the buoyant force on each cylinder, assuming they are totally submerged in water:

\[ \rho_{\text{water}} g V_{\text{Al}} = \]

\[ \rho_{\text{water}} g V_{\text{Pb}} = \]

3. For the diagram at right, what 3 forces are acting on the submerged cylinder? Draw a free body diagram and label each force.
4. Write down Newton’s 2nd Law for the forces acting on the cylinder. Solve your equation (algebraically) for the buoyant force.

5. Start up MacMotion and calibrate the force probe with a 200g mass. Measure the tension in the string for each cylinder in air and when totally submerged in water. (Make sure the tension in air is equal to the cylinder’s weight.)

<table>
<thead>
<tr>
<th>In Air</th>
<th>Submerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T ) (Al) = \</td>
<td>( T ) (Pb) =\</td>
</tr>
</tbody>
</table>

6. Use your expression from step 4 to calculate the buoyant force. Use the weight of the cylinder (string tension when in air) and the “apparent weight” (string tension when submerged).

\[ F_B \) (Al) = \]

\[ F_B \) (Pb) = \]

7. What are your percent differences between the calculated (step 2) and measured (step 6) buoyant forces for each cylinder? Do you think these differences are within expected experimental error? Explain.

\[ \left( \frac{|A - B|}{\frac{1}{2}(A + B)} \right) \times 100\% \]

Project #2: How does the buoyant force depend on the density of the fluid?

1. Do you think the aluminum cylinder will weigh more or less (i.e., will the tension measured by the force probe be more or less) when submerged in alcohol as compared to water? Please explain your prediction.

2. Do the experiment: measure the tension in the string for the Al cylinder totally submerged in alcohol. Was your prediction correct? If not, why?
Buoyancy

Tension (Al cylinder in alcohol) =

3. Calculate the density of your alcohol. Does the value seem reasonable? Explain?

Homework:

H1. How does the pressure in the fluid exert a buoyant force on an object?

H2. Calculate the difference in pressure between the top and bottom surfaces of a cube of size $10 \times 10 \times 10 \text{cm}$ at a depth of $20 \text{cm}$ (see diagram).

Do the same calculation, for the same cube, at a depth of $100 \text{cm}$.

Q: Does the buoyant force depend on depth? Please explain your answer.
H3. Starting with Newton’s 2nd Law for an object under water \((F_B - mg = ma; positive \ direction \ is \ up)\), derive the following expression for the acceleration of the object:

\[
a = g \left( \frac{\rho_{\text{water}}}{\rho_{\text{object}}} - 1 \right)
\]

Is the acceleration positive or negative if \(\rho_{\text{object}} < \rho_{\text{water}}\)

Is the acceleration positive or negative if \(\rho_{\text{object}} > \rho_{\text{water}}\)

H4. Why was the buoyant force for the lead cylinder smaller than the buoyant force for the aluminum cylinder, even though they both had the same mass?

H5. Why do you think the percent difference for the lead cylinder (project #1, step 7) is usually larger than for the aluminum cylinder?