Physics 124 Week Mar 25, 2019 Minilab 8 – Waves 3 and Fluids

This week’s workshop is divided into two parts. In Part I you will use what you know about standing waves in a pipe to determine the speed of sound in air. Part II covers buoyancy and Archimedes’s principle.

**PART I**

We will measure the fundamental wavelengths of standing waves that are possible in an air column. **You can assume that any sounds produced in the air column inside the plastic tube are in their fundamental frequency.**

1. Ring the tuning fork by hitting it against a rigid, but soft surface (like your knee). **Do not hit it against the table or any hard surface.** Note the frequency listed on the tuning fork.

   \[ f = \]

2. Hold the ringing tuning fork just above the open end of the tube and slide the tube up in the cylinder until you find the position at which you hear resonance (it will sound like a much more powerful and deeper sound than in any other position). Record the length of the air column when this happens.

   \[ L = \]

3. To the right is a magnified portion of the figure above. Draw what the standing wave amplitude looks like in it and indicate which distance is \( L \). Write down the wavelength in terms of \( L \).

   \[ \lambda = \]

The speed of sound in a medium is given by \( v = f\lambda \). We can use this model to get a measure of the speed of sound by plugging in values from the data you have collected, but the uncertainty on its value would be large. One way to reduce the uncertainty on the speed of sound measurement is to take multiple readings, rather than just one set of paired values. We could average these multiple readings but a better method is to plot the data and draw a best-fit line through the points.

Similar to what you did the week of Mar 6 for pre-lab, we can rearrange the above equation to be written as \( \lambda = v(1/f) \). This has the form of a straight-line equation \( Y = mX + b \), with \( b \) is 0. \( m \) is the slope, which in this case provides a measure of the speed of sound in air. We can plot a graph of \( Y \text{ vs } X \), draw a best fit line through the points, and find \( v \) by measuring the slope.

4. Repeat steps 1-3 with the other tuning forks of different frequencies and fill in all of the data (including the first one) in the following table.

<table>
<thead>
<tr>
<th>( f ) (Hz)</th>
<th>( 1/f ) (milliseconds)</th>
<th>( L ) (m)</th>
<th>( \lambda ) (m)</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

5. In the graph paper below plot \( Y \text{ (}\lambda\text{)} \text{ vs } X \text{ (}1/f\text{)}. Label your axes with the correct variable and units. Using a ruler draw the best fit line through your points. Calculate the slope of the line with correct units.
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6. Use the slope above to find \( v \), the speed of sound in air and compare it to the value found in your text book.

\[
\begin{align*}
\nu &= \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \\
\nu(\text{textbook}) &= \\
\end{align*}
\]

\( \text{Slope } m = \) ______

\( \nu = \) ______

\( \nu(\text{textbook}) = \) ______
7. Why was your value of the speed of sound different from the value in the textbook? What were your sources of error?

**Part II. Archimedes' principle** is a powerful tool for solving many problems involving equilibrium in fluids. It states the following: “When a body is partially or completely submerged in a fluid (either a liquid or a gas), the fluid exerts an upward force on the body equal to the weight of the fluid displaced by the body”. As a result of the upward Archimedes’ force (often called the *buoyant force*), some objects may float in a fluid, and all of them appear to weigh less. This is the familiar phenomenon of *buoyancy*. Quantitatively, the buoyant force can be found as $F_{\text{buoyant}} = \rho_{\text{fluid}} g V$, where $F_{\text{buoyant}}$ is the force, $\rho_{\text{fluid}}$ is the density of the fluid, $g$ is the magnitude of the acceleration due to gravity, and $V$ is the volume of the displaced fluid.

There are two metal blocks in front of you. One is made out of steel and the other of aluminum. They have the same dimensions.

1. Identify which one is steel and which one is aluminum. What is the same about the two blocks? What are their differences that allowed you to identify them as being different materials?

2. Measure the dimensions of one of the blocks. Use that to calculate the volume.

\[ V = \text{____________________} \]

3. Draw the free-body diagram for one of the blocks when it is attached to a rigid wire and you submerge it completely in water. Label all the forces *and the expressions for them*. Write an expression for the buoyant force in terms of the other forces acting on the block.
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4. If you were to fully submerge the block in water (do not do this, just imagine doing it), what would be the weight of water displaced by one of these blocks? (Density of water = 1000 kg/m³).

\[ W_{\text{water}} = \] ________________

5. How is the weight you found in question 4 related to the buoyant force experienced by the block when it is fully submerged? This is your **predicted value**, and should go into the right-hand column in the table in part 6.

6. In this experiment you will record the readings on the spring scale when the block is suspended in air, and when it is suspended in water, and use them to calculate the measured buoyant force. Take one of the blocks and suspend it in air; record its weight. Next completely submerge the block in water using the spring scale. What is the new spring scale reading? Determine the measured buoyant force based on your measurements.

<table>
<thead>
<tr>
<th></th>
<th>Weight (N)</th>
<th>Force on spring scale when submerged (N)</th>
<th>Measured Buoyant Force (N)</th>
<th>Predicted Buoyant Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aluminum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Steel</strong></td>
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</tbody>
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7. Compare your predicted value to your measured value of the buoyant force. Comment on why discrepancies may exist.