Buoyancy

As you work through the steps in the lab procedure, record your experimental values and the results on this worksheet. Use the exact values you record for your data to make later calculations.

Simulation

Open the Buoyancy Apparatus simulation to do this lab.

Theory

Variation of Pressure with Depth

1. What happens to the upward pressure, P_{up}, and ΔP as the cylinder is lowered? Don't let the cylinder become completely submerged for now.

2. Where is the top of the cylinder when this transition occurs?

3. What happens to ΔP as the cylinder is lowered while completely submerged?

4. What happens to P_{up} and P_{down} as the cylinder is lowered while completely submerged? How does this account for your answer to the previous question?

The Effect of The Pressure Difference, ΔP, on the Buoyant Force

5. As a cylinder of *aluminum* is lowered into our tank, when will the buoyant force, F_{b}, begin to exceed the cylinder's weight?

- (a) when it's partially submerged
- (b) when it's fully submerged
- (c) never

6. Why is this the case?

7. Once the cylinder of aluminum is fully submerged, we might hold it in place by attaching which of the following?

- (a) a block of cork
- (b) a block of aluminum
- (c) a block of water
- (d) none necessary

8. As a cylinder of *water* is lowered into our tank, when will the buoyant force, F_{b}, begin to exceed the cylinder's weight?

- (a) when it's partially submerged
- (b) when it's fully submerged
- (c) never

9. Why is this the case?

10. Once the cylinder of water is fully submerged, we might hold it in place by attaching which of the following?

- (a) a block of cork
- (b) a block of aluminum
- (c) a block of water
- (d) none necessary

11. As a cylinder of *cork* is lowered into our tank, when will the buoyant force, F_{b}, begin to exceed the cylinder's weight?

- (a) when it's partially submerged
- (b) when it's fully submerged
- (c) never

12. Why is this the case?

13. Once the cylinder of cork is fully submerged, we might hold it in place by attaching which of the following?

- (a) a block of cork
- (b) a block of aluminum
- (c) a block of water
- (d) none necessary

14. It's useful to leave all three cylinders fully submerged at about the same depth and then click the different icons to switch among the three materials. There is one thing that is the same regardless of the cylinder chosen. What is it? Why?

I. Confirm Archimedes' Principle for the Case Where $\rho_{\text{object}} > \rho_{\text{liquid}}$ Using Overflow

1. Collect and record W_{al}, W_{cyl}, W'_{al}, and $W_{\text{cyl+water}}$.

2. Calculate the buoyant force, F_{b}, twice, using equation 2 ($F_{\text{b}} = W_{\text{al}} - W'_{\text{al}}$) and equation 3 ($F_{\text{b}} = W_{\text{water displaced}} = W_{\text{cyl+water}} - W_{\text{cyl}}$).

Show your calculations of F_b for each method and the percentage difference between the two.

II. Confirm Archimedes' Principle for $\rho_{\text{object}} < \rho_{\text{liquid}}$ Using Overflow

1. Submit your responses for Figures 8a, 8c, and 8d by uploading **Screenshots** of each. For 8a and 8c, just capture an image of the scale. For 8d, capture an image of the digital scale reading. (*You will upload these files in the WebAssign question.*)

2. Weighing the cork disk in air (Figure 8a) gives us W_{cork}. Weighing it when partially submerged (8c) gives us W'_{cork}. This time it floats. (Note the slack string.)

So, W'_{cork} = ______________.

3. Draw FBD 8e to the left of the floating cork provided. Also use the **Sketch** tool to create a screen-sketch by adding and labeling a pair of vector arrows to the left of the floating cork in the buoyancy apparatus. Take a **Screenshot** of the FBD and the cork and upload it as "Buoy_FBD8e.png". (*You will upload this file in the WebAssign question.*)

4. From FBD 8e, we can say that the following is true. (Use the following as necessary: W_{cork}. Do not substitute numerical values; use variables only.)

Weighing the empty graduated cylinder (8b) gives us W_{cyl}. Weighing the cylinder after receiving the overflow water (8d) gives us $W_{\text{cyl+water}}$. (Use the following as necessary: W_{cyl} and $W_{\text{cyl+water}}$. Do not substitute numerical values; use variables only.)

5-8. Collect and record W_{cork}, W_{cyl}, W'_{cork}, and $W_{\text{cyl+water}}$.

9-11. Calculate the buoyant force, F_{b}, twice, using equation 4 and equation 5.

Show your calculations of F_{b} for each method and the percentage difference.

III. Finding the Density of an Unknown Material

Density of the Cork

1-7. You want to know the volume of the cork. Record V_{al}, $V_{\text{al + cork}}$, W_{cork}, and M_{cork} to find the volume of the cork, V_{cork}, convert it to m^3, and compute its density, ρ_{cork}, in kg/m^3.

Show the calculations for V_{cork} (mL), V_{cork} (m^3), and ρ_{cork}.

Density of the Unknown Material

8. Attach unknown system #1 (bottom right) to the hanging scale. Gradually lower it as far down as it will go. What is different about this compound system relative to the cork/aluminum system?

9. Draw FBD 9 to the left of the floating cork-unknown system provided. Also use the **Sketch** tool to create a screen-sketch by adding and labeling vector arrows to the left of the floating cork in the buoyancy apparatus. Take a **Screenshot** of the FBD and the cork and upload it as "Buoy_FBD9.png". (*You will upload this file in the WebAssign question.*)

10. From your FBD, you can say that the following is true. (Use the following as necessary: W_{cork} and W_{u}. Do not substitute numerical values; use variables only.)

11. So we have two equations, $F_{\text{b}} = W_{\text{cork}} + W_{\text{u}}$, and $W_{\text{u}} = \rho_{\text{u}} g V_{\text{u}}$. Combine the two equations and solve for ρ_{u}. (Use the following as necessary: F_{b}, W_{cork}, g, and V_{u}. Do not substitute numerical values; use variables only.)

Show your algebra.

12-16. Record W_{cork} and F_{b} to find the volume of the unknown, convert it to m^3, and compute its density in $\mathrm{kg/m}^3$.

Show your calculations for F_{b} and ρ_{u}.