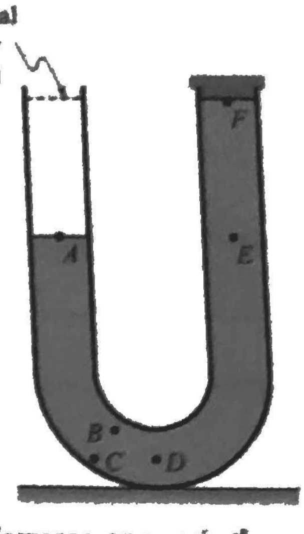
PRESSURE IN A LIQUID

Name ______________________

ST
HW–175

1. A U-tube filled with water is closed on one end. The tube is about one meter tall. When water is removed from the open end, the water level in the closed end does not change.

a. What is the pressure at point *F* before any water is removed?



On the basis of your answer, is there a force exerted by the stopper on the top surface of the water?

b. The water level on the left is lowered until it reaches point *A*.

Does the pressure at point *A* *increase, decrease,* or *remain the same?* Explain.

On the basis of your answer, does the pressure at point *D* *increase, decrease,* or *remain the same?* Explain. If the pressure changes, how does the change in pressure at point *A* compare to the change in pressure at point *D?*

Do the pressures at points *E* and *F* *increase, decrease,* or *remain the same?* How do the changes in pressure at these points compare to the change in pressure at point *A?*

Does the force exerted by the stopper on the top surface of the water *increase, decrease,* or *remain the same?* Explain.

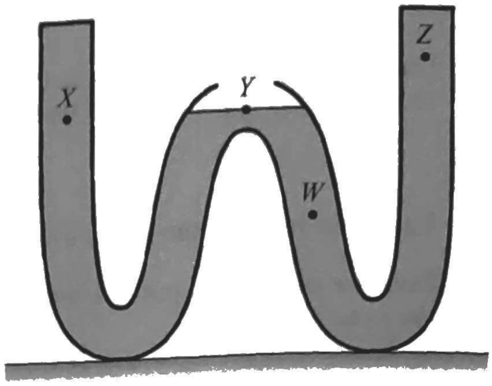
c. Suppose that point *F* is 0.5 m above point *E*. Determine the pressure at point *F*. (*Hint:* What is the pressure at point *E?)* The density of water is $\rho = 1000$ kg/m^3, $g \approx 10$ m/s^2, and atmospheric pressure $P_o = 1.01 \times 10^5$ N/m^2.

d. Suppose instead that the tube is much taller than 1.0 m. Calculate the distance above point *E* at which the pressure in the water would be zero (*i.e.*, find the height of water above point *E*).

e. Use your answers above and the definition of pressure to explain why the water level on the right remains at point *F* for a U-tube that is 1.0 m tall.

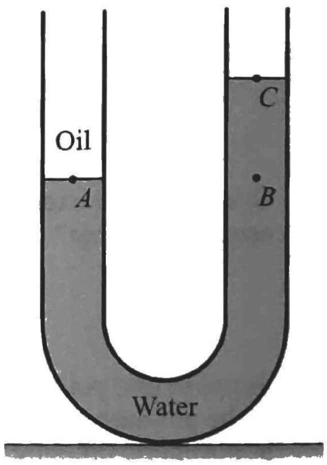
2. A W-shaped piece of glassware is partially filled with water as shown. Point *X* is at the same height as the water level in the center of the tube.

   For each of the following points, state whether the pressure is *greater than, less than,* or *equal to* atmospheric pressure. Explain your reasoning.



   - point *W*
   - point *X*
   - point *Y*
   - point *Z*

3. A U-tube is partly filled with water. Oil is then poured on top of the water on the left side of the tube. The final water levels on both sides are as shown. The surface of the oil is not shown. The density of the oil is less than that of the water.



   Points *A* and *B* are at the same level.

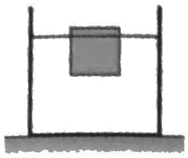
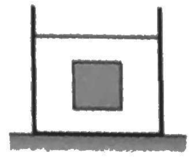
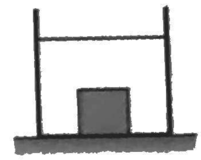
   a. Is the pressure at point *A greater than, less than,* or *equal to* the pressure at point *B?* Explain.

   b. Will the pressure at the top surface of the oil be *greater than, less than,* or *equal to* the pressure at point *C? (Hint:* What is the pressure at point *C?)*

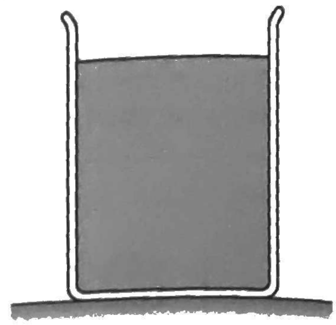
   c. Based on your answers to parts a and b, will the top surface of the oil be *above, below,* or *at the same height as* the top surface of the water? Explain how your answer is consistent with $P = P_o + \rho gh$.

1. Three objects are at rest in three beakers of water as shown.

   a. Compare the mass, volume, and density of the objects to the mass, volume, and density of the displaced water. Explain your reasoning in each case.

Object 1 floats on top	*Object 2 floats as shown*	*Object 3 sinks*
		
Is $m_1 \begin{pmatrix} > \\ < \\ = \end{pmatrix} m_{\text{displaced water}}$? Explain.	Is $m_2 \begin{pmatrix} > \\ < \\ = \end{pmatrix} m_{\text{displaced water}}$? Explain.	Is $m_3 \begin{pmatrix} > \\ < \\ = \end{pmatrix} m_{\text{displaced water}}$? Explain.
Is $V_1 \begin{pmatrix} > \\ < \\ = \end{pmatrix} V_{\text{displaced water}}$? Explain.	Is $V_2 \begin{pmatrix} > \\ < \\ = \end{pmatrix} V_{\text{displaced water}}$? Explain.	Is $V_3 \begin{pmatrix} > \\ < \\ = \end{pmatrix} V_{\text{displaced water}}$? Explain.
Based on your answers above, is $\rho_1 \begin{pmatrix} > \\ < \\ = \end{pmatrix} \rho_{\text{displaced water}}$? Explain.	Based on your answers above, is $\rho_2 \begin{pmatrix} > \\ < \\ = \end{pmatrix} \rho_{\text{displaced water}}$? Explain.	Based on your answers above, is $\rho_3 \begin{pmatrix} > \\ < \\ = \end{pmatrix} \rho_{\text{displaced water}}$? Explain.

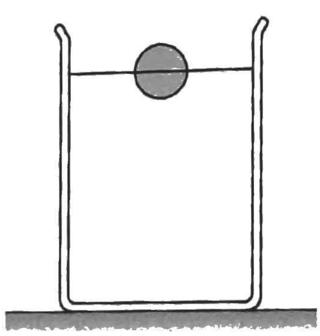
b. Object 2 is released in the center of a beaker full of oil, which is slightly less dense than water. In the space provided, sketch the final position of the block. Explain your reasoning.



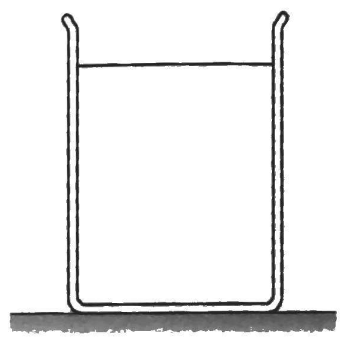
c. On the basis of your answers above, what must be true in order for an object to remain at rest when released in the center of an incompressible liquid?

d. Generalize your answers above to answer the following questions. How does the density of a fluid compare to that of (1) an object that floats in the liquid and (2) an object that sinks in the liquid? Explain.

2. A solid sphere of mass *m* floats in a beaker of water as shown. A second sphere of the same material but of mass 2*m* is placed in a second beaker of water. In the space provided, sketch the final position of the second sphere.



Sphere of mass *m*



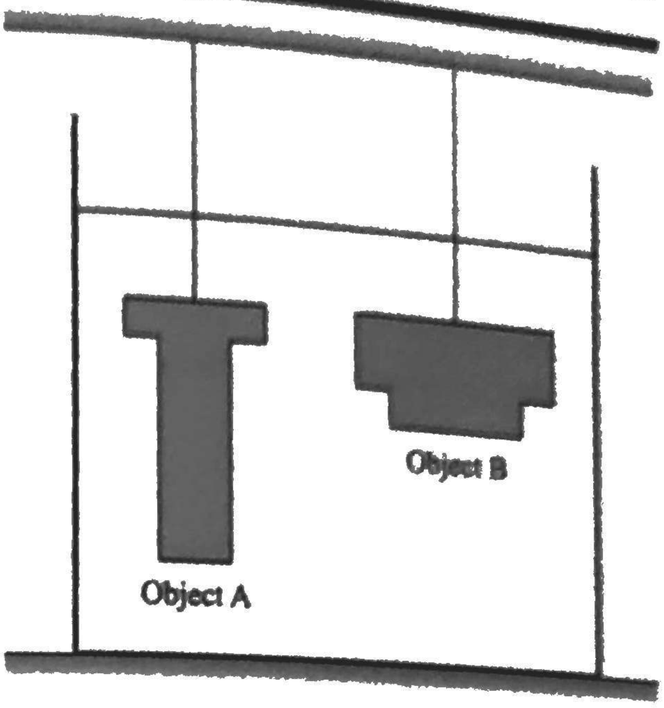
Sphere of mass 2*m*

a. In its final position, how does the buoyant force on the larger sphere compare to its weight?

b. How does the volume displaced by the larger sphere compare to that displaced by the smaller sphere?

c. Are your answers to questions a and b consistent with Archimedes' principle? Explain.

3. Two objects of the same mass and volume but different shape are suspended from strings in a tank of water as shown.



Consider the following student discussion:

Student 1: "Both objects have the same volume, so both have the same buoyant force. Therefore the tensions in the two strings must be the same."

Student 2: "No, that can't be true. The bottom of object A is deeper in the water where the pressure is higher. Therefore the buoyant force on object A must be greater and the tension in that string must be less."

Student 3: "I mostly agree with you, student 1. The buoyant force is the same on both objects. However, you forgot the force exerted down on the top of the objects by the water above. That force is larger for object B because the top surface has a greater area, so the tension in the string supporting object B must be greater."

a. Do you agree with student 1? Explain your reasoning. If student 1 is incorrect, modify the statement so it is correct.

b. Do you agree with student 2? Explain your reasoning. If student 2 is incorrect, modify the statement so that it is correct.

c. Do you agree with student 3? Explain your reasoning. If student 3 is incorrect, modify the statement so that it is correct.