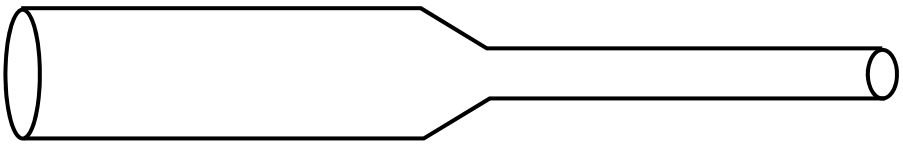
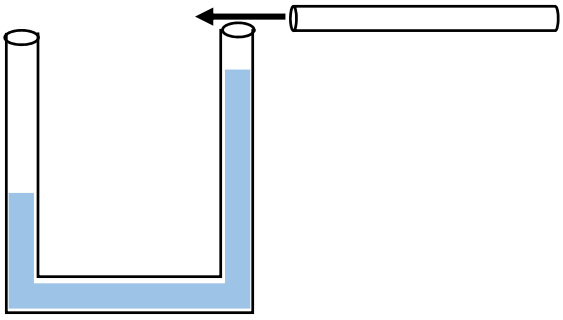
PHYS 1200 Physics of Everyday Experience

Review questions and exercises for Lecture 14 (F-3)

1. What is the condition necessary for an object to float?
2. Why does a steel bolt float in mercury?
3. Why does ice float.
4. Who discovered the laws of fluid dynamics?
5. What is volume flow rate and in what units is it measured?
6. Describe a method for measuring volume flow rate.
7. Fluid enter the large end of the tube shown below at a speed of 0.5 m/s. If the diameter of the large end of the tube is twice that of the small end, what is the velocity of the fluid as it leaves the small end?



8. If a stream of air blows across one side of a U-shaped tube containing a liquid, the liquid level on the other side goes down. Why?

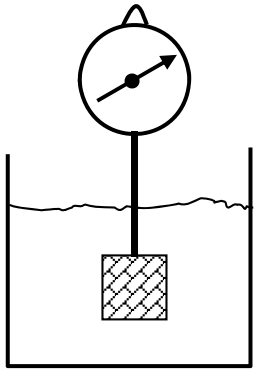


9. What is it necessary to maintain a pressure difference between the ends of a long pipe to keep water flowing through the pipe?
10. What is the pressure at a depth of 50 m below sea level?

11. An object weighing 100 N has a volume of 2 liters. If it is completely submerged in a tank of water, what buoyant force acts on it?

12. An object weighing 100 N and having a volume of 15 liters is placed in a tank of water. What will happen?

13. An object weighing 50 N has a volume of 3 liters. It is suspended from a spring scale and completely submerged in water, as shown in the figure. What does the scale read when it is submerged?



Answers and Solutions (You should try to solve the problems before reading the solutions.)

1. For an object to float, the buoyant force on it must be larger than its weight.

2. A steel bolt will float in mercury because steel has a lower density (7.86 g/ cm^3) than mercury (13.6 g/ cm^3).

3. Ice floats because it is less dense than water. (When water freezes, it expands and thus occupies a larger volume.)

4. Daniel Bernoulli.

5. Volume flow rate is the quantity of fluid by volume that flows per unit time. It is measured in units of m^3/s, gallons per minute (gpm), cubic feet per minute, etc.

6. To measure the volume flow rate you can time how long it takes to fill a container of a given volume with liquid, then the volume flow rate = $Q_V = V/t$, where V is the volume of the container and t is the time it takes to fill it.

7. The principle of continuity of fluid flow states that the rate at which liquid enters one end of a pipe must be the same as the rate at which it leaves the other end. Mathematically this is stated as $Q_{in} = Q_{out}$, and since Q = v A, where v is the velocity of the fluid and A is the cross-sectional area of the pipe, we must have that: $v_{in} A_{in} = v_{out} A_{out.}$ Then, $v_{out} = v_{in} (A_{in} / A_{out})$. Now for a pipe of circular cross section, $A = \pi (d/2)^2$ where d is the diameter of the pipe. Thus the cross-sectional area of the small end of the pipe is 4 times smaller than that of the larger end, so that $A_{in} = 4 A_{out}$, then $v_{out} = 4v_{in} = 4$ (0.5 m/s) = 2 m/s.

8. According to Bernoulli's principle, the pressure of a moving fluid is less than the pressure of a fluid at rest. Therefore the air pressure is lower on the side of the tube where the air flow is applied. The greater air pressure on the other side pushes the liquid from the left side to the right side.

9. When water flows through a pipe it experiences a friction force with the inner walls of the pipe which tends to slow it down. To maintain the flow, a force must be applied to the liquid. This force is applied by a pump which maintains a higher pressure on the inlet side of the pipe.

10. P_o is atmospheric pressure, so

$$P = P_o + \rho gh = 1\times10^5\, Pa + (1000\, kg/m^3)(10 m/s^2)(50\, m)$$
$$= 1\times10^5 + 5\times10^5 = 6\times10^5\, Pa$$

11. The buoyant force is the weight of the water displaced by the object.

$$F_B = V_{submerged} \times 10 \text{ N/liter} = 2 \text{ liters} \times 10 \text{ N/liter} = 20 \text{ N}.$$

12. The maximum buoyant force if the object were completely submerged is $F_{B,\,Max}$ = 15 liters x 10 N/liter = 150 N. Since the weight of the object is 100 N, only 2/3 of the maximum buoyant force is needed for the object to float. Thus, the object will float with 2/3 of its volume submerged.

13. When an object is weighed underwater, the scale balance will read the difference between the actual weight (in air) and the buoyant force. The buoyant force on the object is the weight of the water that it displaces or F_B = 3 liters x 10 N/liter = 30 N. Thus the scale will read: $W_{water} = W_{air} – F_B$ = 50 N – 30 N = 20 N.