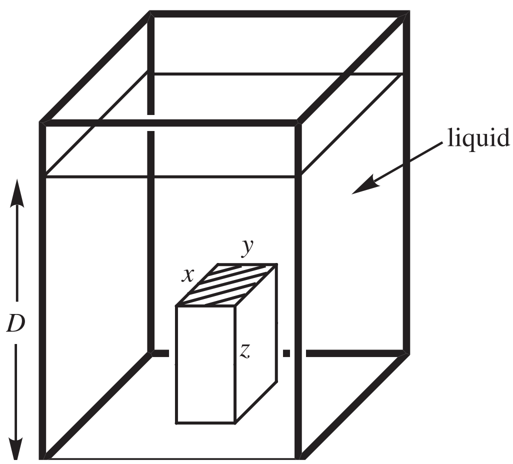
Chapter 3 Review Questions

Solutions can be found in Chapter 12.

Section I: Multiple Choice

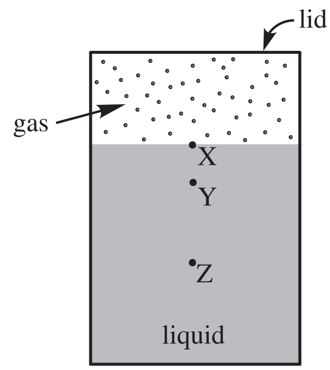
1. A large tank is filled with water to a depth of 6 m. If Point X is 1 m from the bottom and Point Y is 2 m from the bottom, how does p_X, the hydrostatic pressure due to the water at Point X, compare to p_Y, the hydrostatic pressure due to the water at Point Y ?

   (A) $p_X = 2p_Y$
   (B) $2p_X = p_Y$
   (C) $5p_X = 4p_Y$
   (D) $4p_X = 5p_Y$



2. In the figure above, a box of dimensions x, y, and z rests on the bottom of a tank filled to depth D with a liquid of density ρ. If the tank is open to the atmosphere, what is the force on the (shaded) top of the box?

   (A) $xy(p_{atm} + \rho gD)$
   (B) $xyz[p_{atm} - \rho g(z - D)]$
   (C) $xy[p_{atm} + \rho g(D - z)]$
   (D) $xyz[p_{atm} + \rho gD]$



3. The figure above shows a closed container partially filled with liquid. Point Y is at a depth of 1 m, and Point Z is at a depth of 3 m. If the pressure at Point Y is 13,000 Pa, and the pressure at Point Z is 29,000 Pa, what is the pressure at the surface, Point X ?

   (A) 3,000 Pa
   (B) 4,000 Pa
   (C) 5,000 Pa
   (D) 7,000 Pa

4. A plastic cube 0.5 m on each side and with a mass of 100 kg floats in water. What fraction of the cube's volume is above the surface of the water?

   (A) $\frac{1}{5}$
   (B) $\frac{1}{4}$
   (C) $\frac{3}{4}$
   (D) $\frac{4}{5}$

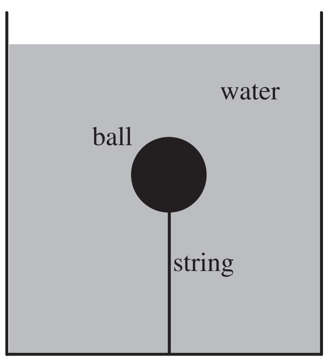
5. A block of Styrofoam, with a density of ρ_S and volume V, is pushed completely beneath the surface of a liquid whose density is ρ_L, and released from rest. Given that $\rho_L > \rho_S$, which of the following expressions gives the magnitude of the block's initial upward acceleration?

(A) $(\rho_L - \rho_S)g$

(B) $\left(\dfrac{\rho_L}{\rho_S} - 1\right)g$

(C) $\left(\dfrac{\rho_L}{\rho_S} + 1\right)g$

(D) $\left[\left(\dfrac{\rho_L}{\rho_S}\right)^2 - 1\right]g$

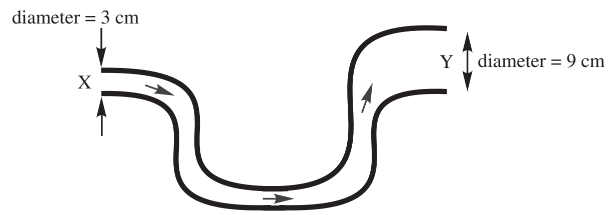


6. In the figure above, a ball with a density of 400 kg/m^3 and volume 5×10^{-3} m^3 is attached to a string, the other end of which is fastened to the bottom of the tank. If the tank is filled with water, what is the tension in the string?

(A) 20 N
(B) 30 N
(C) 40 N
(D) 50 N

7. An object with a density of 2000 kg/m^3 weighs 100 N less when it's weighed while completely submerged in water than when it's weighed in air. What is the actual weight of this object?

(A) 200 N
(B) 300 N
(C) 400 N
(D) 600 N



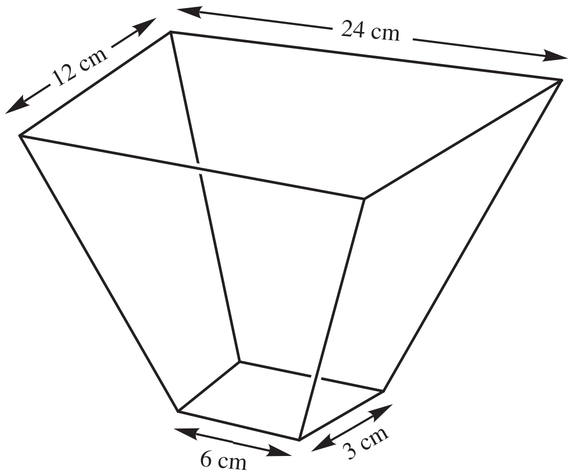
8. In the pipe shown above, which carries water, the flow speed at Point X is 6 m/s. What is the flow speed at Point Y ?

(A) $\dfrac{2}{3}$ m/s

(B) 2 m/s

(C) 18 m/s

(D) 54 m/s



9. The figure above shows a portion of a conduit for water, one with rectangular cross sections. If the flow speed at the top is v, what is the flow speed at the bottom?

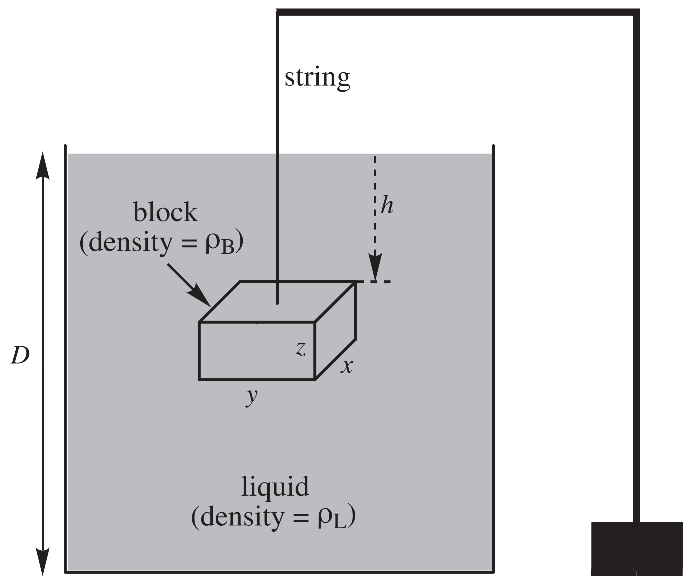
(A) $4v$
(B) $8v$
(C) $12v$
(D) $16v$

10. A pump is used to send water through a hose, the diameter of which is 10 times that of the nozzle through which the water exits. If the nozzle is 1 m higher than the pump, and the water flows through the hose at 0.4 m/s, what is the difference in pressure between the pump and the atmosphere?

(A) 108 kPa
(B) 260 kPa
(C) 400 kPa
(D) 810 kPa

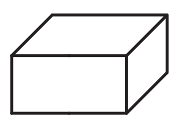
Section II: Free Response

1. The figure below shows a tank open to the atmosphere and filled to depth D with a liquid of density ρ_L. Suspended from a string is a block of density ρ_B (which is greater than ρ_L), whose dimensions are x, y, and z (meters). The top of the block is at depth h meters below the surface of the liquid.



In each of the following, write your answer in simplest form in terms of ρ_L, ρ_B, x, y, z, h, D, and g.

(a) Find the force due to the pressure on the top surface of the block and on the bottom surface. Sketch these forces in the diagram below:



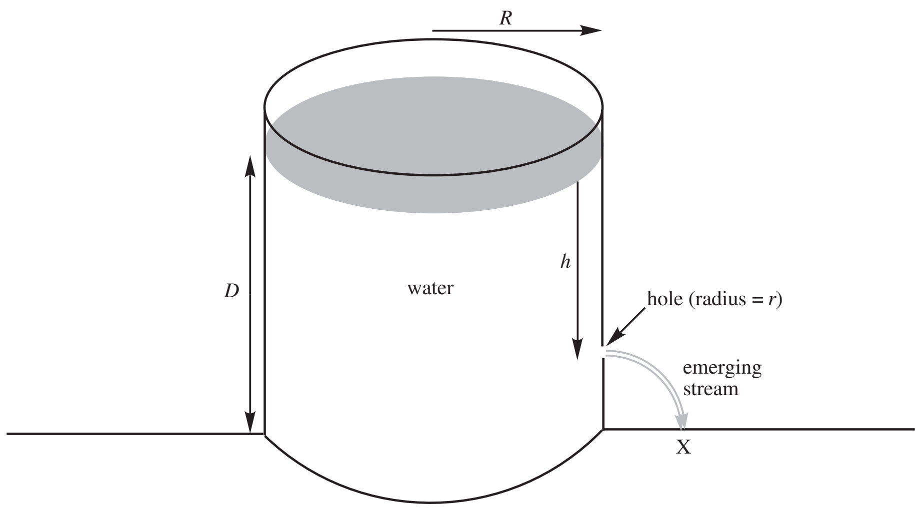
(b) What are the average forces due to the pressure on the other four sides of the block? Sketch these forces in the diagram above.

(c) What is the total force on the block due to the pressure?

(d) Find an expression for the buoyant force on the block. How does your answer here compare to your answer to part (c)?

(e) What is the tension in the string?

2. The figure below shows a large, cylindrical tank of water, open to the atmosphere, filled with water to depth D. The radius of the tank is R. At a depth h below the surface, a small circular hole of radius r is punctured in the side of the tank, and the point where the emerging stream strikes the level ground is labeled X.



In parts (a) through (c), assume that the speed with which the water level in the tank drops is negligible.

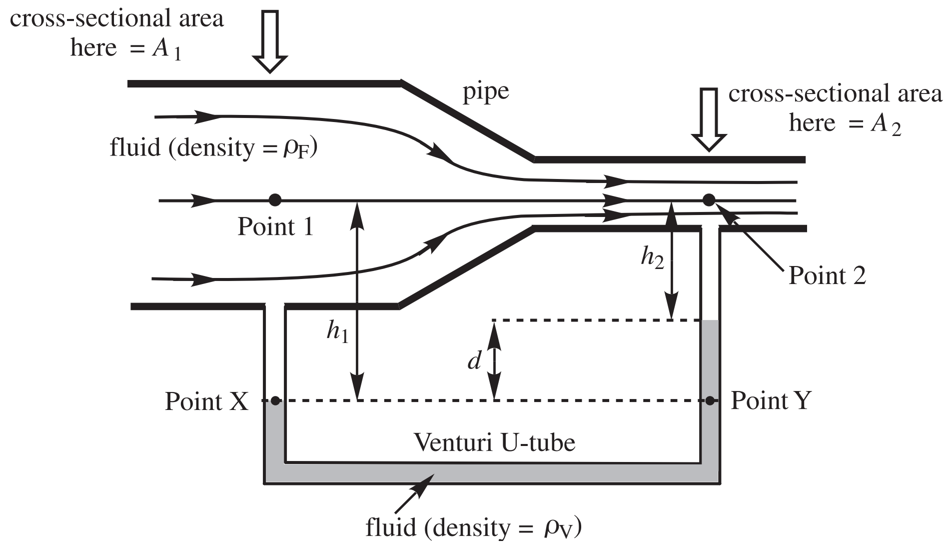
(a) At what speed does the water emerge from the hole?

(b) How far is point X from the edge of the tank?

(c) Assume that a second small hole is punctured in the side of the tank, a distance of $h/2$ directly above the hole shown in the figure. If the stream of water emerging from this second hole also lands at Point X, find h in terms of D.

(d) For this part, do *not* assume that the speed with which the water level in the tank drops is negligible, and derive an expression for the speed of efflux from the hole punctured at depth h below the surface of the water. Write your answer in terms of r, R, h, and g.

3. The figure below shows a pipe fitted with a Venturi U-tube. Fluid of density ρ_F flows at a constant flow rate and with negligible viscosity through the pipe, which constricts from a cross-sectional area A_1 at Point 1 to a smaller cross-sectional area A_2 at Point 2. The upper portion of both sides of the Venturi U-tube contain the same fluid that's flowing through the pipe, while the lower portion is filled with a fluid of density ρ_V (which is greater than ρ_F). At Point 1 in the pipe, the pressure is P_1 and the flow speed is v_1 ; at Point 2 in the pipe, the pressure is P_2 and the flow speed is v_2. All the fluid within the Venturi U-tube is stationary.



(a) What is P_X, the hydrostatic pressure at Point X? Write your answer in terms of P_1, ρ_F, h_1, and g.

(b) What is P_Y, the hydrostatic pressure at Point Y? Write your answer in terms of P_2, ρ_F, ρ_V , h_2, d, and g.

(c) Write down the result of Bernoulli's Equation applied to Points 1 and 2 in the pipe, and solve for $P_1 - P_2$.

(d) Since $P_X = P_Y$, set the expressions you derived in parts (a) and (b) equal to each other, and use this equation to find $P_1 - P_2$.

(e) Derive an expression for the flow speed, v_2, and the flow rate, f, in terms of A_1, A_2, d, ρ_F, ρ_V, and g. Show that v_2 and f are proportional to $\sqrt{d}$.