

Physics 123 Fluid Mechanics Review

I. Definitions & Facts

Density

Pressure

Streamline, laminar flow

Turbulence

Specific gravity ($= \rho_{material} / \rho_{water}$)

Atmosphere, bar, Pascal

Gauge pressure

Density of water is 1000 kg/m^3

II. Mathematics & Tools

None

III. Basic Concepts

An ideal fluid: incompressible, laminar, irrotational, no viscosity.

Pascal's principle: A pressure applied at any point in the fluid at rest is spread throughout the entire fluid.

Archimedes' principle: The buoyant force equals the weight of the displaced liquid.

Fluid "in the air" is always at atmospheric pressure.

Bernoulli's equation is a result of conservation of energy.

IV. Equations to Memorize

Continuity equation:

$$A v = \text{flow rate}, \quad A_1 v_1 = A_2 v_2$$

Bernoulli's equation:

$$P + \rho gh + \frac{1}{2} \rho v^2 = \text{constant}$$

Review Problems

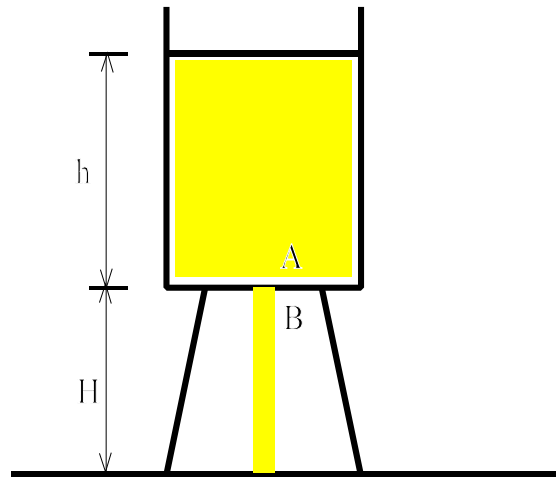
Conceptual Questions

1. Bernoulli's Equation, as we derived it, holds only for an ideal fluid. An ideal fluid must have each of the following characteristics **except**:

- A. it must have streamline flow.
- B. it must be incompressible.
- C. it must have no viscosity.
- D. it must not have rotational motion.
- E. All of the above are characteristics of an ideal fluid.

2. An open-topped tank has water flowing out through a hole in the bottom, as illustrated. The height of the water level above the ground is $h + H = 2.00$ m. In order to increase the **flow rate** through the hole, you could:

- A. Increase H , leaving $H + h$ constant.
- B. Increase H , leaving h constant.
- C. Increase the size of hole to allow more water to flow through the hole.
- D. Decrease the size of the hole in order to increase the velocity of the water out of the hole.
- E. None of the above.



3. A hydraulic lift is best understood by applying

- A. Pascal's Principle.
- B. Euler's Angles.
- C. Bernoulli's Equation.
- D. The continuity equation.
- E. None of the above.

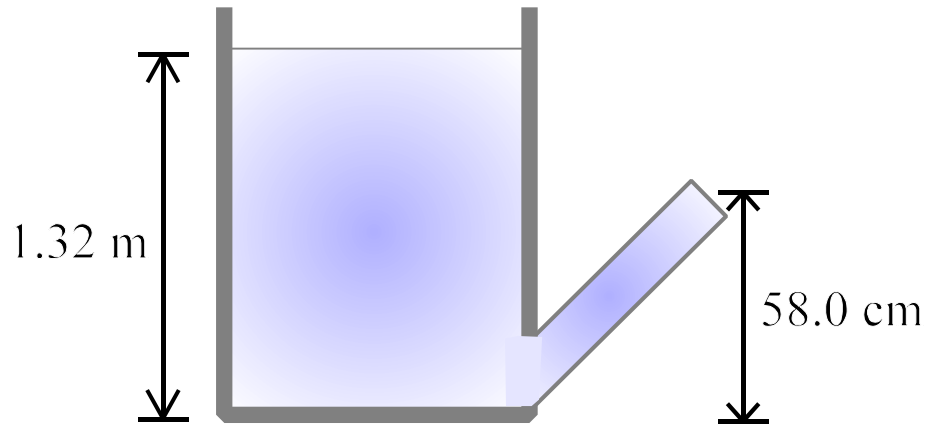
Problems

4. A block of iron of dimensions $50.0\text{ cm} \times 50.0\text{ cm} \times 10.0\text{ cm}$ is placed in a large tank of mercury. The specific gravity of iron is 7.86 and the specific gravity of mercury is 13.52.

(a) How much of the iron will float above the mercury?

(b) What is the maximum buoyant force this block would experience in mercury?

5. A tank 1.50 m in height is filled with water to a level of 1.32 m. At the bottom of the tank a hose is attached. The hose goes up at an angle of 55.0° with respect to the ground. The end of the hose is at a height of 58.0 cm above the bottom of the tank. Atmospheric pressure is 1.00 bar.



(a) Find the velocity of the water coming out of the hose.

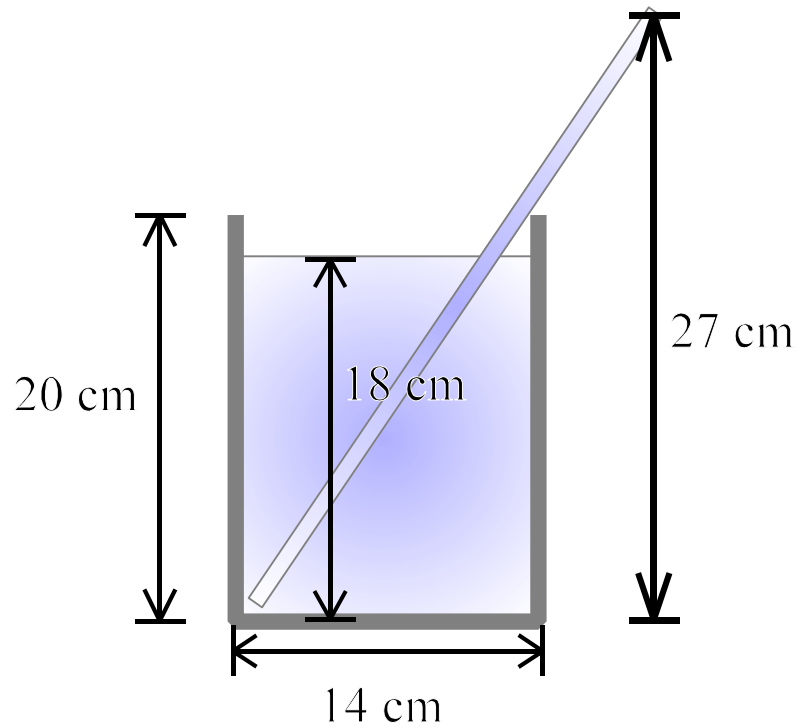
(b) Find the velocity of the water **inside the hose** at the bottom end of the hose (next to the tank).

(c) Find the pressure of the water **inside the hose** at the bottom end of the hose (next to the tank).

(d) Is the pressure you found in part (c) the same as the pressure at the bottom of the tank (not inside the hose)? Briefly explain.

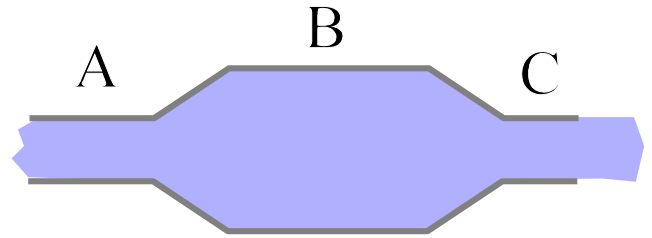
6. A person is drinking water from a cylindrical tumbler by using a straw. The dimensions of the system are shown in the diagram to the right. The person maintains a gauge pressure of -3000 Pa in her mouth. The diameter of the straw is 5.00 mm .

(a) What is the flow rate of the water into the person's mouth? (Assume the straw is narrow enough that you may ignore the velocity of the water in the tumbler.)



(b) If the person keeps the pressure in her mouth constant while drinking, what will happen to the flow rate as the level of water in the tumbler drops? (Give a descriptive answer, you do not need to calculate the flow rate as a function of water level.)

7. A horizontal pipe consists of three sections as shown in the diagram to the right. The right section, C, is open to the air where water flows out at a speed of 12.00 m/s. (The speed, of course, is the same just inside and just outside the pipe.) Section A is **not** open to the air. The diameter of sections A and C is 2.00 cm. The diameter of section B is 4.00 cm.



(a) What is the velocity of the water in section B?

(b) What is the pressure of the water in section B?

(c) What is the pressure of the water in section A?

Answers.

Conceptual Questions

1. E. 2. C. 3.A.

Problems

4. (a) We know that if the iron floats, the buoyant force must be equal in magnitude to the weight of the iron. Thus:

$$F_B = W$$
$$\rho_{Hg} V_{displaced} g = \rho_{Fe} V_{Fe} g$$
$$\rho_{Hg} A h = \rho_{Fe} A H$$

where A is the cross-sectional area
 h is the height of the block below the surface
 H is the total height of the block

$$h = \frac{\rho_{Fe}}{\rho_{Hg}} H = 5.81 \text{ cm}$$

Thus the amount out of the water is 4.19 cm.

(b) The maximum buoyant force occurs when the block is totally submerged.

$$F_{B,max} = \rho_{Hg} V_{Fe} g$$
$$= 13520 \text{ kg/m}^3 \times 0.500 \text{ m} \times 0.500 \text{ m} \times 0.100 \text{ m} \times 9.80 \text{ m/s}^2$$
$$= 3.31 \times 10^3 \text{ N}$$

5.

(a) We apply Bernoulli's Equation to the water surface in the tank and the end of the hose:

$$\text{Total head at the surface: } P_0 + \rho g h_{top}$$
$$\text{Total head at the hose opening: } P_0 + \rho g h_{open} + \frac{1}{2} \rho v_{open}^2$$
$$v_{open} = \sqrt{2g(h_{top} - h_{open})}$$
$$= \sqrt{2 \times 9.80 \times 0.740} \text{ m/s}$$
$$= 3.81 \text{ m/s}$$

(b) By the continuity equation, the velocity of the water in the hose must be the same as in part (a), 3.81 m/s.

(c)

$$\text{Total head at the bottom of the hose: } P_{bot} + \frac{1}{2} \rho v_{open}^2$$
$$P_{bot} + \frac{1}{2} \rho v_{open}^2 = P_0 + \frac{1}{2} \rho v_{open}^2 + \rho g h_{open}$$
$$P_{bot} = P_0 + \rho g h_{open}$$
$$= 1.00 \times 10^5 \text{ Pa} + 1000 \times 9.80 \times 0.580 \text{ Pa}$$
$$= 106 \text{ kPa}$$

(d) No, the pressure of the hose is less than the pressure in the bottom of the tank. Since the height of the water in the bottom of the tank is the same as in the bottom of the hose, and the velocity of the water increases as it enters the hose, the pressure must drop to keep the total head constant.

6. (a)

First we find the velocity of the water by using Bernoulli's Equation:

$$\begin{aligned}\text{Total head at the surface: } & P_0 + \rho g h_{top} \\ \text{Total head at the straw opening: } & P_0 - 3000 \text{ Pa} + \rho g h_s + \frac{1}{2} \rho v^2 \\ & \frac{1}{2} \rho v^2 = 3000 \text{ Pa} - \rho g (h_s - h_{top}) \\ v_{open} = & \sqrt{3000 \times \frac{2}{1000} - 2 \times 9.80 \times (0.27 - 0.18)} \text{ m/s} \\ & = 2.06 \text{ m/s}\end{aligned}$$

Letting A denote the cross sectional area of the straw, the flow rate is:

$$\Phi = A \times 2.06 \text{ m/s} = 0.0000196 \text{ m}^2 \times 2.06 \text{ m/s} = 4.04 \times 10^{-5} \text{ m}^3/\text{s}$$

(b) The difference in height between the mouth and the surface gets larger as so the flow rate will decrease. (It is harder to pull the water up a larger distance.)

7. (a) We apply the continuity equation:

$$\begin{aligned}A_C v_C &= A_B v_B \\ v_B &= \frac{A_C}{A_B} v_C = \frac{1}{4} v_C = 3.00 \text{ m/s}\end{aligned}$$

(b) Note that the velocity of the water and the height of the water are the same at C and just after the water leaves the hose. Therefore, the pressure at point A must be P_0 . By Bernoulli's Equation:

$$\begin{aligned}P_B + \frac{1}{2} \rho v_B^2 &= P_0 + \frac{1}{2} \rho v_C^2 \\ P_B &= P_0 + \frac{1}{2} \rho (v_C^2 - v_B^2) \\ &= 1.00 \times 10^5 \text{ Pa} + \frac{1}{2} \times 1000 \times (144 - 9.0) \text{ Pa} \\ &= 168 \text{ kPa}\end{aligned}$$

(c) By the continuity equation, the velocity of the water in A must be the same as in C . Hence:

$$\begin{aligned}\text{Total head at A: } & P_A + \frac{1}{2} \rho v_C^2 \\ \text{Total head at C: } & P_0 + \frac{1}{2} \rho v_C^2 \\ P_A &= P_0\end{aligned}$$