1. What will happen to the scale reading as the mass is lowered?

![Image of a mass submerged in fluid]

**Solution:**
*Using Archimedes Principle*: any body fully or partially submerged in a fluid is buoyed up by a force equal to the weight of the fluid displaced. If mass is more dense than fluid, mass will sink and scale will read weight of fluid and full weight off mass. If mass is less dense than fluid, object will float and scale will increase until equilibrium is reached between buoyancy and weight of mass.

2. Find pressure as a function of time. At time \( t = 0 \), the water level is 2 feet. Cross-sectional area is 8 ft\(^2\) for the top and 1 ft\(^2\) for the bottom.

![Image of a container with water and rates of addition and subtraction]

**Solution:**
*Container with cross sectional area perpendicular to y-axis of 6-y/2. What is pressure at bottom?* Rate of water addition is \( (3-t) \) ft\(^3\)/min and leaves continuously at \( t^2 \) ft\(^3\)/min.
\[ P = \rho gh \]
\[ \frac{dh}{dt} = \frac{dv}{dt} = \frac{(3-t)-t^2}{6-h} \]
\[ \int (6 - \frac{h}{2}) dt = \int (3 - t - t^2) dt \]
\[ 6h - \frac{h^2}{4} = 3t - \frac{t^2}{2} - \frac{t^3}{3} + c \]
\[ c = ?; t = 0, h = 2; 12 - 1 = c; c = 11 \]
\[ \frac{h^2}{4} - 6h + (11 + t - \frac{t^2}{2} - \frac{t^3}{3}) = 0 \]
\[ h = 12 \pm 2 \sqrt{36 - 11 - 3t + \frac{t^2}{2} + \frac{t^3}{3}} \]
\[ t = 0, h = 2 \]
\[ h = 12 + 2\sqrt{25} \]
\[ 2 = 12 - 2\sqrt{25} \]
\[ \therefore h = 12 - 2 \sqrt{25 \cdot 3t + \frac{t^2}{2} + \frac{t^3}{3}} \]
\[ P(t) = \rho g(12 - 2 \sqrt{25 \cdot 3t + \frac{t^2}{2} + \frac{t^3}{3}}) \]

3. For a hydrofoil aircraft, why is turbulent flow preferable?

Solution:
The indentations create turbulence in the boundary layer downstream of the indentations, changing the characteristics of the flowing fluid to a turbulent boundary layer ahead of the normal point of separation of the fluid from the foil, this causing the fluid to cling close to the surface of the foil and postpone or delay trailing edge separation of the fluid stream from the foil. The noise level is reduced, the performance and efficiency of the foil is improved, or both the noise level is reduced and the performance and efficiency of the foil is improved.

4. In the following simplified system, where is pressure the greatest?

Solution:
Highest pressure is downstream of the pump (counterclockwise rotation).

5. If the flow rate is increased by a factor of three, how does the pressure change at both points?

Solution:
Pressure will decrease by a factor of nine.
Bernoulli’s equation states that, in a streamline fluid flow, the greater the speed of the flow, the less the static pressure, and the less the speed of the flow, the greater the static pressure. There exists a simple exchange between the dynamic and static pressures such that their total remains the same. As one increases, the other must decrease. Use the relationship: \( \frac{1}{2} \rho V^2 + P = P_t \)

6. What is force \( F \)?

Solution:
Assume at fluid is water 20 degrees Celsius and at sea level, therefore \( \rho_{\text{water}} = 0.037 \text{lbf/in}^3 \)

\[
\frac{F}{9 \text{ in}^2} + \frac{0.037 \text{lbf/in}^3 \cdot 12 \text{ in} \cdot 9 \text{ in}^2}{9 \text{ in}^2} = \frac{9000 \text{lbf}}{900 \text{ in}^2}
\]

\[
F = 9 \text{ in}^2 \left( \frac{9000 \text{lbf}}{900 \text{ in}^2} - \frac{0.037 \text{lbf}}{\text{in}^3} \cdot 12 \text{ in} \right)
\]

\[
F = 86 \text{lbf}
\]

7. A ball of diameter 10 cm and mass 10 grams is dropped in a container of water. The cross-sectional area of the container is 100 cm\(^2\). What is the change in the height of the water column?

Solution:
Assume cross-sectional area of the container is constant and temperature is 20 deg C.
Density of ball:
\[ \rho_{\text{ball}} = \frac{4}{3} \pi \left( \frac{10}{2} \right)^3 \cdot 0.019 \text{ g/cm}^3 \]

\[ \rho_{\text{ball}} < \rho_{\text{water}}, \text{ so the ball floats. So the weight of the water displaced is } 10 \text{ g.} \]

Volume of water displaced:

\[ V = \frac{m}{\rho} = \frac{10 \text{ g}}{1 \text{ g/cm}^3} = 10 \text{ cm}^3 \]

\[ \Delta h = h_1 - h_0 = \frac{V_1 - V_0}{A} = \frac{V_0 + 10 \text{ cm}^3 - V_0}{A} = \frac{10 \text{ cm}^3}{A} \]

8. The cross-sectional area of the siphon tube is constant. The fluid flows from tub 1 to tub 2. Determine the maximum height \( h \) that will still result in fluid flow.

Solution:

Maximum height of a siphon is (using Bernoulli’s equation), and velocity of siphon is as slow as possible.

\[ h_{\text{max}} = \frac{P_{\text{atm}}}{\rho g} \]

9. The motor on a centrifugal pump is hooked up backwards, causing the impeller to spin the wrong direction. What will happen to the head vs. gpm curve?

Solution:

While flow would continue in the proper direction the efficiency of the pump would decrease. The head vs. gpm curve would decrease.

10. Describe how a Venturi meter works and show how it can be used to calculate fluid flow (Bernoulli’s Eqn. and the Continuity Eqn.)

Solution:

Venturi meter utilizes a nozzle to measure the mass flow rate of a fluid by measuring the differential pressure.

Energy equation
\[ q - w = \Delta gpe + \Delta ppe + \Delta ke \]
\[ 0 - 0 = 0 + (P_1 - P_2) / \rho + (v_2^2 - v_1^2) / 2 \]
\[ (v_2^2 - v_1^2) / 2 = (P_2 - P_1) / \rho \]

**Continuity Equation:**
\[ \dot{m} = vA \Rightarrow v_1 = \dot{m} / A_1 ; v_2 = \dot{m} / A_2 \]

Substitute:
\[ (\frac{\dot{m}}{fA_2})^2 - (\frac{\dot{m}}{fA_1})^2 = \frac{2(P_2 - P_1)}{\rho} \]

\[ \dot{m} = \left( \frac{2A_1^2 A_2^2 \rho}{A_1^2 - A_2^2} \right) \sqrt{P_1 - P_2} \]

11. What happens to the water level with respect to the shore when the sailor throws the lead anchor overboard?

**Solution:**
*Use Archimedes Principle:* where an object partly or wholly immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced.

\[ V_a = \left( \frac{\rho_{lead}}{\rho_{water}} \right) = V_a \left( \frac{11.34}{1} \right) = 11.34V_a \]

Therefore, anchor is displacing an amount equal to its volume. 11.34\(V_a\) reducing water level.

12. How far will the water shoot out?

**Solution:**
*Energy Balance*
\[ E_p = E_k \]
\[ mgh_1 = \frac{v_{ox}^2}{2} \]
\[ v_{ox} = 2gh_1 \]
\[ v_{ox} = \sqrt{2gh_1} \]
\[ h_2 = v_x t^2 + \frac{gt^2}{2} \]
\[ t = \frac{\sqrt{2h_2}}{g} \]
\[ d = v_{ox}t + \frac{a_x t^2}{2} = (\sqrt{2gh_1})(\sqrt{2h_2}/g) \]
\[ d = 2\sqrt{h_1h_2} \]

13. Explain how you would estimate the flow rate in a pipe.

**Solution:**
*Measure flow in cfs. If water is dropping from a pipe you can measure with carpenter’s ruler. Measure horizontal distance, the vertical drop y.*
*Cross section of a pipe: Flow rate=area*velocity*roughness factor (least accurate +/-20%)*
*Timed volume using bucket and stopwatch: flow rate=volume/time*

14. If the liquid is flowing in the direction indicated, at what point is the pressure greatest?

![Diagram of a pipe system with points A, B, C, D, and E]

15. Given a fluid flowing through a pipe in the direction indicated, what difference in parameters exists between points A and B?

![Diagram of a fluid flow with points A and B]

**Solution:**
*Pressure is lower as point B than point A due to energy losses in the pipe (head loss. The energy is converted to heat.)*

16. What is meant by laminar and turbulent flow? If you had a piping system, which type of flow would be better and why?

**Solution:**
Laminar flow is a fluid flow characterized by non-turbulent and inefficient heat transfer capability. Turbulent flow has a great deal of mixing and friction. Laminar flow is more desired in piping because pump power is reduced due to the lower head loss. Turbulent flow is desirable when heat transfer needs to be maximized.

17. Which will raise the water level in a tank higher when added – a one pound block of iron or a one pound block of wood?

Solution:
Archimedes Principle Equation
Wood displaces more volume of water than lead