Peer instruction question

Suppose that a caterer packed some food in an air tight container with a flexible top at sea-level. This food was loaded on to an airplane with a cruising altitude of ~6 mi above the earth’s surface. Assuming that the airplane cabin is imperfectly pressurized, what do you expect the container to look like during the flight?

(A) (B) (C)

Peer instruction question

Suppose that a caterer packed some food in an air tight container with a flexible top at sea-level. This food was loaded on to a submarine which typically submerges at 200m below sea level. Assuming that the submarine cabin is imperfectly pressurized, what do you expect the container to look like during the submersion?

(A) (B) (C)

Fluid dynamics: Ideal Fluids

An ideal fluid has four properties:

1) There is no internal friction (viscosity).

2) The flow is steady, i.e. the velocity at a given point in the fluid does not change over time.
   
   Note: We are considering points NOT particles in the fluid.

3) The flow is incompressible, i.e., the density is constant.

4) The flow is irrotational, i.e. no angular momentum about any point.
Fluid dynamics: Ideal Fluids and flow

If we have a nonuniform flow (due to partial clogging of arteries for example), we have to consider the effects of constriction on fluid flow.

The flow is steady and we can't lose mass in the middle, so the same amount of mass must enter and leave (in the same \( \Delta t \)).

Therefore, \( \rho A_1 v_1 \Delta t = \rho A_2 v_2 \Delta t \) => \( A_1 v_1 = A_2 v_2 \)

Energetics of fluids:

\[ \Delta x_1 = v_1 \Delta t \]
\[ \Delta x_2 = v_2 \Delta t \]
\[ A_1 \Delta x_1 = A_2 \Delta x_2 \]
\[ m = \rho A_1 \Delta x_1 \]

\( K_2 + U_2 = K_1 + U_1 + W_{12} \)
\( \frac{1}{2} mv_2^2 + mgh_2 = \frac{1}{2} mv_1^2 + mgh_1 + (P_1 A_1 \Delta x_1 - P_2 A_2 \Delta x_2) \)

\[ P_2 + \frac{1}{2} \rho v_2^2 + \rho gh_2 = P_1 + \frac{1}{2} \rho v_1^2 + \rho gh_1 \]
Fluid dynamics: Conservation of Energy

Let us consider conservation of energy for a moving fluid,

\[ A_1 v_1 \quad A_2 v_2 \]

This implies that

\[ P_1 + 0.5 \rho v_1^2 + \rho g y_1 = P_2 + 0.5 \rho v_2^2 + \rho g y_2, \]

or in general

\[ P + 0.5 \rho v^2 + \rho g y \text{ is a constant} \]

The work done at this end is

\[ -F_1 \Delta x_1 = -P_1 A_1 \Delta x_1 = -P_1 V \]

The work done at this end is

\[ -F_2 \Delta x_2 = -P_2 A_2 \Delta x_2 = -P_2 V \]

This implies that \( P_1 + 0.5 \rho v_1^2 + \rho g y_1 = P_2 + 0.5 \rho v_2^2 + \rho g y_2 \), or in general

\[ P + 0.5 \rho v^2 + \rho g y \text{ is a constant} \]

Bernoulli’s equation:

\[ P_2 + 0.5 \rho v_2^2 + \rho g h_2 = P_1 + 0.5 \rho v_1^2 + \rho g h_1 \]

Example: Suppose we know \( A_1, A_2, \rho, P, y_1, y_2 \)

\[ P + 0.5 \rho v_2^2 + \rho g y_2 = P_0 + 0.5 \rho v_1^2 + \rho g y_1 \]

\[ \eta = \frac{\sqrt{2g h - (P_0 - P)/\rho} - \sqrt{h_1}}{1 - \sqrt{\eta}} \]

Streamline flow of air around an airplane wing:

\[ F_{\text{lift}} = (P_2 - P_1) A \]

\[ P_1 + 0.5 \rho v_1^2 + \rho g h_1 = P_2 + 0.5 \rho v_2^2 + \rho g h_2 \]

\[ \eta = \frac{\sqrt{2g h - (P_0 - P)/\rho} - \sqrt{h_1}}{1 - \sqrt{\eta}} \]

\[ F_{\text{lift}} = \frac{1}{2} \rho A \left( v_1^2 - v_2^2 \right) \]

Example:

\[ v_1 = 270 \text{ m/s} \]
\[ v_2 = 260 \text{ m/s} \]
\[ \rho = 0.6 \text{ kg/m}^3 \]
\[ A = 40 \text{ m}^2 \]
\[ F_{\text{lift}} = 63,600 \text{ N} \]

http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html
Homework problem: A hypodermic syringe contains a medicine with the density of water. The barrel of the syringe has a cross-sectional area $A=2.5\times10^{-5}$ m$^2$, and the needle has a cross-sectional area $a=1.0\times10^{-8}$ m$^2$. In the absence of a force on the plunger, the pressure everywhere is 1 atm. A force $F$ of magnitude 2 N acts on the plunger, making the medicine squirt horizontally from the needle. Determine the speed of the medicine as it leaves the needle’s tip.