18.1 Forces in a fluid

Wednesday, February 20, 2019 8:51 PM

- Different types of stresses caused by equal forces to solid objects

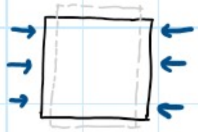
  ---- Shape changed by the force

  - Tensile stress

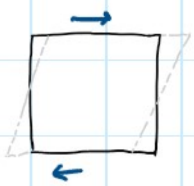
    V increases by a small amount

  - Compressive stress

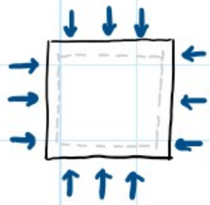
    V decreases by a small amount.

  - Shear stress

    V–, shape changes

  - Bulk stress

    V↓

- Nonviscous: fluids that cannot support static tensile/shear stress
  Viscous: fluids can support a shear stress
  (shape returns to before)
  - A component of non-viscous exerts a normal force to the surface.
- In mechanical equilibrium, a fluid in a container exerts a (normal) force that is distributed along all surfaces of the container that's in contact with the fluid.
- Main difference between gases & liquids
  - gases tend to compress easily, often greatly changing V, therefore the mass density ($\rho = \frac{m}{V}$)
  - V, ρ of liquid do not change easily ⇒ incompressible
- Pressure $P = \frac{F}{A}$
  - A scalar, taken to be positive when under compression
  - $P > 0$ for gases; P can be less than 0 for liquid.

- If solid, ... to be positive when under compression
- $P > 0$ for gases; P can be less than 0 for liquid.

- The force exerted by a container wall on a fluid (which causes the pressure in the fluid) and the force exerted by the fluid on the container wall form an interaction pair.

- A gas always expand to fill the container.
- The pressure in a liquid at rest in a container decreases linearly with height, regardless of the shape of the container.
  - Gas also has this property, but much less pronounced.
  - Average atmospheric pressure at sea level: $1 \times 10^5\ N/m^2$

- Pascal's principal: A pressure changed applied to an enclosed liquid is transmitted undiminished to every part of the liquid and to the walls of the container in contact with the liquid.

- $P = \rho \cdot g \cdot h$ for liquids.

  $P = \frac{F}{S} = \frac{mg}{S} = h \cdot \frac{mg}{V} = \rho g h$

18.2 Buoyancy

Wednesday, February 20, 2019 11:06 PM

F^b

- **Buoyant force**: an upward force experienced by objects when they are either fully or partially submerged in a fluid.

  Buoyancy: the tendency of certain objects to float in air or water.

  - $F^b = m_{water} g$, m_{water}: water displaced by the object.

    $= V_{displaced} \cdot \rho \cdot g$

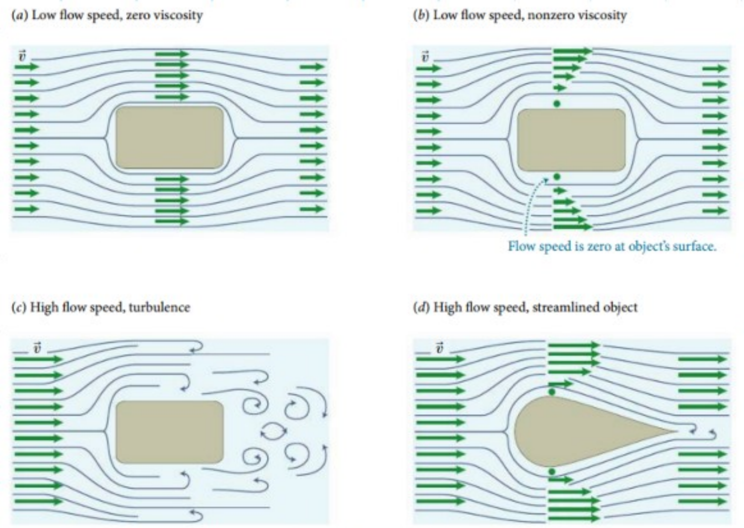
    → Archimedes' principle.

18.3 Fluid Flow

Wednesday, February 20, 2019 11:12 PM

- Fluid flow {
  - laminar : velocity at any given position is constant.
  - turbulent : velocity charactised by chaotic changes.
  - o streamlines : lines drawn to represent paths taken by particles in a fluid in motion.

- Vortex (vortices) : circularly moving regions of fluid.
- Wheather a flow of fluid past a stationary obj is laminar or turbulent depends on
  - · v of flow
  - · shape of obj
  - · fluid's viscosity.



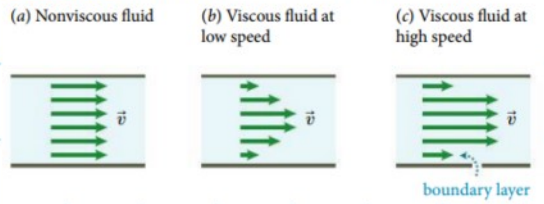
- Streamline objs can prevent turbulence and minimize energy dissipation.

- flow in pipe
  - o flow speed=0 at pipe walls

- ... in pipe
  - flow speed = 0 at pipe walls
  - speed highest at center.
  - At high flow speed, the speed is more constant across diameter of pipe, dropping off only in a boundry layer.

    $v \uparrow$ thickness of boundry layer $\downarrow$

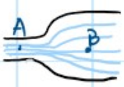
Figure 18.19 Flow speed patterns through a pipe of fixed diameter.



- Streamlines in a laminar flow

  $\begin{cases} \text{get closer to each other} \Rightarrow \text{flow speed} \uparrow \\ \text{get farther apart} \Rightarrow \text{flow speed} \downarrow \end{cases}$

  - flowing fluid speeds up if travels to narrower places, slows down if travels to wider places.
- Bernoulli effect: When flow speed in a laminar flow increases, P in the fluid decreases. $\boxed{v\uparrow \ P\downarrow}$



- B has a greater P, because there'll be decelleration from A to B.

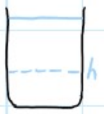
  ? $m = \rho V$, to make m equals, must let more V pass at a time.

18.5 Pressure and Gravity

Tuesday, February 26, 2019 8:45 AM

- Pressure $P \equiv \frac{F}{A}$ unit: Pa (pascal)
    - $1\ Pa = 1 N/m^2$
    - Perfect vaccum $P = 0$. vacuum $P \leq 1 Pa$.
    - $P_{atm} = 101 kPa$
- Pressure of liquid

  $P = P_{atm} + \rho g h$ (stationary liquid)



- Buoyant force $F = \rho_{liquid}\, g V$
    - V: displaced volume

Session 67739552

numerical question

How many meters below the surface of a deep body of water is the pressure twice what it is at the surface? The density of water is 1.0×10^3 kg/m^3 and atmospheric pressure is 1.01310^5 N/m^2.
Enter your answer in meters, but only include the number.

You responded to this question; your response was **10.3**.

$1.03\times10^5 N \times 2 = P_{atm} + \rho g h$

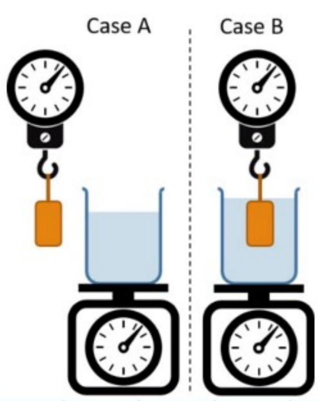
$\rho g h = 1.03\times10^5$

$h = \frac{1.03\times10^5 Pa}{10^3 kg/m^3 \cdot 9.8 N/m} = 10.3 m$

Session 67739552

numerical question

In case A, a mass is hung from a spring scale and the scale measures a force of 20.0 N (4⅜ lbs). In case B, the mass is then submerged in a beaker of water and the spring scale measures a force of 12.5 N (2¾ lbs). The density of water is 1.00×10^3 kg/m^3. What is the density of the mass?
Enter your answer in kg/m^3, but only include the number.



$F_b = \rho_f\, g\, V_{dis}$

$20 - 12.5 = 10^3 \times 9.8 V$

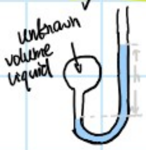
$V = 7.65 \times 10^{-4}\ m^3$

$\rho = \dfrac{20/9.8}{7.65 \times 10^{-4}} = 2667\ kg/m^3$

18.6 Working with Pressure

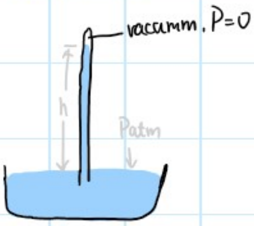
Tuesday, February 26, 2019 8:54 AM

- $P = P_{gauge} + P_{atm}$
- Pressure Gauge $P_{measure} > P_{atm}$ e.g. open-tube manometer.
  Vacuum Gauge $P_{measure} < P_{atm}$
  - Open-tube manometer



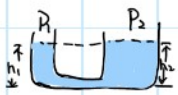
$P = P_{atm} + \rho g h$

  - barometer



$P_{atm} = \rho g h$

- hydraulic systems



$P_1 = P_2$ when $h_1 = h_2$

- Steps to solve:

I. Identify boundries & factors affect pressure.

II. Determine pressure at each surface

III. Use horizontal planes

18.7 Bernoulli's Equation

Tuesday, February 26, 2019 9:13 AM

- Continuity equation $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$ (laminar flow of nonviscous fluid)
  - v_1, v_2 are speed
  - $A_1 v_1 = A_2 v_2$ (laminar flow of nonviscous incompressible fluid).

    ρ doesn't change for incompressible fluid.
  - $Q = \frac{V}{\Delta t} = Av$ volume flow rate
- Bernoulli's equation $P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

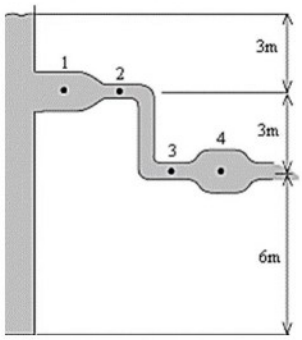
  (laminar flow of incompressible, nonviscous fluid)
  - y_1, y_2 is the height
  - If height is the same $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

☆☆☆☆

Session 54943667

multiple choice question

A non-viscous fluid is discharged from the tank in the manner shown. The flow is laminar and the narrow pipe has one third the radius of the wide pipe. At point 1 the fluid is flowing with a speed of 1 m/s.
Compare the pressures at points 1 and 3.



A. $P_1 < P_3$

B. $P_3 < P_1$

$A_1 v_1 = A_2 v_2$

$A_1 = 9A_2$

$\therefore V_2 = 9V_1 = V_3$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_3 + \rho g y_3 + \frac{1}{2}v_3^2$

$P_3 - P_1 =$

B.

☆

multiple choice question

When you pour coffee, the height of the coffee inside the coffee urn does not drop significantly, but the height in the sight glass at the front does. What does this tell you about the pressure below the sight glass, P_s, compared to the pressure in the coffee urn, P_u, at the same height?

A. $P_s = P_u$

B. $P_s > P_u$

C. $P_s < P_u$

It's not a stationary fluid.

$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

$V_s > V_u$

$\therefore \quad P_s < P_n \qquad C$

When doing fluid probs:

I. Is it stationary/same height?

Probs

Sunday, February 24, 2019 4:03 PM

☆

Water from a faucet can fill a 3.00-L bucket in 1 min.

Part A

If the diameter of the water pipe feeding the faucet is 12.5 mm, what is the speed of the water in the pipe?

Express your answer to three significant digits and include the appropriate units.

$v =$ 0.407 $\frac{\mathrm{m}}{\mathrm{s}}$

Submit Previous Answers

✔ Correct

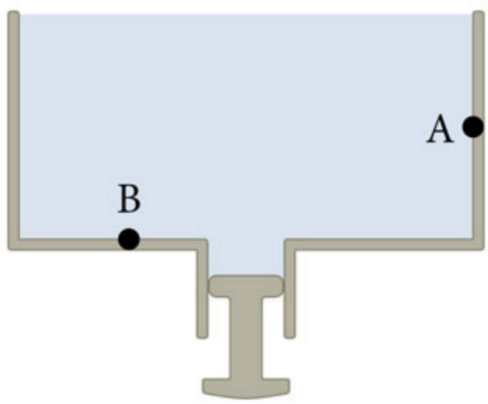
$Av = \frac{V}{\Delta t}$, V 为 m m^3

$V = \frac{3\times10^{-3} m^3}{60s \cdot \pi \cdot (\frac{12.5}{2}\times10^{-3})^2 m^2}$

$= 0.407 m/s$

☆☆

The fixed container in (Figure 1) is filled with a liquid and fitted with a piston at the bottom.



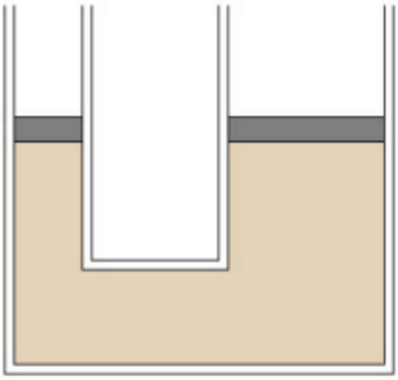
Give the direction (if any) of the force $\vec{F}^{c}_{\ell p}$ exerted by the liquid on the piston if the piston is pulled.

- The force is directed to the right.
- The force has no direction.
- The force is directed downward.
- The force is directed upward.
- The force is directed to the left.

No matter where it goes, water always exert downforward on B.

☆☆☆

A U-tube is filled with water, and the two arms are capped.(Figure 1) The tube is cylindrical, and the right arm has twice the radius of the left arm. The caps have negligible mass, are watertight, and can freely slide up and down the tube.



A one-inch depth of sand is poured onto the cap on each arm. (Figure 2) After the caps have moved (if necessary) to reestablish equilibrium, is the right cap higher, lower, or the same height as the left cap?

▸ **View Available Hint(s)**

- higher
- lower
- the same height

$P_{add} = \rho_{sand} \cdot g \cdot h_{sand}$

h should be the same.

Submit   Previous Answers

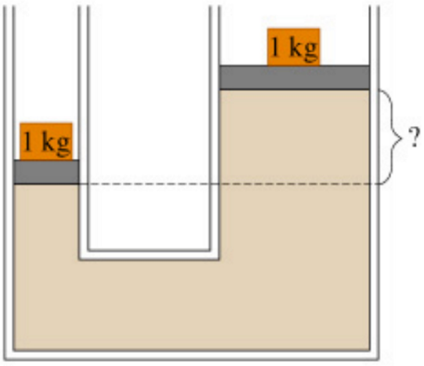
The sand is removed and a 1.0-kg-mass block is placed on each cap. (Figure 3) After the caps have moved (if necessary) to reestablish equilibrium, is the right cap higher, lower, or the same height as the left cap?

▸ **View Available Hint(s)**

- higher
- lower
- the same height

$\frac{1\,kg \times 9.8\,N/m^2}{S} > \frac{1\,kg \times 9.8\,N/m^2}{2^2 S}$

Submit   Previous Answers



If a 1.0-kg-mass block is on the left cap, how much total mass must be placed on the right cap so that the caps equilibrate at equal height?

Express your answer in kilograms.

▸ **View Available Hint(s)**

4.0 kg

$S_1 : S_2 = 1 : 4$

$\therefore m_1 : m_2 = 1 : 4$

Submit   Previous Answers

✔ **Correct**

Part D

The locations of the two caps at equilibrium are now as given in this figure. (Figure 4) The dashed line represents the level of the water in the left arm. What is the mass of the water located in the right arm between the dashed line and the right cap?

Express your answer in kilograms.

▸ **View Available Hint(s)**

3.0 kg

$4kg - 1kg = 3kg$

or

$\rho g h + \frac{1 \times g}{4S} = \frac{1 \times g}{S}$

$\rho h = \frac{3}{4S}$

Submit   Previous Answers

✔ **Correct**

✔ Correct

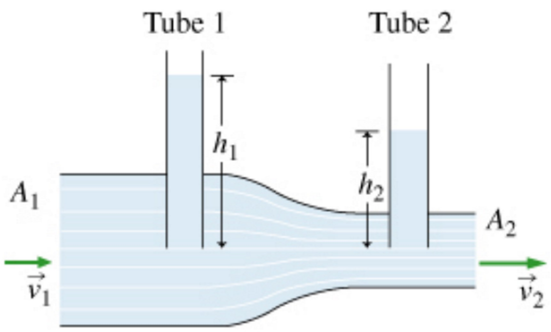
$\rho h = \frac{3}{45}$

$\rho h \cdot 45 = 3\ \text{kg}$

☆☆☆☆

Constants | Periodic Table

A pair of vertical, open-ended glass tubes inserted into a horizontal pipe are often used together to measure flow velocity in the pipe, a configuration called a *Venturi meter*. Consider such an arrangement with a horizontal pipe carrying fluid of density ρ. The fluid rises to heights h_1 and h_2 in the two open-ended tubes (see figure). The cross-sectional area of the pipe is A_1 at the position of tube 1, and A_2 at the position of tube 2.
(Figure 1)



Find v_1, the speed of the fluid in the left end of the main pipe.

Express your answer in terms of h_1, h_2, g, and either A_1 and A_2 or γ, which is equal to $\frac{A_1}{A_2}$.

▸ **View Available Hint(s)**

$v_1 = \sqrt{2g\frac{h_2-h_1}{1-\gamma^2}}$

Submit   Previous Answers

$P_1 = \rho g h_1$

$P_2 = \rho g h_2$

$P_2 - P_1 = \frac{1}{2}\rho(v_1^2 - v_2^2)$

(Bernoulli)

$\rho g(h_2 - h_1) = \frac{1}{2}\rho(v_1^2 - v_2^2)$

$A_1 v_1 = A_2 v_2$

$\therefore v_2 = \frac{A_1}{A_2} v_1 = \gamma v_1$

$\therefore 2g(h_2 - h_1) = (1-\gamma^2)v_1^2$

$v_1 = \sqrt{2g\frac{h_2-h_1}{1-\gamma^2}}$

☆☆☆☆

Constants | Periodic Table

When a garden hose with an output diameter of 20 mm is directed straight upward, the stream of water rises to a height of 0.18 m. You then use your thumb to partially cover the output opening so that its diameter is reduced to 10 mm.

How high does the water rise now? Ignore drag and assume that the smaller opening you create with your thumb is circular.

Express your answer with the appropriate units.

$h =$ 2.9 m

Submit   Previous Answers

$\frac{1}{2}mv_1^2 = mgh_1$

$$\frac{1}{2}mv_1^2 = mgh_1$$

$$v_1 = \sqrt{2gh_1} = \sqrt{2 \times 9.8 \times 0.18}$$

$$A_1 v_1 = A_2 v_2$$

$$v_2 = \frac{A_1}{A_2} v_1 = 4 v_1 = 7.5 m/s$$

$$\therefore \frac{1}{2}mv_2^2 = mgh_2$$

$$h_2 = 2.9 m$$