Fluids

Density : ρ "rho"

formula : mass / volume units : kg/m^3

$\rho_{H_2O} = 1000\ kg/m^3$ if $\rho_{sub} > \rho_{H_2O}$ sinks

if $\rho_{sub} < \rho_{H_2O}$ floats

$$\text{Specific Gravity} = \frac{\rho_{substance}}{\rho_{H_2O}}$$

sp. gr. of $H_2O = 1.0$ if sp. gr. > 1.0 sinks

No Unit! if sp gr. < 1.0 floats

1. $Sp.\ Gr._{gas} = .72$ a) What is the density? b.) Does it float?

2. Block of Aluminum What is the sp. gr. of Al?
   $V = .002 m^3$ mass $= 5.4 kg$

① Fluids (at rest & flowing)

Density $\rho = \frac{\text{mass}}{\text{volume}}$ $\quad$ P = pressure $= \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$

What is the standard unit for density? _____

What is specific gravity? $SG =$ _____

Does S.G. have units? ____ Why or Why not?

If a substance has a specific gravity of 7, how many times denser is it compared to water at 4°C? (water is the most dense at 4°C) Answer? ☐

$100^\circ C \xrightarrow{\text{contracts}} 4^\circ C \xrightarrow{\text{expands}} 0^\circ C \xrightarrow{\text{expands even more}} 0^\circ C \xrightarrow{\text{contracts slightly}}$ Colder ice

$\approx 958\ kg/m^3$ $\quad$ $999.97\ kg/m^3$ $\quad$ WATER $999.84\ kg/m^3$ $\quad$ ICE $917\ kg/m^3$ $\quad$ $934\ kg/m^3$ at $-180^\circ C$

Why do pot holes form after freezing wet weather? Explain.

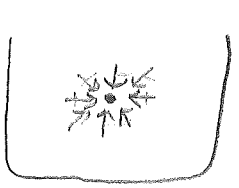
$\rho_{H_2O} = 1\ g/cm^3$ or $1\ g/mL =$ _____ kg/m^3

How many kg of water are in a $1\ m^3$ cube? _____

What is the standard unit for pressure? _____

F_{thumb} $\quad$ F_{finger} $\quad$ P_{thumb} $\quad$ P_{finger} $\quad$ $Pain_{thumb}$ $\quad$ $Pain_{finger}$

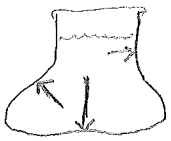
(2) Fluids exert pressure in all directions.



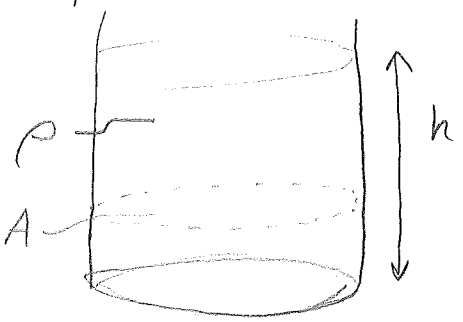
For fluids at rest:

At any point, pressure is the same in all directions.

The force due to fluid pressure is always $\perp$ to contact surfaces.



$P_{\substack{\text{Fluid} \\ \text{at rest}}} = \rho g h$ h is depth



$$P = \frac{F}{A} = \frac{mg}{A} = \frac{(\rho h A)g}{A} = \rho h g$$

Volume $= h \cdot A$ = height cross sectional area

$m = \rho(h \cdot A)$

* There is additional pressure from the atmosphere (P_0).

(3) Standard atmospheric pressure

$= 1\,atm = 101,300\,Pa \approx 10^5\,Pa = 10^5\,N/m^2$

How much force is experienced by a hand (palm side) with area $.013\,m^2$?

Why do we not consciously feel atmospheric forces?

What is the difference between absolute & gauge pressure?

If a tire has gauge pressure 250 kPa, what is its absolute pressure?

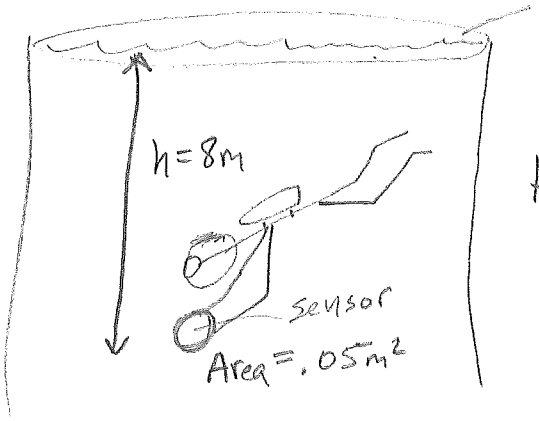
Pressure 'P' Formula: $\frac{F}{A}$ and ρgh

Units: N/m^2 Pascal Pa

$1_{ATM} \approx 101,000$ Pa

kPa = 1000 Pa

How much pressure does a 5.4kg Al block exert on the ground if Area $.016m^2$ and $V=.002m^3$?



$P_0 = 101,000$ Pa $\quad P_{abs} = P_0 + P_{gauge}$

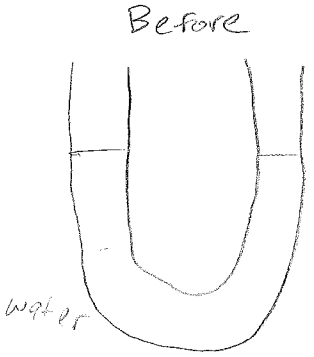
How much force is the sensor experiencing?

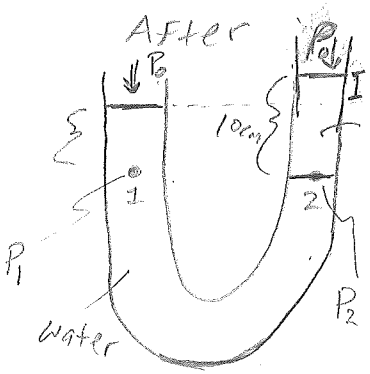
(4) When each of 4 tires of a car is inflated to a gauge pressure of 250 kPa, the 2 front tires each has a footprint of .012 m^2 and the 2 rear tires each has a footprint of .001 m^2. What is the mass of the car?

(5) A scuba diver dives down to a depth of 30m in a fresh water lake. What is the pressure at that depth in atm, in Pa and in cm Hg? ($\rho_{Hg} = 13600\ kg/m^3$)

What is the gauge pressure in atm, in Pa, and in Hg?

(6)



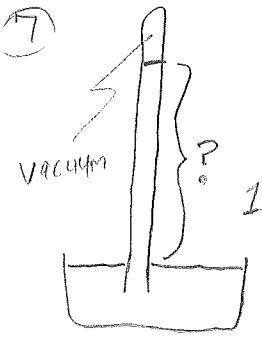


Oil is added to a U-shaped tube filled with water. $P_0 = 1\,atm$

1. Which point has greater pressure P_1 or P_2?

2. The oil column is 10cm high and it is 1.8 cm higher than the water level on the other side. Find the density of the oil. $\rho_{H_2O} = 1000\ kg/m^3$

(7)



Barometer: measures atmospheric pressure.
.93 atm at the center of a hurricane.

1. Find the height of the barometer when it is located at the center of a hurricane; assume the barometer is filled with mercury.

$\rho_{Hg} = 13{,}600\ kg/m^3$

$1\,atm \Rightarrow .76m\,Hg$

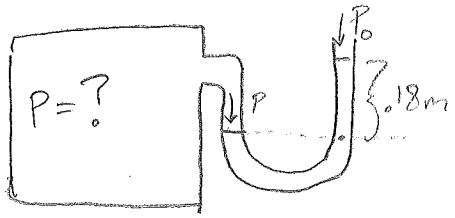
2. Find the height if the barometer were filled with water. $\rho_{H_2O} = 1000\ kg/m^3$

3. Why do we use Hg instead of H_2O in barometers?

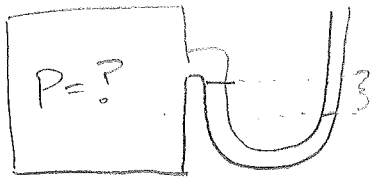
(8) Manometer : measures pressure inside a container

Find a.) P in cm Hg and Pa

b.) P_{gauge} in cm Hg ($\rho_{Hg} = 13600\ kg/m^3$)



What if the diagram were as follows?

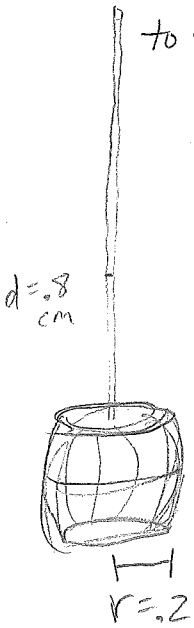


a.)

b.)

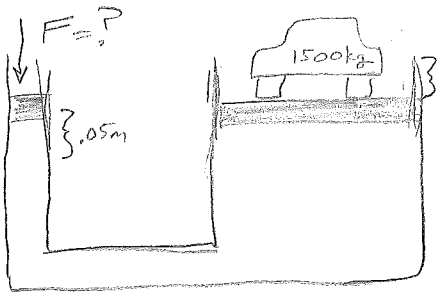
(9.) Pascal's Principle : An external pressure applied to a confined fluid is transmitted undiminished thoughout the entire fluid.

When water was filled to 10m high level inside the tube, the barrel burst and began to leak. Find the (a) mass of water in tube (b) the pressure on the inside lid (c) inside to outside pressure difference across the lid & (d) force on the force on the lid.



(10)

Hydraulic Lift



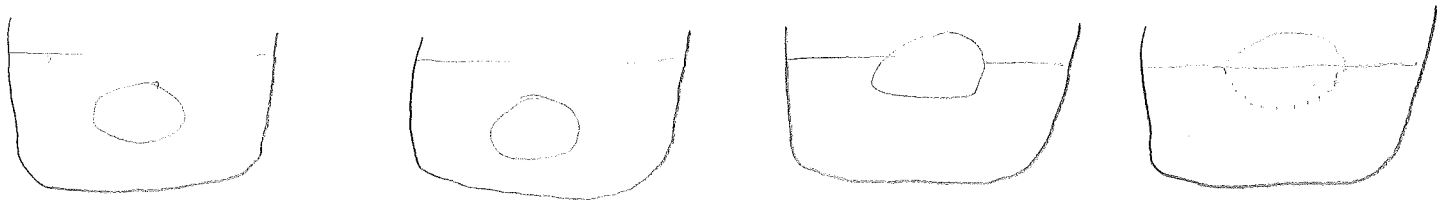
diameters are .1m and .3m of pistons

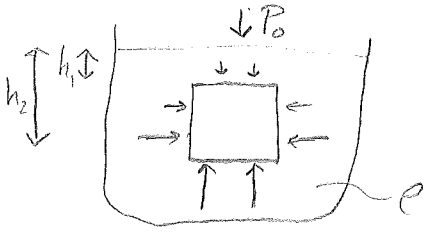
1. Why is the heavy car placed on the larger piston?

2. What force must be applied to the small piston to maintain the heights of the pistons the same level?

3. When the small piston is push down .05m, how far is the car lifted?

(11) Archimedes principle - any object, wholly or partially immersed in a fluid: $F_{buoyant} = W_{displaced\ fluid}$

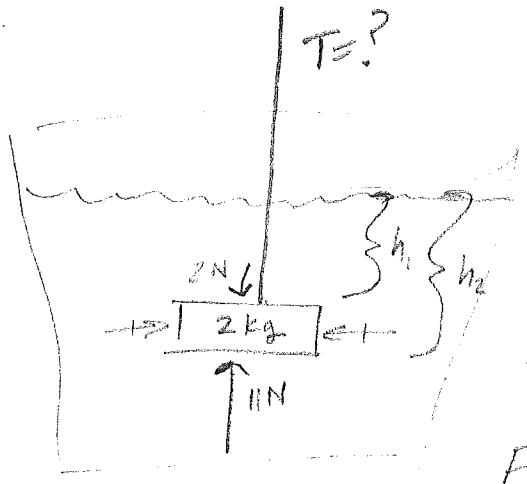




(12) A 150,000 metric ton (1.5×10^8 kg) iceberg floats in sea water.

$\rho_{ice} = 920\ kg/m^3$ a.) Find $F_{buoyant}$ on the iceberg

$\rho_{sea\ water} = 1025\ kg/m^3$ b.) What fraction of the iceberg is above the water surface?



$F_{buoyant}$ = Net upward force

$F_{buoyant}$ = |Weight of displaced fluid|

$F_{buoyant} = (\rho_{fluid} V_{fluid}) g$

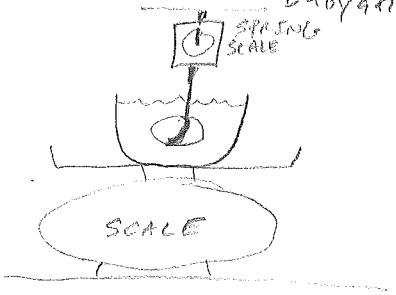
$V_{fluid} = V_{object\ submerged}$

$F_{b\ part} = (\rho_{fluid} V_{subm.}) g$

An aluminum sphere ($m = 5.4$ kg and $V = .002\ m^3$) rests on the bottom of a pool of olive oil (sp. gr. .7). Find the apparent weight of the sphere? F_N = Apparent Weight

(13) A 3 kg rock has $m = 2\,kg$ when completely in water.

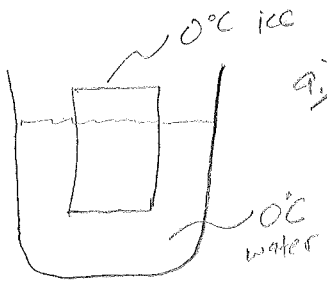
a.) $F_{buoyant} =$ _____ b.) $\rho_{rock} =$ _____



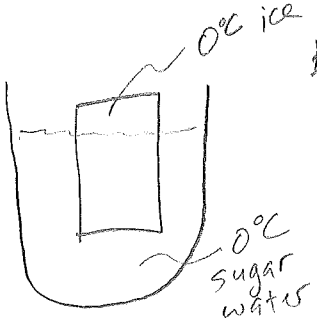
(14)

The helium balloon has a volume of $.02\,m^3$. $\rho_{helium} = .18\,kg/m^3$
$\rho_{air} = 1.29\,kg/m^3$ deflated balloon is 3g.

(15)



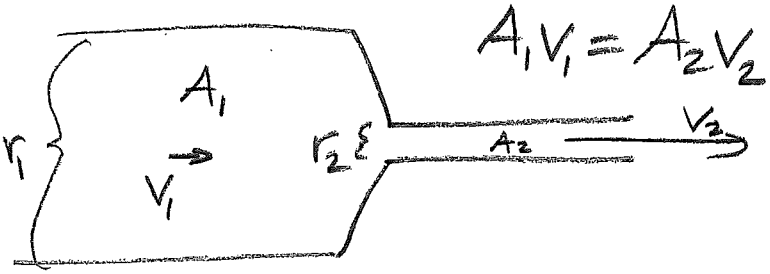
a.) As the ice melts the temperature stays at 0°C. Will the liquid level go up, down, or stay the same?



b.) What if sugar were added to the water making the water more dense?

Continuity Equation

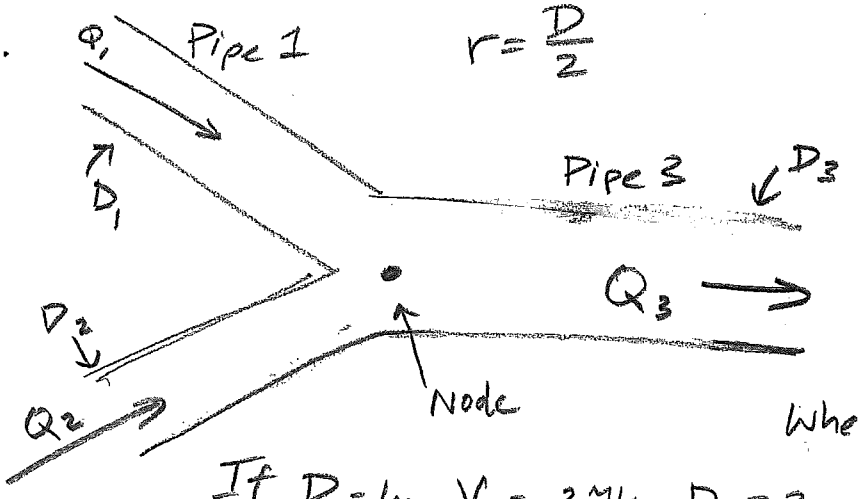
Conditions:
1. Incompressible
2. Low Viscosity
3. Laminar



$$A_1V_1 = A_2V_2$$

1. $r_1 = 2\,cm$ $V_1 = .7\,m/s$ $r_2 = .3\,cm$ $V_2 = ?$

2. If V_2 needs to be $100\,m/s$ while A_1 and V_1 remain the same, what should be r_2?

3. 

The amount of fluid flowing into the node must equal the amount of fluid flowing out.

$$Q_1 + Q_2 = Q_3$$

Where $Q = AV$ and $A = \frac{\pi D^2}{4}$

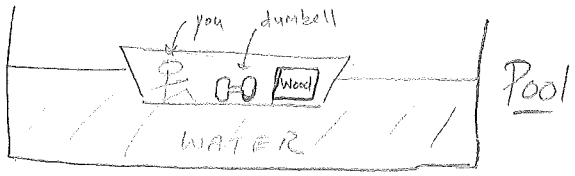
If $D_1 = 1m$ $V_1 = 2\,m/s$ $D_2 = 3m$ $V_2 = 4\,m/s$ & $D_3 = 5m$
Find $V_3 = ?$

(16) Wate level goes up, down, or stay the same?

a.) dumbbell to bottom

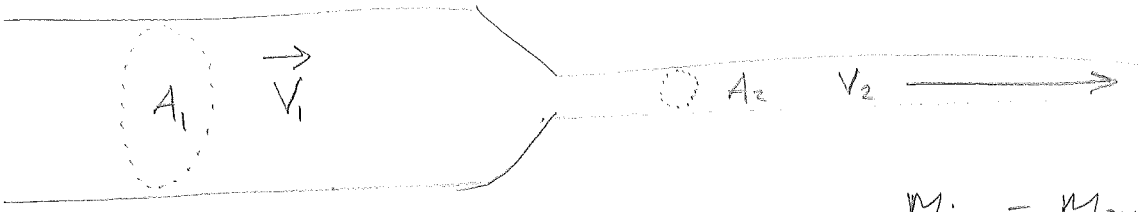
b.) wood floats in pool

c.) you get out on land



(17) Fluids in motion: Simplified 'ideal' fluids which are

(a) nonviscous (b) incompressible (c) fluid flow steady, no turbulence

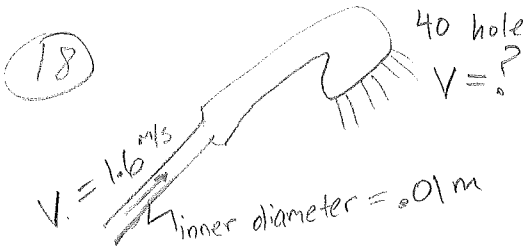


Because mass is conserved, mass flow rate $\frac{M_{in}}{\Delta t} = \frac{M_{out}}{\Delta t}$

$\boxed{\frac{d}{t} = v}$ $\quad \frac{\rho_1 A_1 d_1}{\Delta t} = \frac{\rho_2 A_2 d_2}{\Delta t} = \rho_1 A_1 V_1 = \rho_2 A_2 V_2$

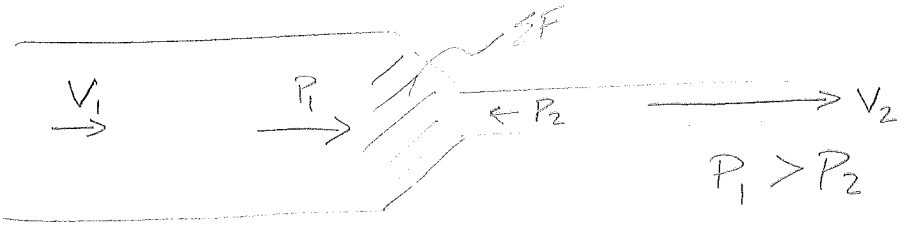
$\boxed{\text{incompressible fluids} \Rightarrow \rho_1 = \rho_2} \Rightarrow A_1 V_1 = A_2 V_2$ Equation of Continuity

(18)



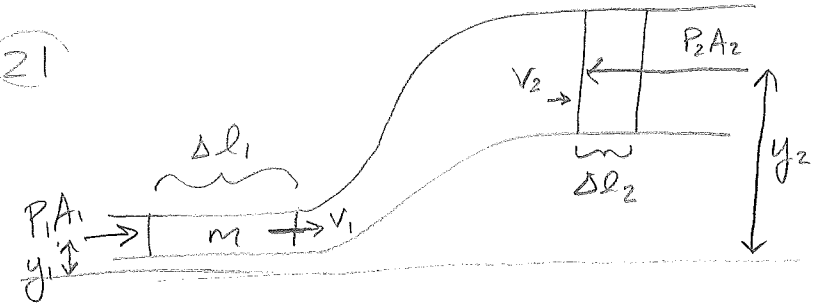
(19) Water comes out of a 2 cm inner diameter faucet opening at the speed of 3 m/s. How long does it take to fill a .6m x 1.5m x .4m bathtub?

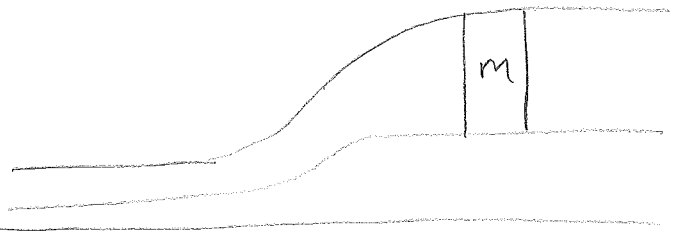
(20)



Why does your car (or motorcycle) feel shaken when passing an opposite traveling semi truck on the highway?

(21)



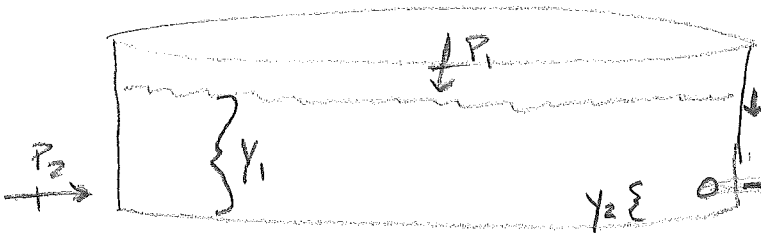


Consider a steady flow of incompressible fluid with negligible viscosity.
Derive Bernoulli's Equation:
(Use conservation of energy concepts)

Bernoulli's Equation

$$P_1 + \rho g y_1 + \tfrac{1}{2}\rho V_1^2 = P_2 + \rho g y_2 + \tfrac{1}{2}\rho V_2^2$$

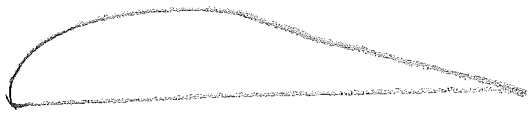
$P_1 \approx P_2$ Atmospheric Pressure



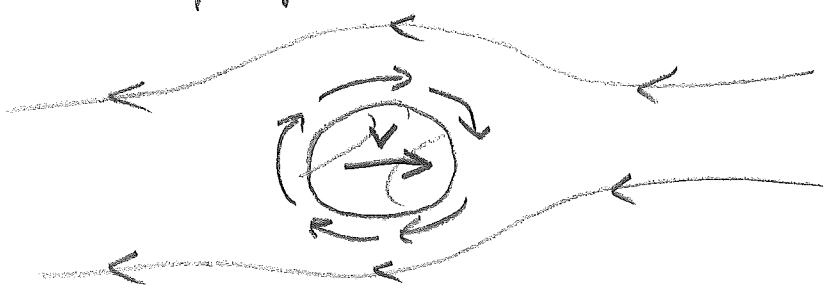
V_1 = how fast water level drops ≈ 0 m/s

Solve for V_2:

Wing $\quad P_{top} + \rho g y_1 + \tfrac{1}{2}\rho V_{top}^2 = P_{bottom} + \rho g y_2 + \tfrac{1}{2}\rho V_{bottom}^2$

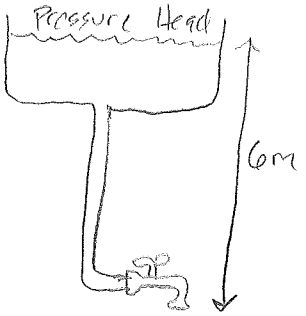


Top Spin



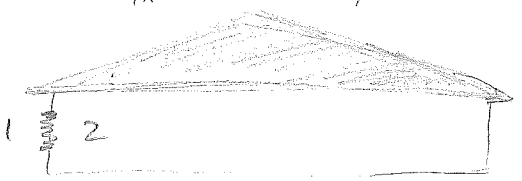
* Hose & Cylinder Demo

(22) Find the speed of water coming out of a faucet if the pressure head is 6m above the faucet mount?



(23) A wind gust of 15 m/s (about 34mph) blows across a .8m x 1.5m window. a) Estimate the force produced by air pressure difference on the closed window. $\rho_{air} = 1.29\ kg/m^3$

b.) What is the direction of this force?

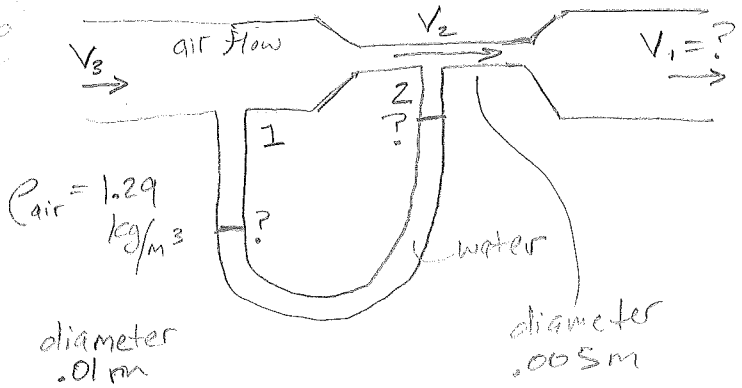


c.) Now if the window experiences a hurricane where wind speed = 34 m/s (about 70mph), find the force produced by air and the direction of the force.

(24) In the afternoon of Oct. 29 2012, Hurricane Sandy had winds of 40 m/s (about 90 mph). Estimate the pressure at the center of Sandy at that time. $\rho_{air} = 1.29\ kg/m^3$

(25) A jumbo jet has a total wing area of 525 m^2. If the effective air speed is 290 m/s above the wing and 240 m/s below the wings, what is the lift force on the jet due to Bernoulli's principle? ($\rho_{air} = .366\ kg/m^3$)

(26)

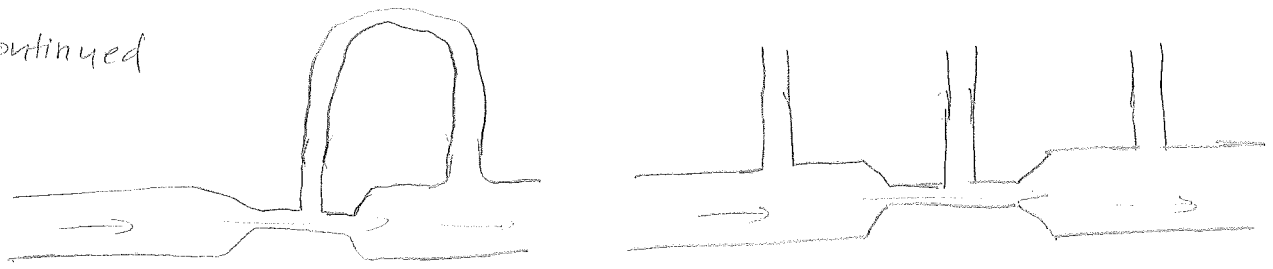


Venturi Meter: Measures flow speed.

1. Water level is higher on which side? 1 or 2

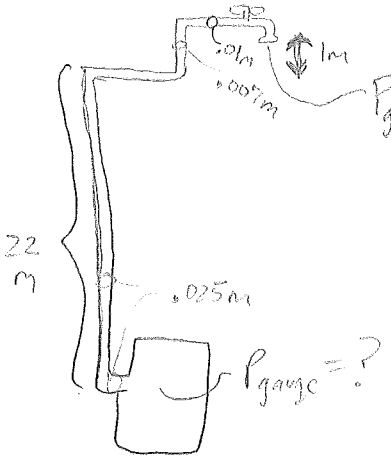
2. Suppose that the diameter of the pipe is .01 m. The diameter of the constricted is .005 m. The water column on the right side is .05 m taller than the left side. The density of this flowing air is 1.29 kg/m^3. Find the speed V_1.

(26) continued



Draw the appropriate water levels in the pipes above.

(27) What is to come out of the faucet at 2 m/s. What is P_{gauge} at (a) the pump (b) the faucet?



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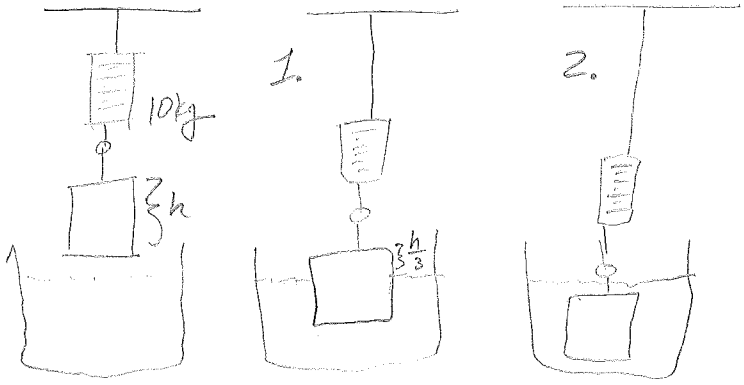


1 What is the buoyant force

A) 80N B) 60N C) 40N D) 20N

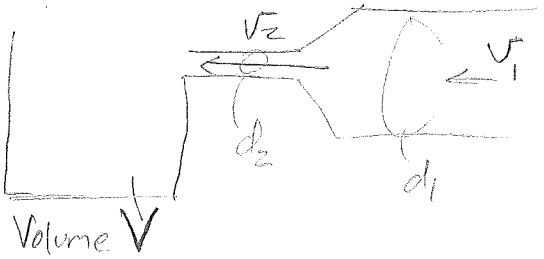
E) not enough information

2. What is the apparent mass?

A) 7kg B) 6kg C) $10/3$kg D) 4kg

E) none of the above

29



1. V_2 = A.) V_1 B.) $V_1 \cdot d_1/d_2$ C.) $V_1 d_2/d_1$

D.) $V_1 \cdot \frac{d_1^2}{d_2^2}$ E.) $V_1 \cdot d_2^2/d_1^2$

2. Time to fill volume V is:

a.) $4\pi V d_1^2 V_1$ b.) $\pi V d_1 V_1$ c.) $\frac{4V}{\pi d_1^2 V_1}$ d.) $\frac{V}{\pi d_1 V_1}$ e.) $\frac{\pi d_1 V_1}{V}$