Good morning!

No labs today

Please, login into webassing, locate LectureMCQ_L21 (PY105) and answer question 1 (but ONLY Q1!).

Pressure

$\vec{F}_{\text{no arrow}} \Rightarrow |\vec{F}| = F$

Magnitude!

$$P = \frac{F}{A} = \frac{F_{1m^2}}{1m^2}$$

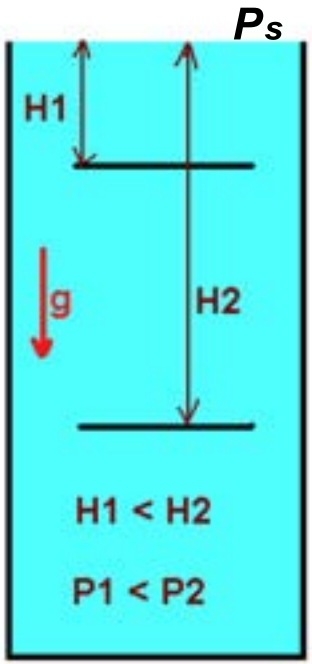
The SI unit is Pa

= “FROCE DISTRIOBUTION OVER AREA”

The SI unit Pa = N/m^2

Pressure in a medium

Static **fluid!**



The lower the level is (deeper in fluid), the more is the pressure provided by the fluid.

"The pressure at the bottom…"

The reason is the force of gravity acting on the liquid.

The top plate has less fluid above it then the bottom plate!

Which one?

or

$m = \rho V$

$V = Ah$

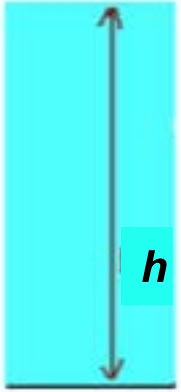
The amount of the fluid acting on the bottom plate.

The amount of the fluid acting on the top plate.

$$P = \frac{F_{mg}}{A}$$

$$P = \frac{mg}{A} = \frac{\rho V g}{A}$$

$$P = \frac{\rho A h g}{A} = \rho g h$$

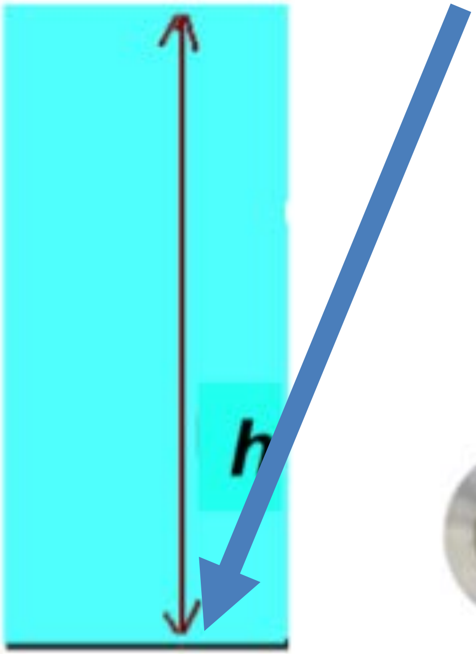


$P_{total} = P_{surface} + P_{gauge}$

Gauge pressure

Static **fluid!**

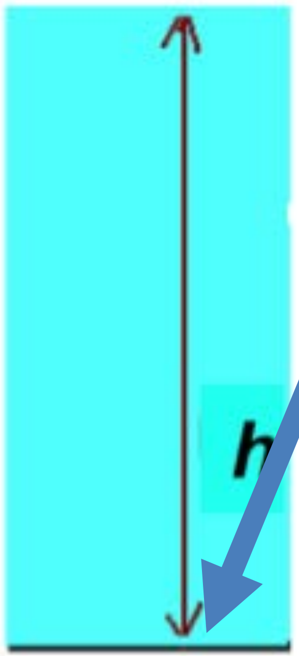
1. Pressure has ***no*** direction



$$P_G = \rho g h$$

Gauge pressure

Static fluid!



$$P_G = \rho g h$$

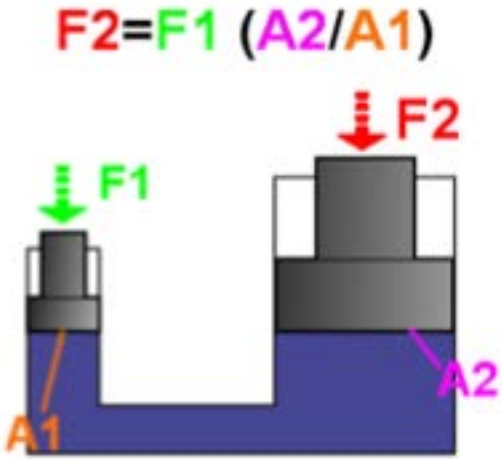
Gauge pressure

1. Pressure has *no* direction

2. Pascal's principle:

(https://en.wikipedia.org/wiki/Pascal's_law)

"A pressure change occurring anywhere in a confined incompressible fluid is transmitted throughout the fluid such that the same change occur everywhere".

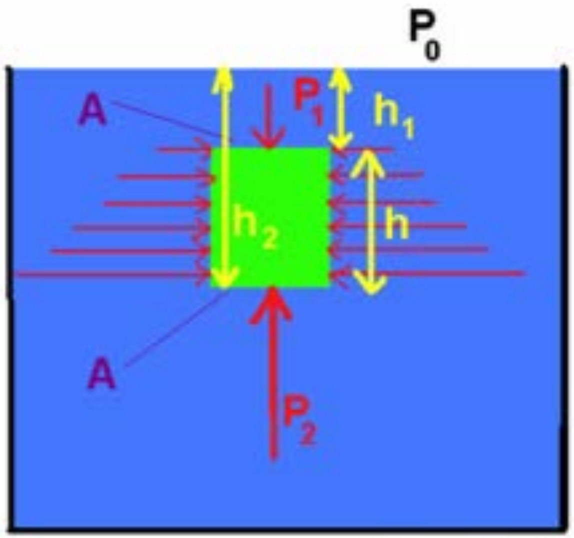


$$\frac{F_1}{A_1} = P_1 = P_2 = \frac{F_2}{A_2}$$

For curious people

The buoyant force (mathematically)

Buoyant force is the net force acting on an object due to pressure from a fluid



$$F_1 = P_1*A$$

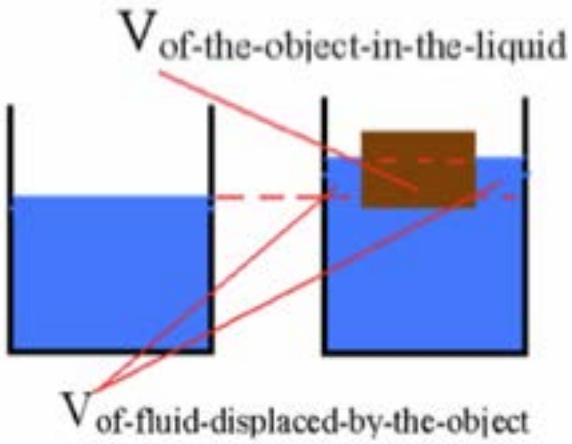
$$F_2 = P_2*A$$

The buoyant force

$$F_b = F_2 - F_1$$

Hence,

$$F_b = P_2*A - P_1*A = (P_2 - P_1)*A = \Delta P*A$$



$$\Delta P = P_2 - P_1 = (P_0 + \rho g h_2) - (P_0 + \rho g h_1) = \rho g(h_2 - h_1) = \rho g h$$

so

$$F_b = \rho g h*A$$

But $h*A = V_{of-the-object-in-the-liquid}$ and $\rho = \rho_{liquid}$

$$\mathbf{F_b = \rho_{liquid} g V_{of-the-object-in-the-liquid}}$$

Static **fluid (HYDROLIC EQUILIBRIUM)**

For WebA

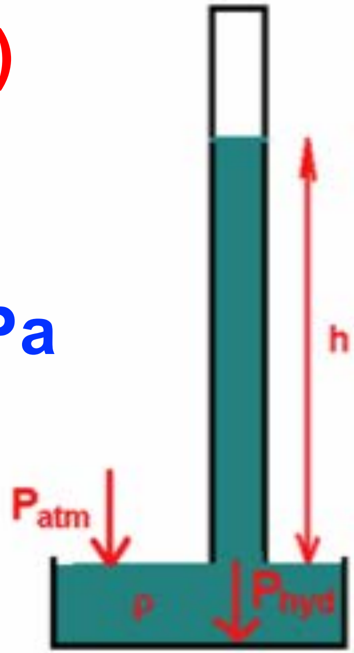
P_{atm} = 101.3 kPa

For us

$P_{atm} = 10^5$ Pa

Measuring Pressure

1643 Evangelista Torricelli



A standard mercury barometer to measure atmospheric pressure is a tube with one end sealed.

The sealed end is close to zero pressure, while the other end is open to the atmosphere. The pressure difference between the two ends of the tube can maintain a column of fluid in the tube, with the height of the column being proportional to the pressure difference.

$$P_{atm} = P_{hyd} = \rho g h$$

1 atm = 1.01×10^5 Pa = 14.7 lb/in^2 = 760 torr = 760 mm Hg

1 torr = 1 millimeter of mercury = 1 mm Hg

Atmospheric Pressure

Air is a fluid (a gas). At the sea level atmospheric pressure is about:

1 atm = 101300 Pa

Every square meter feels a force of over 100,000 N (the weight of 5 heavy trucks!) from the weight of all the air above it.

This is a huge force!

Atmospheric Pressure

Air is a fluid (a gas). At the sea level atmospheric pressure is about:

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Atmospheric Pressure

Webassign: L21 Q2

Air is a fluid (a gas). At the sea level atmospheric pressure is about:

1 atm = 101300 Pa

Every square meter feels a force of over 100,000 N from the weight of all the air above it.

This is a huge force, so why don't WE get collapsed from the force? Because …

1. we are also huge
2. we are smart
3. Trump protects all of us
4. None of the above
5. All of the above

Why don't WE collapse from the force?

Because …

Webassign: L21_Q2

Crush the Can

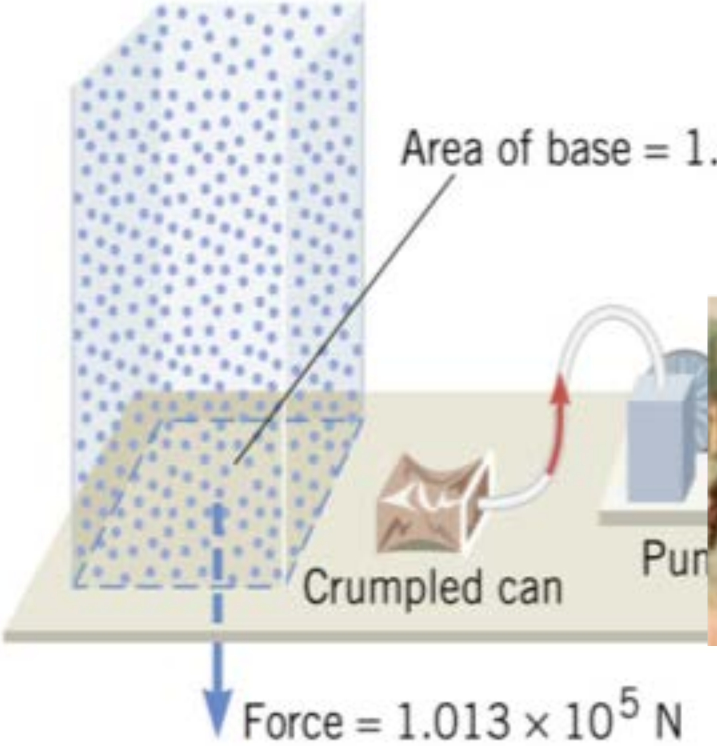
Otto von Guericke
Magdeburg's hemispheres
(1656)

1. we are also huge
2. 2. we are smart
3. Trump protects all of us
4. None of the above
5. All of the above

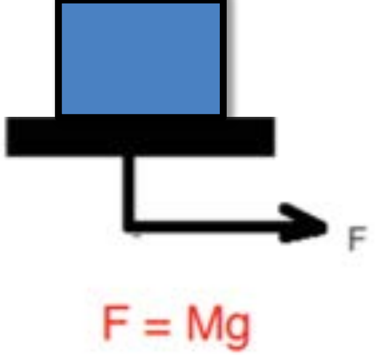
Atmospheric Pressure at Sea Level: 1.013x10^5 Pa = 1 atmosphere

https://www.youtube.com/watch?v=cD1e0BNNifk

Air cannon demonstration



Atmospheric Pressure



Air is a fluid (a gas). At the sea level atmospheric pressure is about: 1 atm = 101300 Pa ~ 10^5 Pa

Every square meter feels a force of over 100,000 N from the weight of all the air above it.

This is a huge force, so why don't things (including ourselves) collapse from the force?

We have holes!

“Total Recall”, 1990

Fluid Dynamics

Ideal Fluid

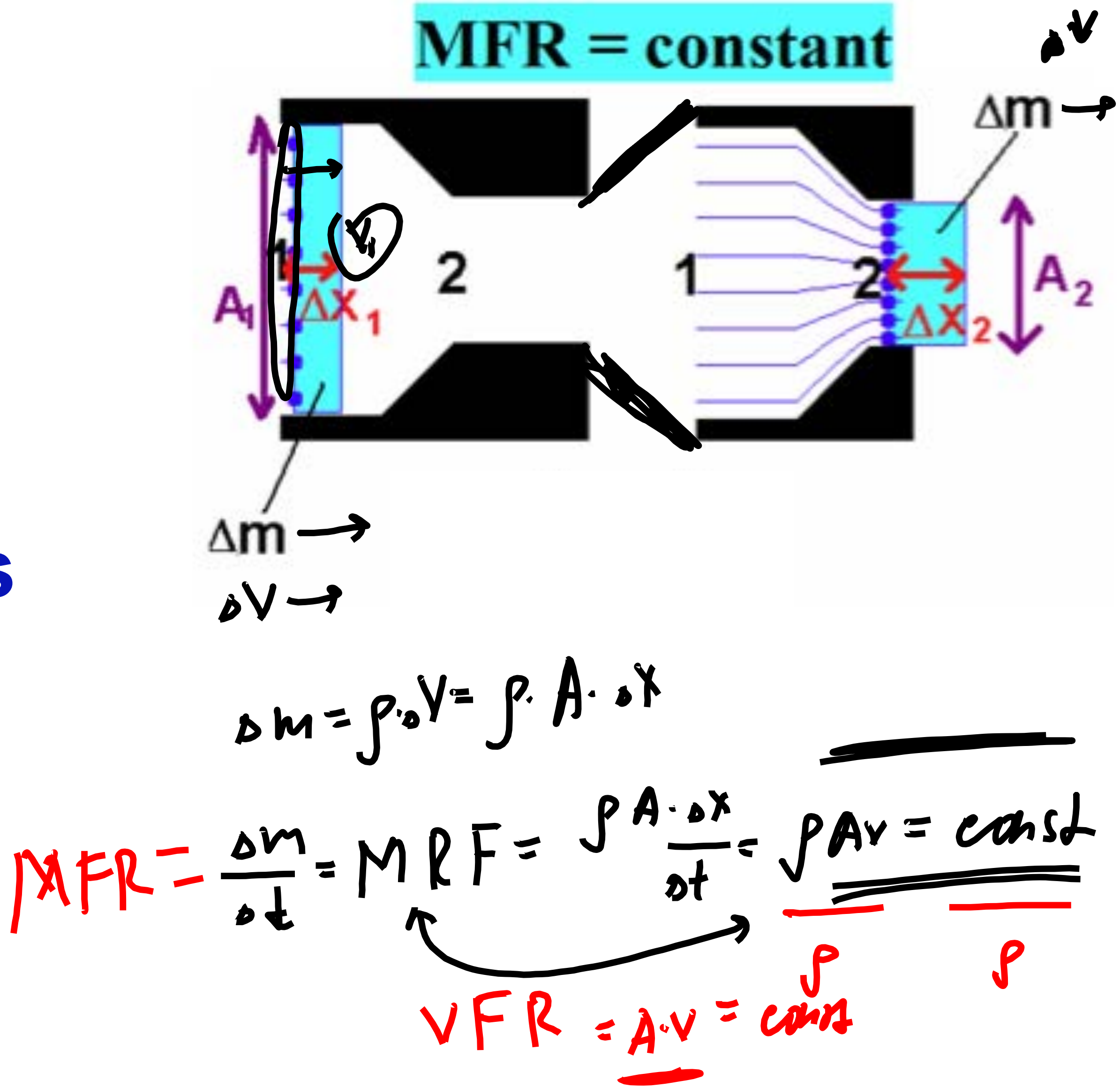
Fluid Dynamics deals with *moving* fluids.

An ideal fluid:

1. **Steady** – the velocity of the fluid at a point remains constant with respect to time.
2. **Laminar** - no turbulence, no disconnections in the current, the flow is smooth and uniform.
3. **Incompressible** - the density of the fluid does not change.
4. **Non-viscous (inviscid)** - no resistive force from objects or pipe walls.
5. **Irrotational** - the fluid won't make an object spin about its own axis.

An *ideal* fluid must travel **the same amount every second!**

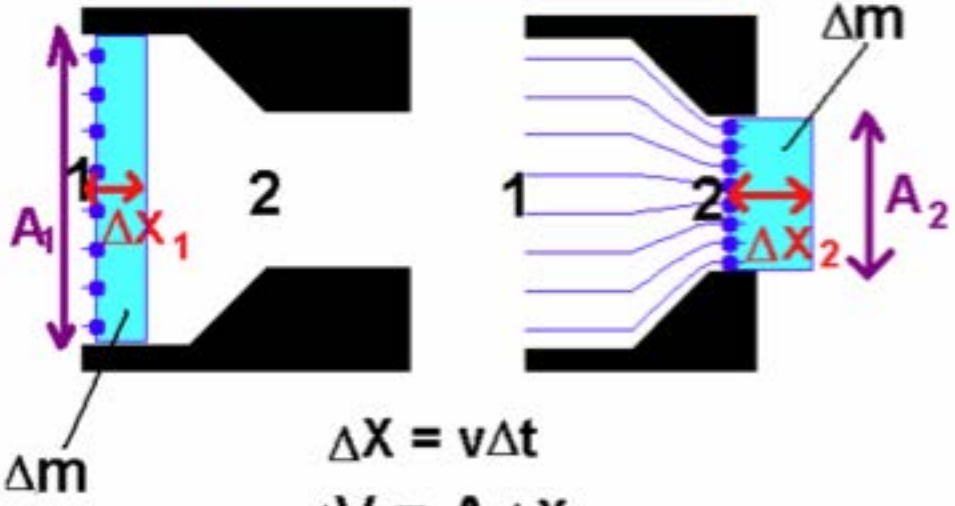
When a pipe gets ***narrower***, the flowing moves ***faster***! ("squeezing a hose")



An *ideal* fluid must travel <u>the same amount every second!</u>

When a pipe gets ***narrower***, the flowing moves ***faster***! ("squeezing a hose")

MFR = constant



$\Delta X = v\Delta t$

$\Delta V = A\,\Delta X$

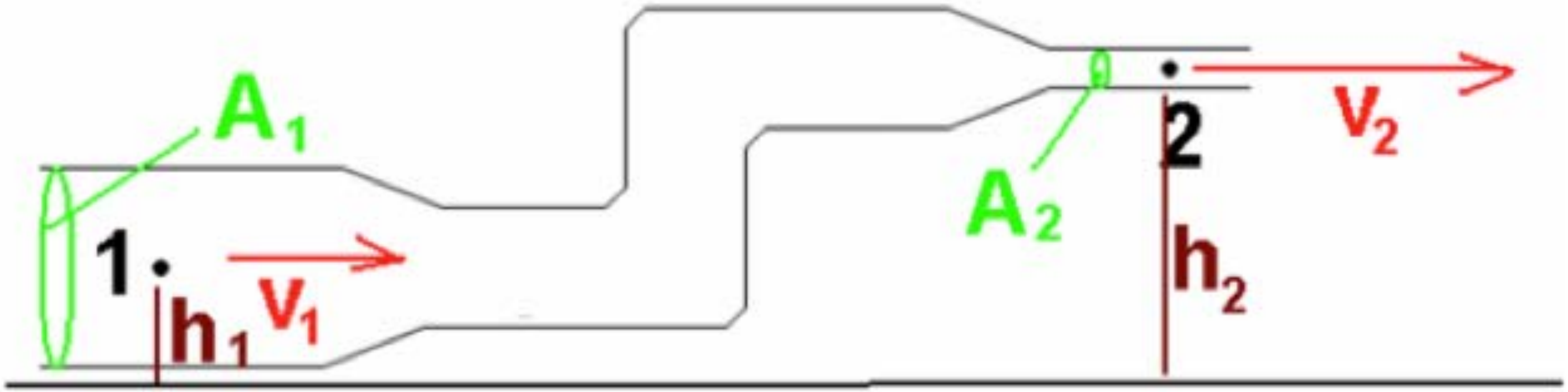
<u>At any point (1 or 2): if</u>

v is the velocity of the flow;

A is a cross-sectional area;

ρ is the density of the fluid:

$$\text{MFR (mass flow rate)} = \frac{\Delta m}{\Delta t} = \frac{\rho\,\Delta V}{\Delta t} = \frac{\rho A\,\Delta x}{\Delta t} = \rho A v$$



MFR = $\rho A v$ = constant or $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$

In *an incompressible fluid* the density is constant, $\rho_1 = \rho_2 = \rho$,

so

The continuity equation

VFR = Av = constant or $A_1 v_1 = A_2 v_2$ "LCAF"

An *ideal* fluid flows with NO friction!

+ Work done by ΔP

An *ideal* fluid flows with NO friction!

WKET

$$\frac{mv_2^2}{2} - \frac{mv_1^2}{2} = W_{NET}$$

Work – kinetic energy theorem applied to a 1m x 1m x 1m cube of fling fluid.

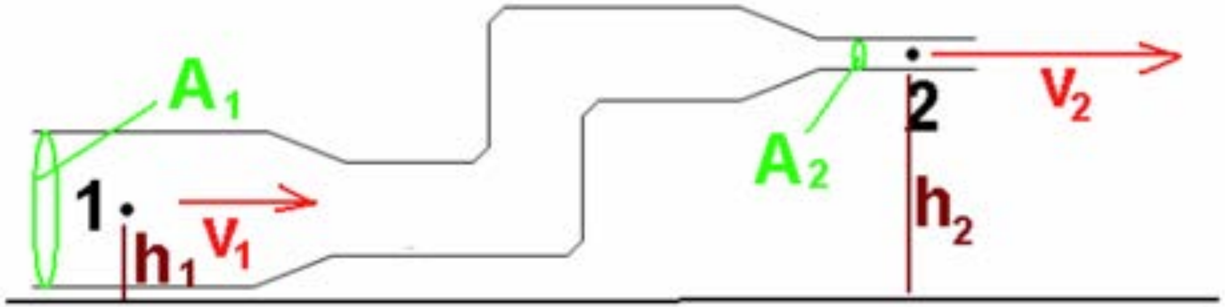
$$m_{1x1x1} = \text{density}$$

$$\frac{\rho v_2^2}{2} - \frac{\rho v_1^2}{2} = W_{pressure\ difference} + W_{gravity}$$

(no friction)

Bernoulli's equation:

(Law of Conservation of Energy!)



$$\tfrac{1}{2}\rho v_2^2 - \tfrac{1}{2}\rho v_1^2 = P_1 - P_2 + \rho g(y_1 - y_2)$$ WKET

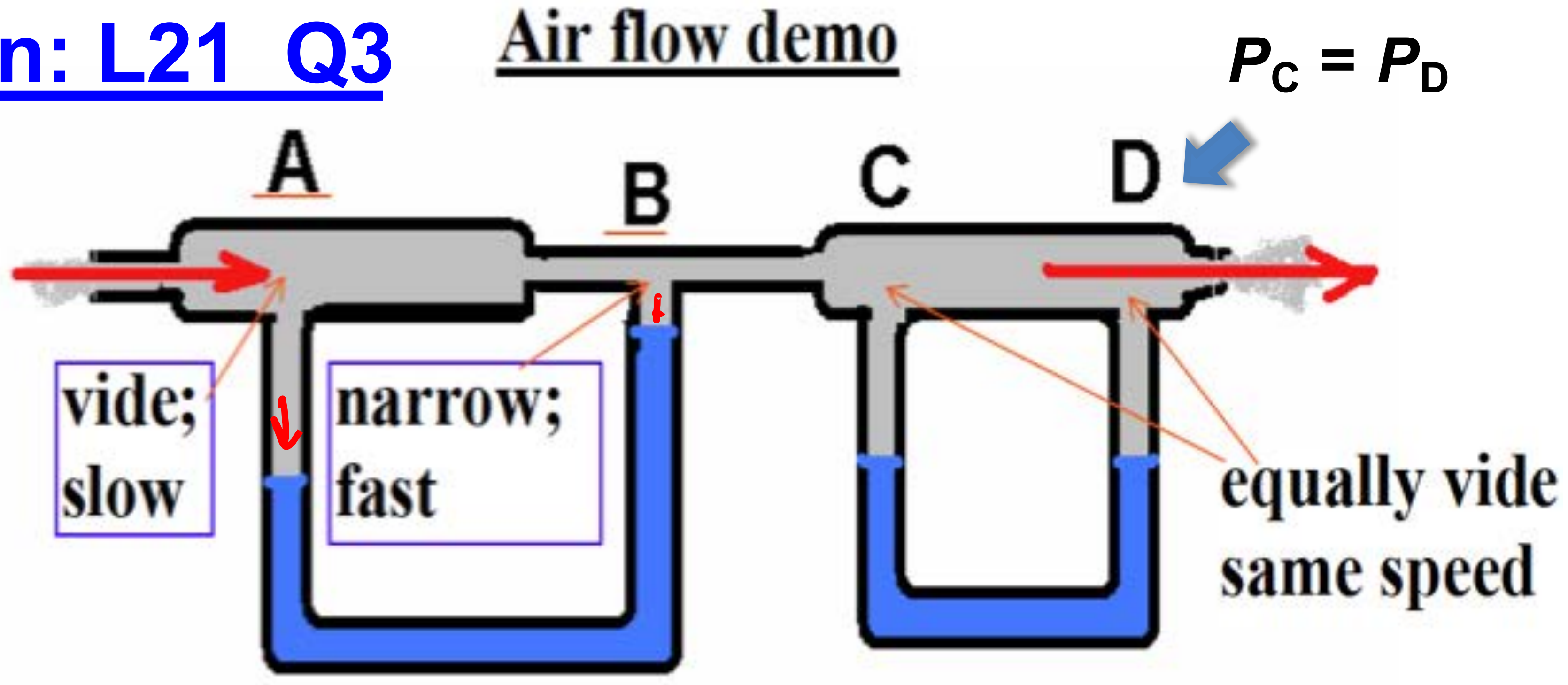
or

$$\rho g y_1 + \tfrac{1}{2}\rho v_1^2 + P_1 = \rho g y_2 + \tfrac{1}{2}\rho v_2^2 + P_2$$ LCME

and do not forget the Continuity Equation

$$A_1 v_1 = A_2 v_2$$ "LCAF"

Webassign: L21 Q3

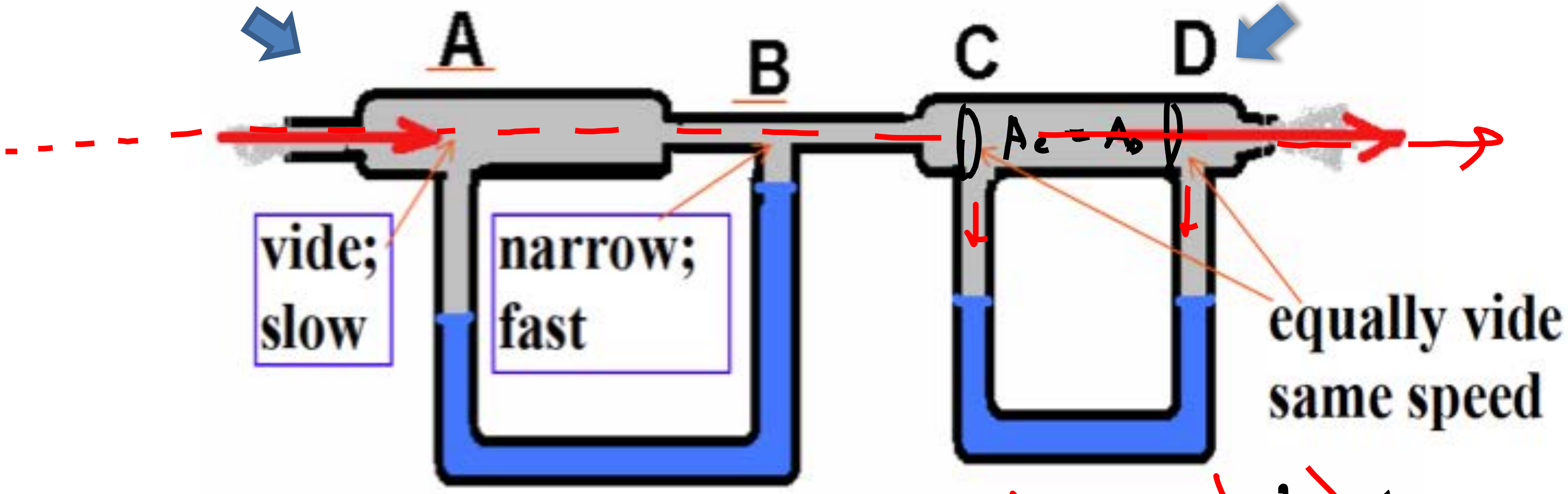


1. $P_A < P_B$
2. $P_A = P_B$
3. $P_A > P_B$

3. $P_A > P_B$

Air flow demo

$P_C = P_D$



Proving: $P_C = P_D$

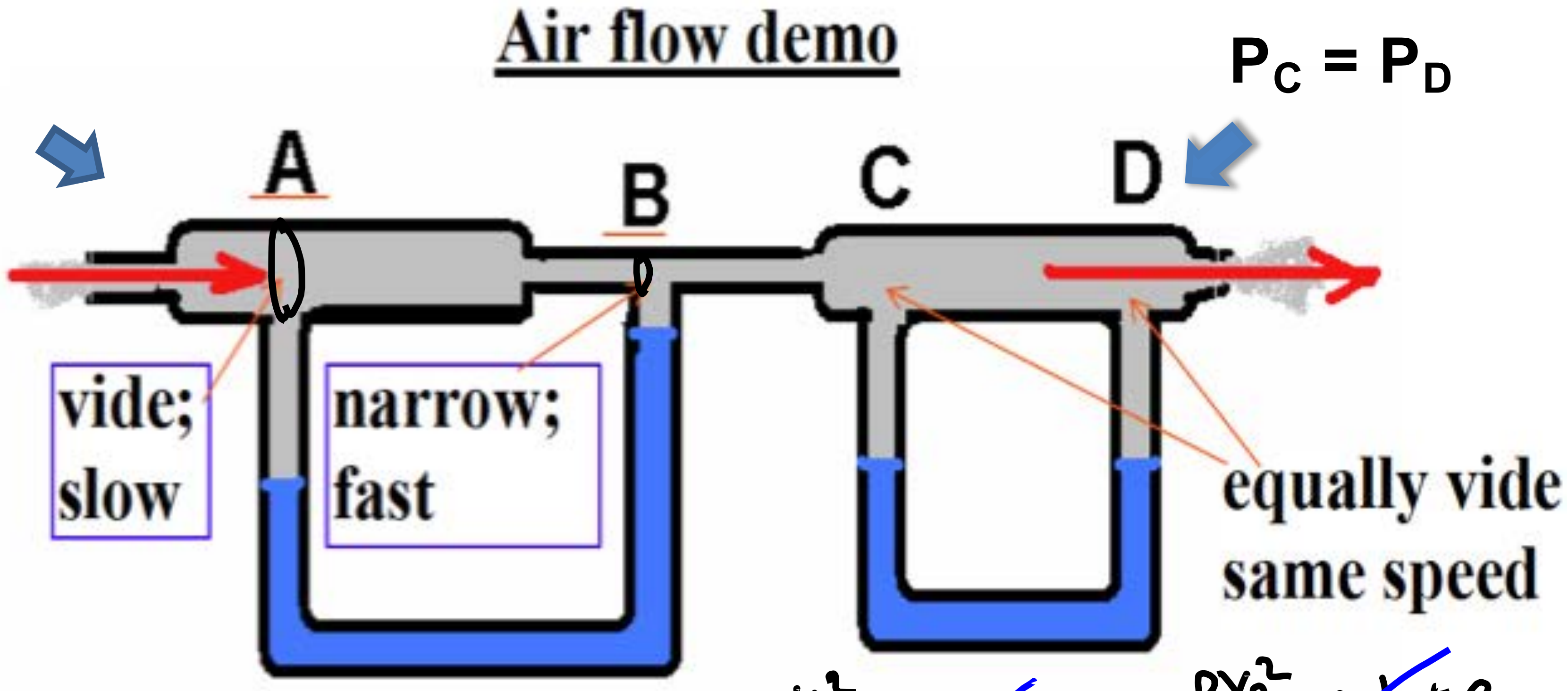
$A_1 V_1 = A_2 V_2$; $\frac{\rho v_1^2}{2} + \rho g h_1 + P_1 = \frac{\rho v_2^2}{2} + \rho g h_2 + P_2$

$A_c V_c = A_D V_D$

$V_c = V_D$

$P_1 = P_2$

3. $P_A > P_B$



Proving: $P_A > P_B$

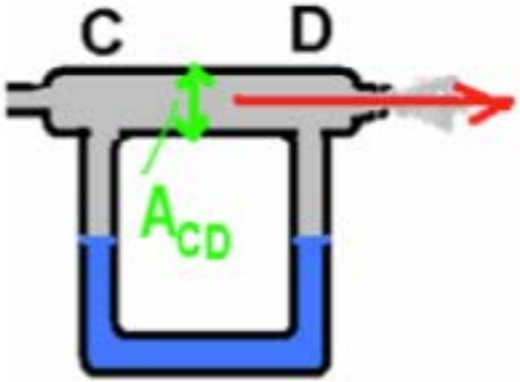
$A_A V_A = A_B V_B$; $\rho \frac{V_A^2}{2} + \rho g h_A + P_A = \rho \frac{V_B^2}{2} + \rho g h_B + P_B$

$A_A \gtreqless A_B$

$V_A \gtreqless V_B$; $\frac{V_B}{V_A} = \frac{A_A}{A_B} > 1 \Rightarrow V_B > V_A$

$P_A - P_B = \frac{\rho}{2}(V_B^2 - V_A^2) > 0$

$P_A - P_B \gtreqless 0$

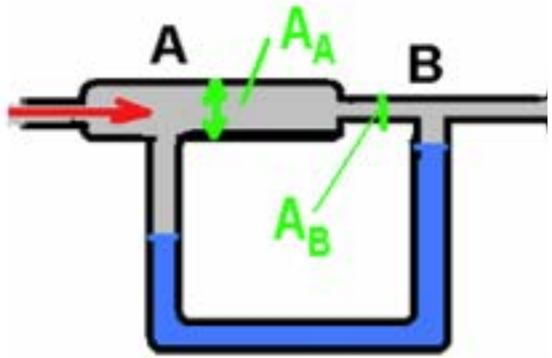


$$A_1 v_1 = A_2 v_2$$

$$\rho g y_1 + \tfrac{1}{2}\rho v_1^2 + P_1 = \rho g y_2 + \tfrac{1}{2}\rho v_2^2 + P_2$$

For the points C and D: the level is the same, the area is the same (hence the speed is the same); and the result

$$P_C = P_D$$



$$A_1 v_1 = A_2 v_2$$

$$\rho g y_1 + \tfrac{1}{2}\rho v_1^2 + P_1 = \rho g y_2 + \tfrac{1}{2}\rho v_2^2 + P_2$$

When the height is the same => Faster flow => lower pressure!

For the points A and B: the level is the same, but the area is different (hence the speed is different);

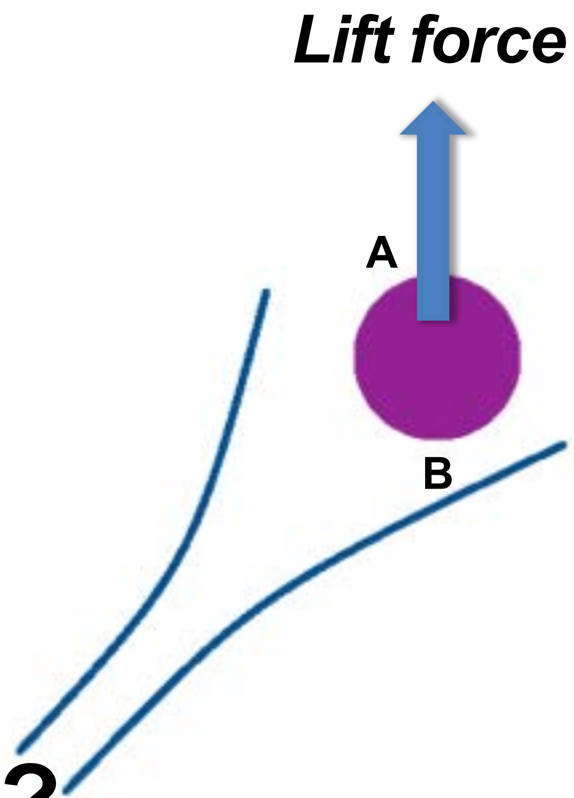
$A_A > A_B$ => $v_A < v_B$ and the result

$P_A > P_B$

Faster flow => lower pressure!

$v_A > v_B$

$P_A < P_B$



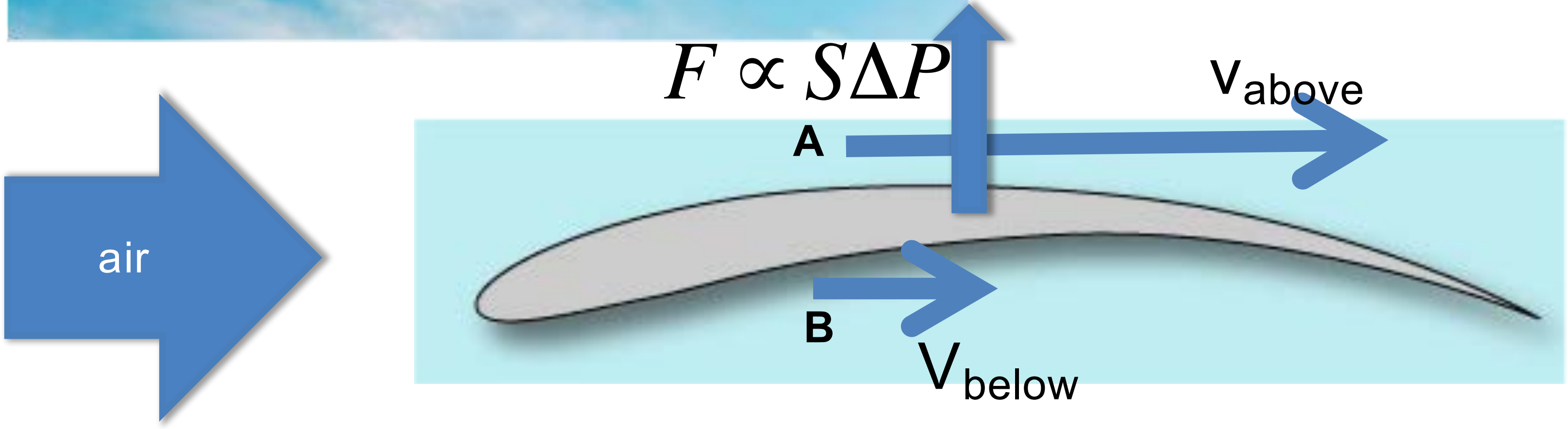
Practical applications?

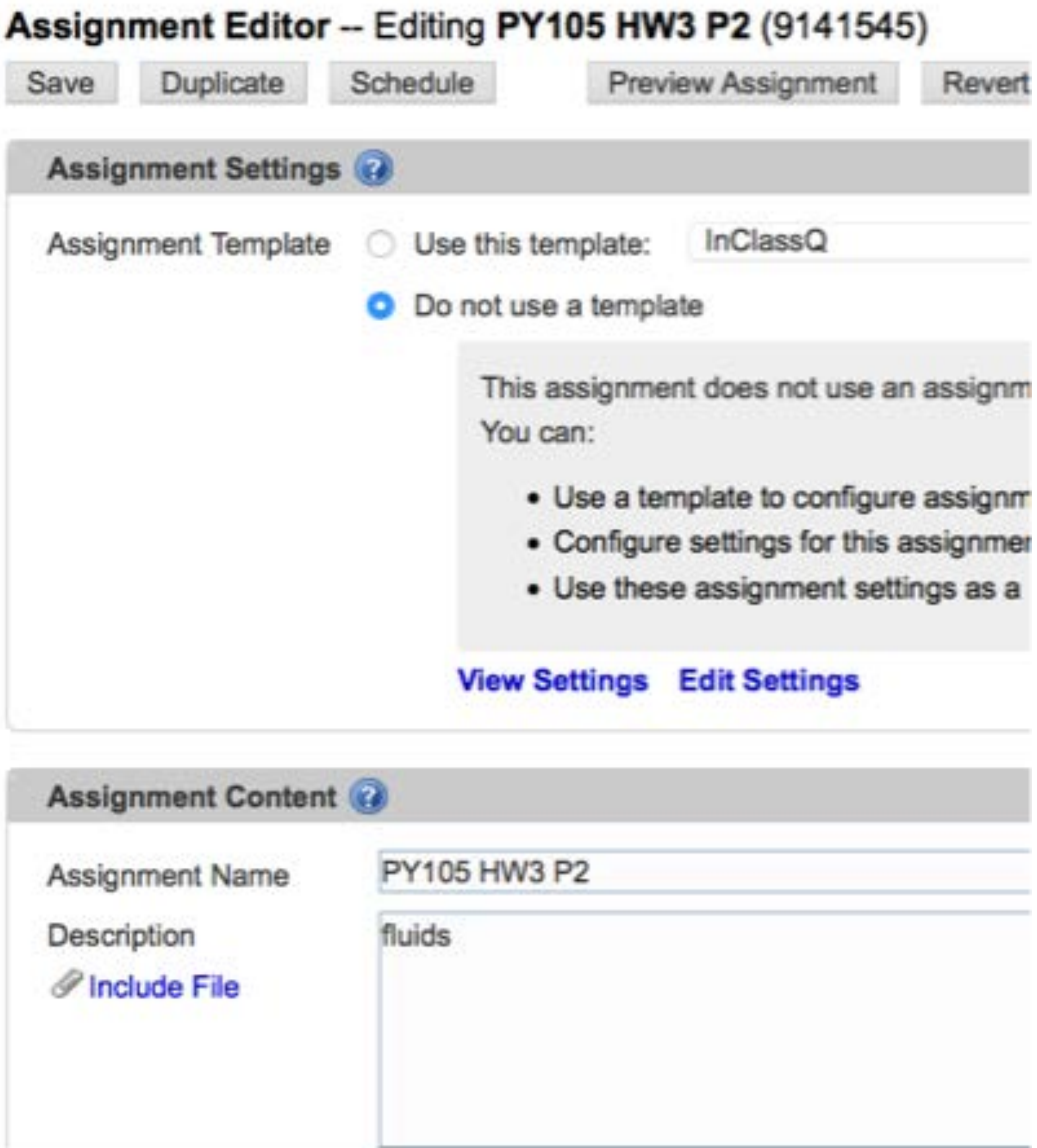
Practical applications!

$$v_A > v_B$$

$$P_A < P_B$$

$$F \propto S\Delta P$$





Ready to finish HW3P2

(theoretically)!

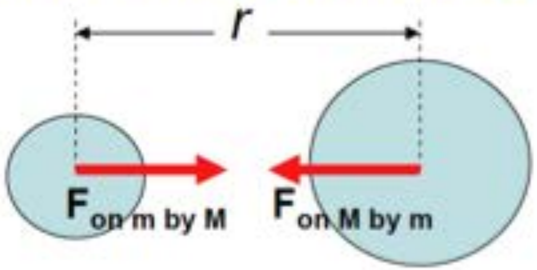
Gravity

(theory)

Newton's Law of Universal Gravitation

$$W_{gravity} = U_i - U_f$$

Two objects of mass *m* and *M*,
with their centers of mass
separated by a distance *r*,
exert attractive forces on one another.
(Equal magnitude but opposite direction, by Newton's Third Law)



The *EXACT* expression for GPE

The magnitude of this gravitational force is given by:

NLG $$|F_g| = \frac{GmM}{r^2} \quad \text{or} \quad |F_G| = G\frac{m_1 m_2}{r^2}$$

$$U_G = -G\frac{m_1 m_2}{r}$$

where G is the universal gravitational constant:

$$G = 6.67 \times 10^{-11}\ \text{N m}^2/\text{kg}^2$$

Problems on attraction => N2L, NLG, FBD

Circular Orbits

- Orbit radius r = Planet radius R + height h above

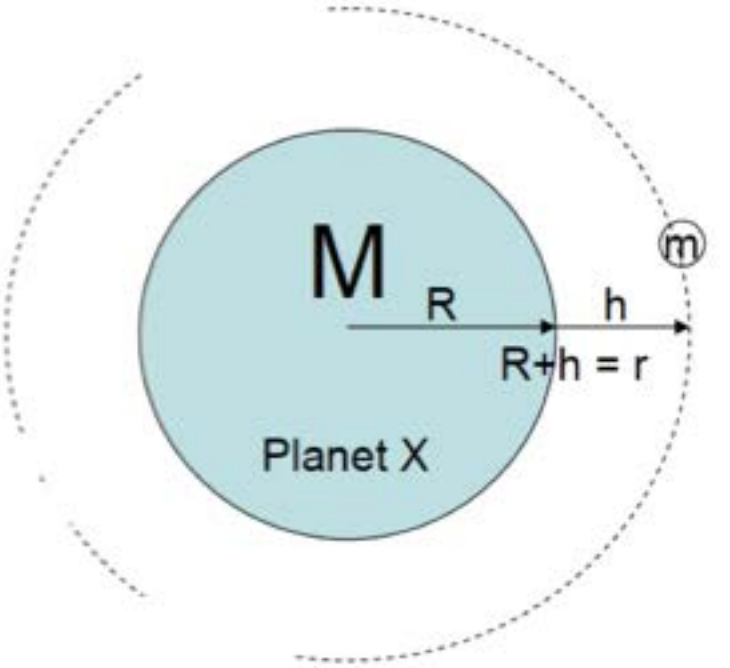
Newton's Second Law

+

Newton's Law of Gravity

+

Circular Motion



Circular Orbits

- Orbit radius r = Planet radius R + height h above

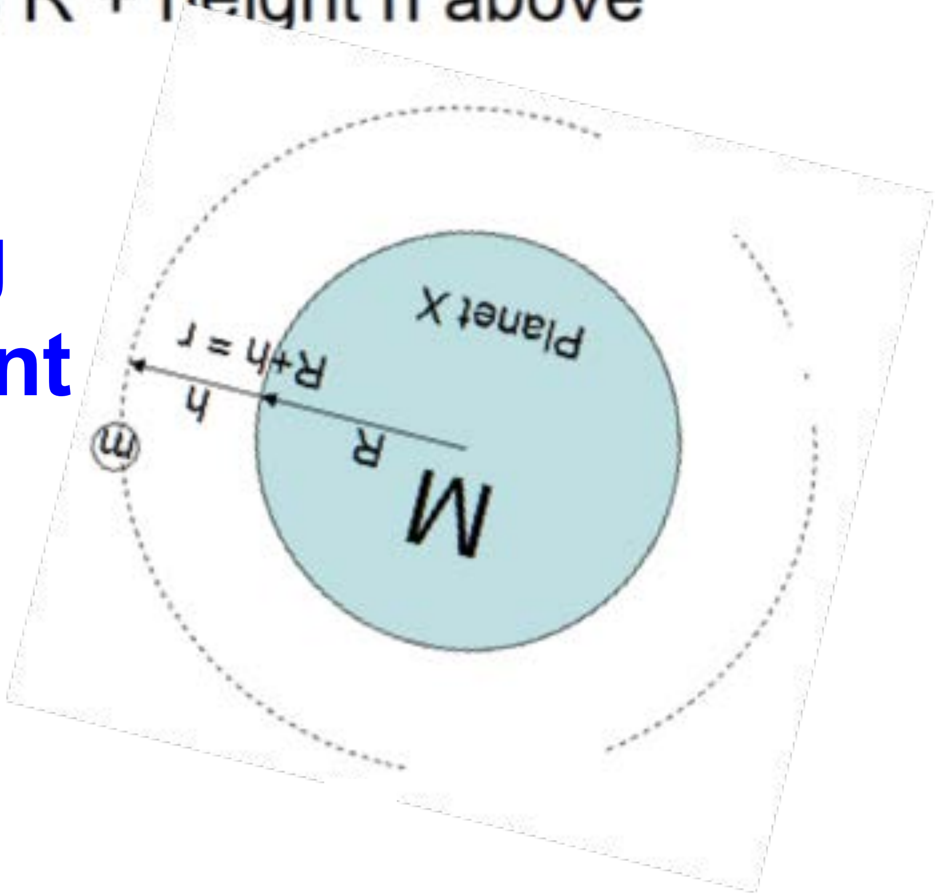
Webassign: L21_Q4

For a small satellite orbiting a large planet with a constant speed, the acceleration at the shown instant points:

1. Up **2. Down**

3. Left **4. Right**

5. Away from the planet



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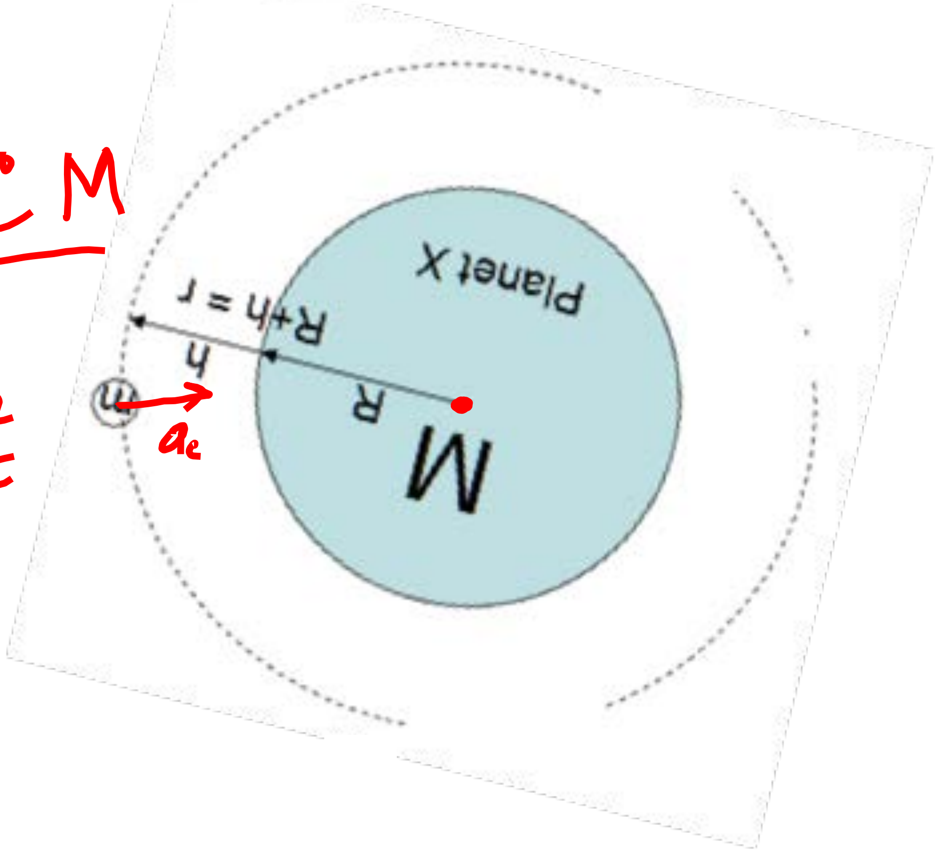
UCM

$$a = a_c = \frac{v^2}{r}$$



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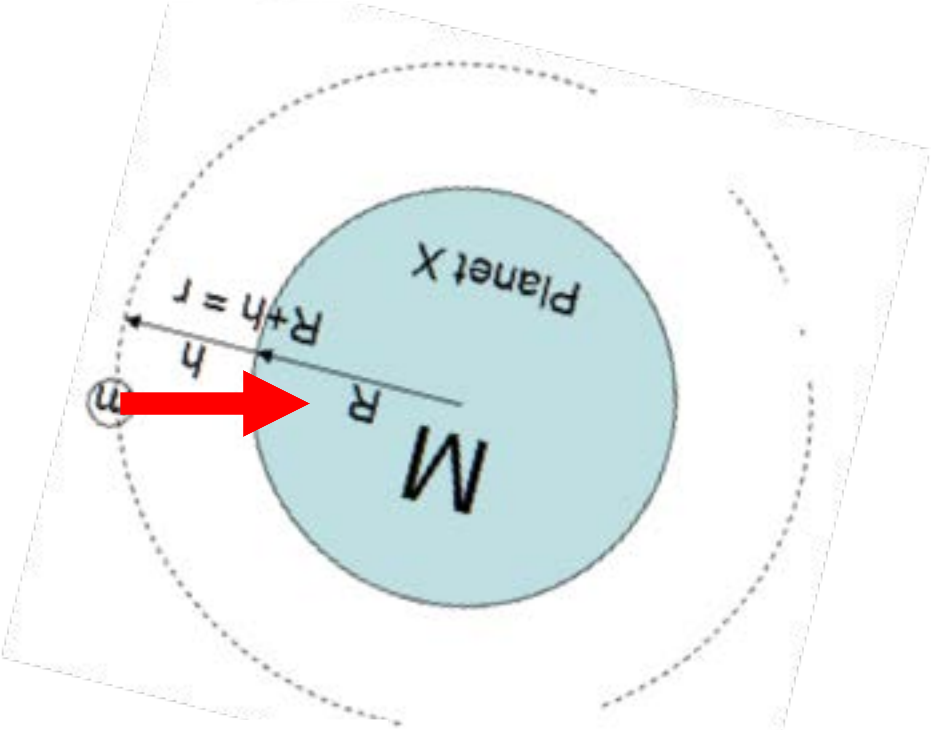


$$a = a_C = V^2/(R+h)$$

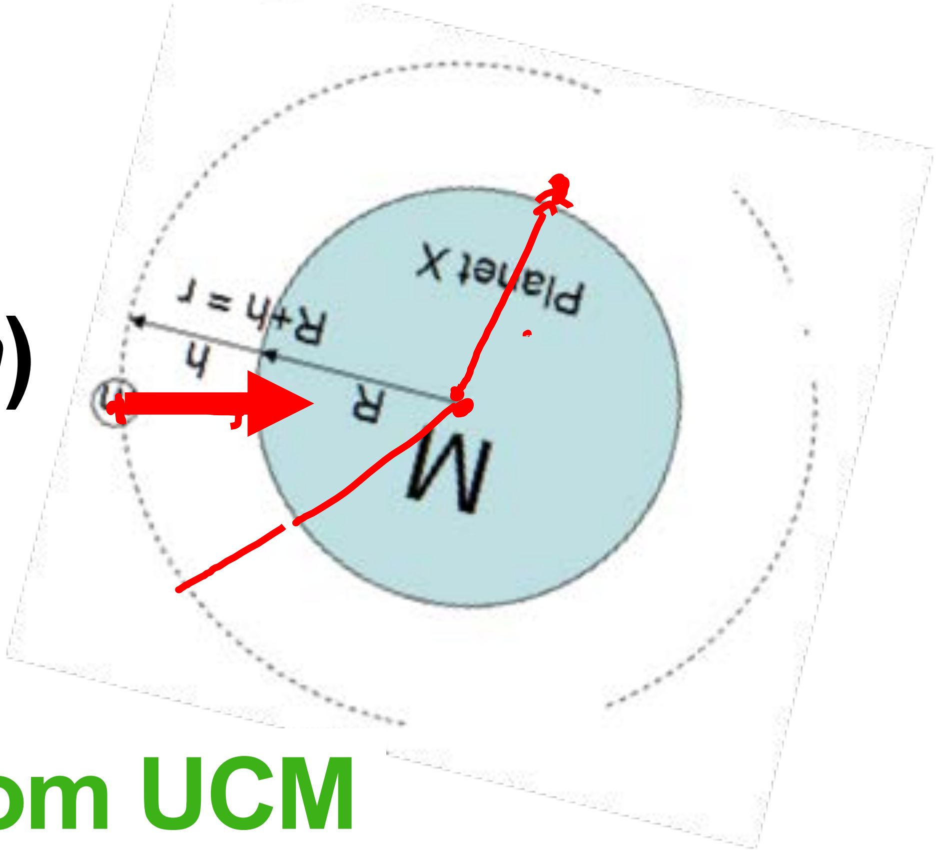
Circular Orbits

- Orbit radius r = Planet radius R + height h above

$$F_G = G\frac{m_1 m_2}{r^2} = G\frac{mM}{(R+h)^2} = ma$$

N2L

$$a = a_C = V^2/(R+h)$$



+ Anything else from UCM

PY105 HW3 P3 (10429150)

Previewer Tools

Show New Randomization   Open in Editor   Print

Show: All, None   ☑ Assignment Score ☑ Key ☑ Solution ☑ Help/Hints ☑ Mark ☐ Answer Format Tips

Current Score: 0/9   **Due:** Thu Jun 29 2017 11:00 PM EDT

Question	1	2	3	4	5	6	Total
Points	0/2	0/1	0/2	0/2	0/1	0/1	0/9

HW3 P3 Pr. 1 - 4

Description

gravity, temperature, heat, heating, thermal equilibrium

Instructions

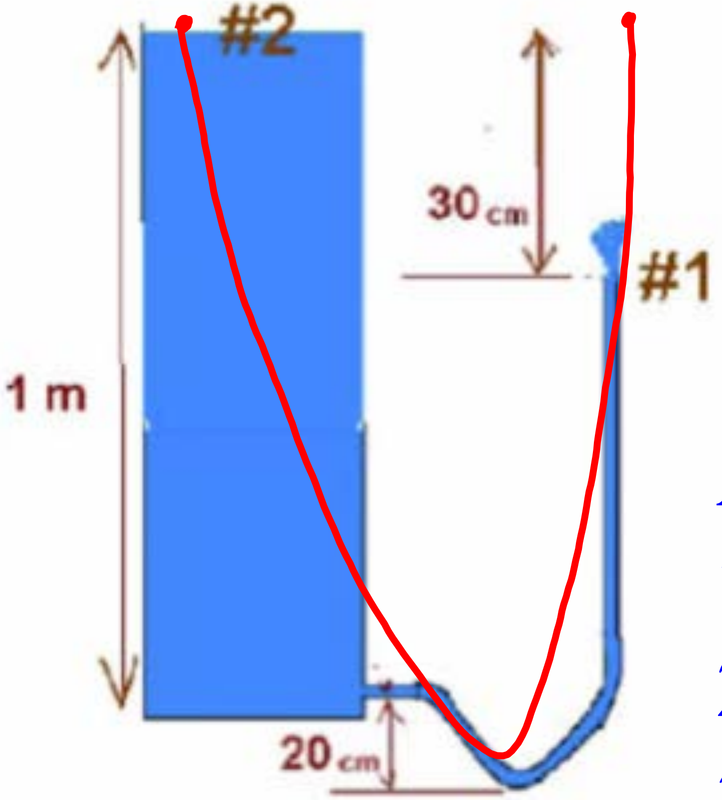
note: in pr. 2 expression 1/360 g (or similar) means 9.81*(1/360) m/s^2

1. 0/2 points   OSColPhys2016 6.5

Two spheres A and B are placed in the arrangement shown below.

(a) If m_A = 3m and m_B = 9m, where on the dashed line should a third sphere C of mass 9m be pla
net force on it is zero?

Solving problems on fluid dynamics and gravity



Building a fountain

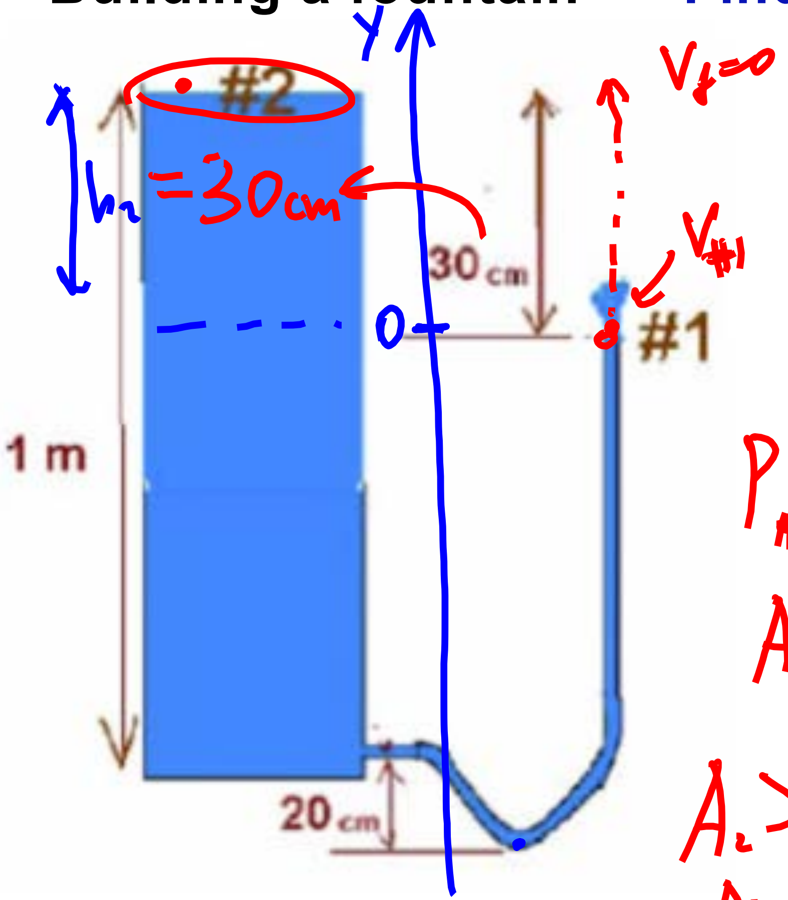
Find the speed of water leaving the hose at point 1.

Webassign: L21_Q5

After leaving point 1, the water …

1. **Immediately stopes**
2. **Travels up for about 30 cm**
3. **Travels up for about 60 cm**

Building a fountain



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Webassign: L21_Q5

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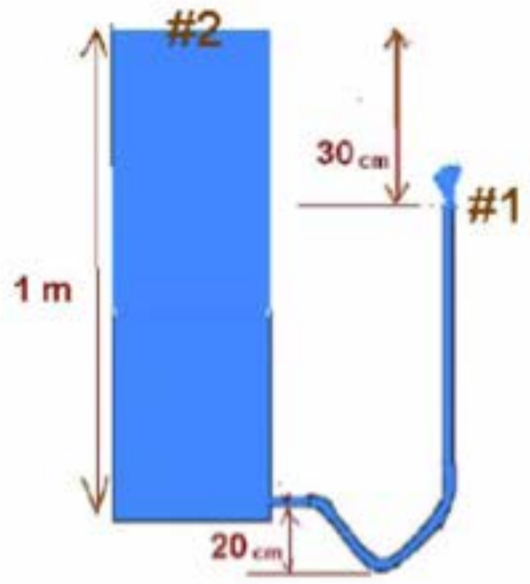


A big and very wide tank full of water has a hose attached to it.

What is the speed of the water when it leaves the hose?

Use the Bernoulli's equation.

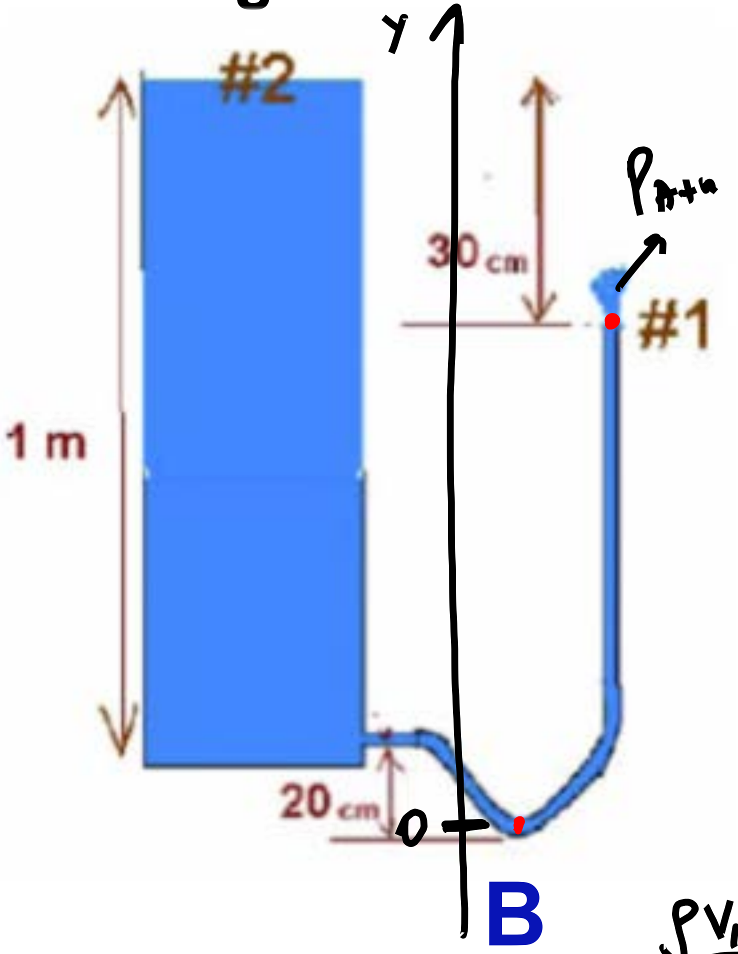
$$\rho g y_1 + \tfrac{1}{2}\rho v_1^2 + P_1 = \rho g y_2 + \tfrac{1}{2}\rho v_2^2 + P_2$$

Notice that the points # 1 and # 2 are open to the atmosphere.

$y_1 = 0$ $y_2 = 0.3$ m $v_2 \cong 0$ (since area A_2 is huge!)

$P_1 = P_2 = P_{atm}$ (since the surface is open to the atmosphere

Building a fountain



Webassign: L21_Q6

The speed of water at point B is …

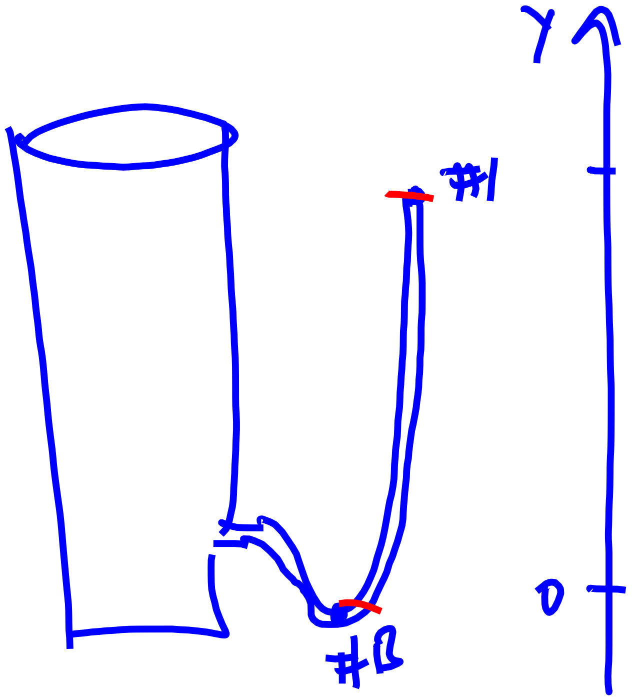
1. Greater than at point 1
2. The same as at point 1
3. Lower than at point 1.

$$A_1 V_1 = A_2 V_2 \Rightarrow A_1 \cdot V_1 = A_B \cdot V_B$$

$$A_1 = A_B$$

$$V_1 = V_B$$

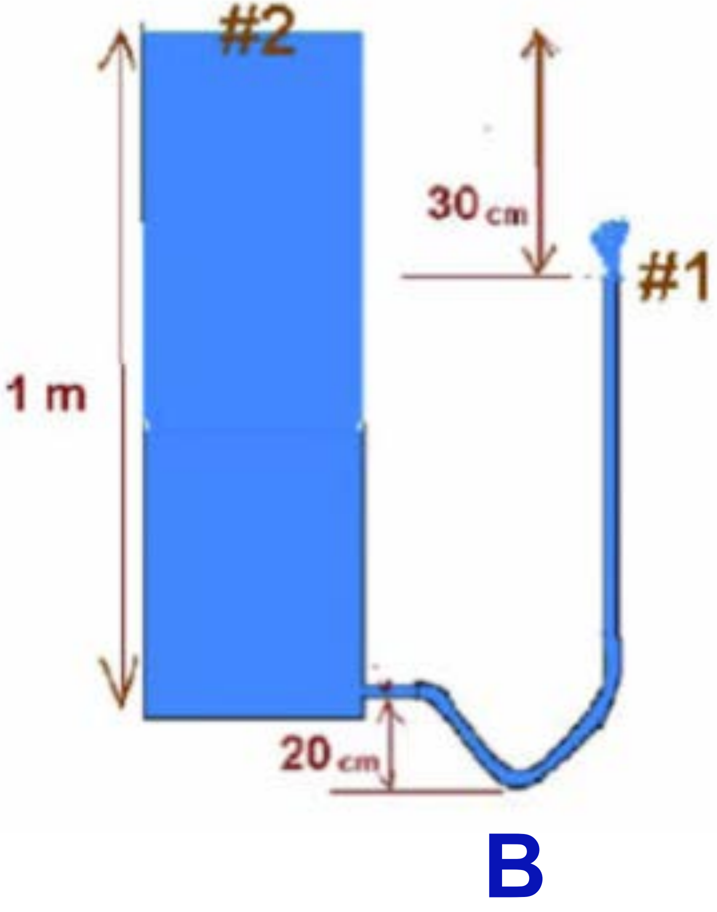
$$\rho \frac{v_1^2}{2} + \rho g h_1 + P_1 = \rho \frac{v_2^2}{2} + \rho g h_2 + P_2$$



$v_1 \approx v_B$

$$\frac{\rho v_1^2}{2} + \rho g h_1 + P_{Atm} = \frac{\rho v_B^2}{2} + \rho g \phi + P_B$$

$$P_B = P_{Atm} + \rho g h$$



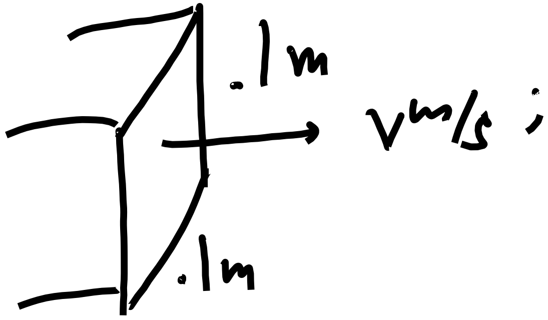
Building a fountain

Webassign: L21_Q4

Since the tube has the same area at both points,
the speed of water at point B is …

1. Greater than at point 1
2. The same as at point 1
3. Lower than at point 1.

Water travels through a rectangular pipe with a 10 cm by 10 cm cross-section. The speed of the flaw is 2 m/s. Calculate MFR.



$$MFR = \frac{\Delta m}{\Delta t} = \rho\, v \cdot A =$$

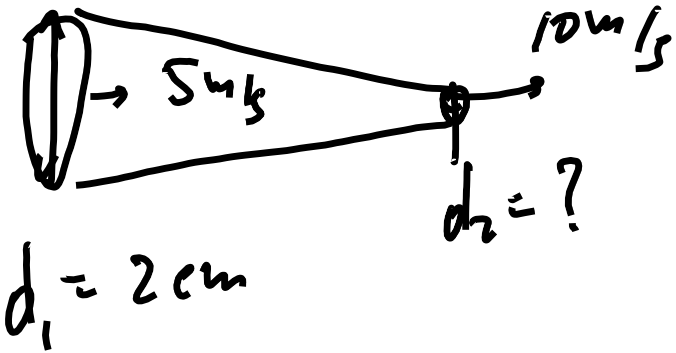
$$= 1000 \cdot 2 \cdot 0.1 \cdot 0.1 = 20\ \frac{kg}{s}$$

$$\Delta m = MFR \cdot \Delta t = 20 \cdot 3600 = 72\,000\ kg$$

($\Delta t \rightarrow 1h$)

Water is moving through a hose with a speed of 5 m/s. The internal diameter of the hose is 2 cm. (a) If you attach a nozzle, the velocity of water leaving it increases to 10 m/s. Find the diameter of the nozzle. (b) If instead you attach a shower head with 30 small holes 5 mm in diameter each, find the velocity of water leaving the head.

Water is moving through a hose with a speed of 5 m/s. The internal diameter of the hose is 2 cm. (a) If you attach a nozzle, the velocity of water leaving it increases to 10 m/s. Find the diameter of the nozzle. (b) If instead you attach a shower head with 30 small holes 5 mm in diameter each, find the velocity of water leaving the head.

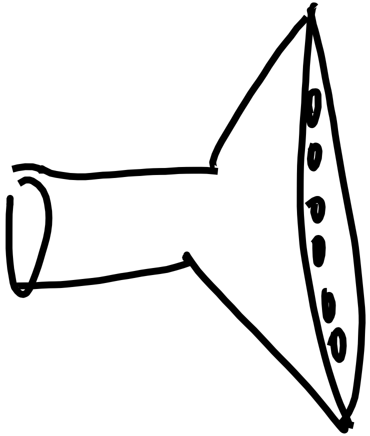


$$A_1 V_1 = A_2 V_2$$

$$\pi \left(\frac{d_1}{2}\right)^2 \cdot V_1 = \pi \left(\frac{d_2}{2}\right)^2 \cdot V_2$$

$$d_2^2 = d_1^2 \cdot \frac{V_1}{V_2} \Rightarrow d_2 = \sqrt{d_1^2 \frac{V_1}{V_2}} \Rightarrow$$

$$d_2 = d_1 \cdot \sqrt{\frac{V_1}{V_2}} = 2\,\text{cm} \cdot \sqrt{\frac{5}{10}} = \frac{2}{\sqrt{2}}\,\text{cm}$$



MFR = const; VFR = const

$$A_1 V_1 = A_2 V_2$$

↓

$$A_2 = A_{hole} \cdot N$$

$$A_1 \cdot V_1 = A_{hole} \cdot N \cdot V_2$$

$$V_2 = \frac{A_1 \cdot V_1}{A_{hole} \cdot N}$$

A big horizontal pipe 40 cm in diameter lies on the ground and is being used to fill up a large tank with water. For reaching the tank the pipe goes 20 m up to the brink of the tank, becomes horizontal again, and widens to 80 cm in diameter. If the pressure on the ground is 2 Atm, and the pressure at the top is 6 kPa, calculate VFR, MFR.

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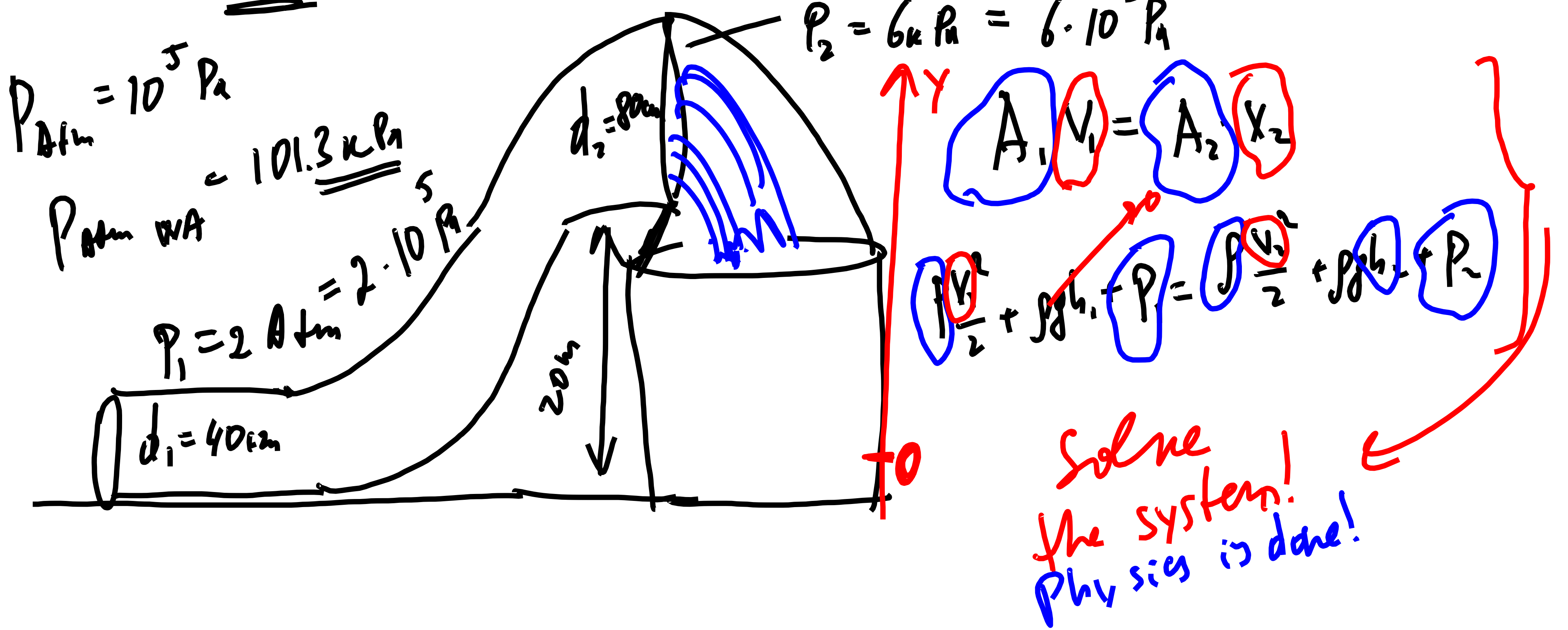
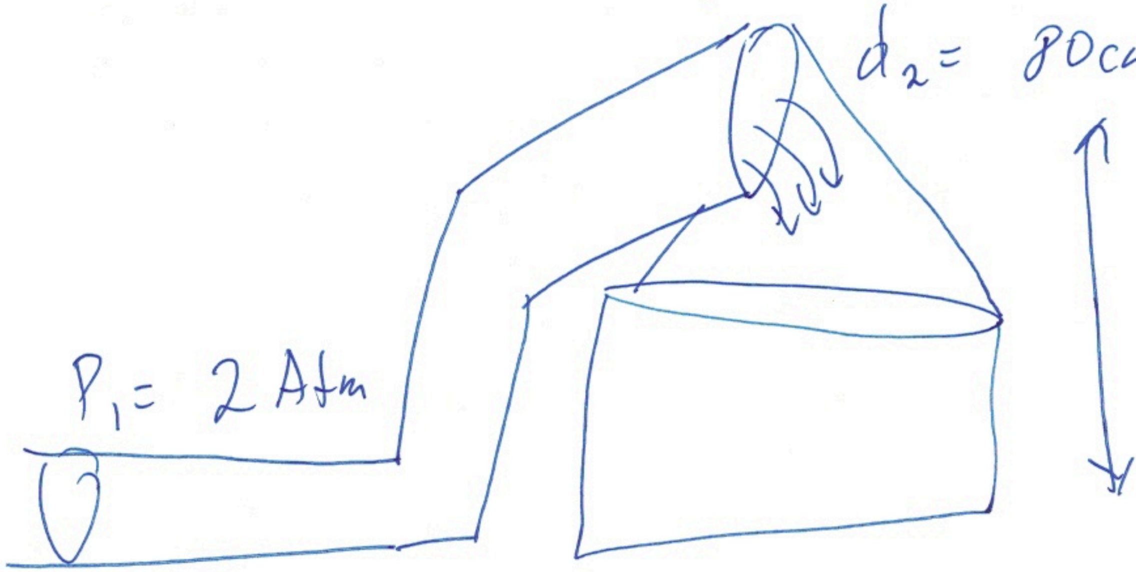


-1-



$A_1 V_1 = A_2 V_2$; $\pi \left(\frac{40cm}{2}\right)^2 \cdot V_1 = \pi \left(\frac{80cm}{2}\right)^2 \cdot V_2$

$\Rightarrow V_1 = \left(\frac{80cm}{40cm}\right)^2 \cdot V_2 \Rightarrow V_1 = 4 \cdot V_2$

$P_1 = 2 \cdot 10^5 \, Pa$ $P_2 = 6 \cdot 10^3 \, Pa$

$$\rho\frac{V_1^2}{2} + \rho g h_1 + P_1 = \rho\frac{V_2^2}{2} + \rho g h_2 + P_2$$

$$h_1 = 0 \Rightarrow h_2 = 20m$$

$$\frac{1000 \cdot (4 \cdot V_2)^2}{2} + \phi + 2 \cdot 10^5 = \frac{1000 \cdot V_2^2}{2} + 1000 \cdot 10 \cdot 20 + 6 \cdot 10^3$$

$\div 10^3$ (or $\div 1000$)

$\Downarrow$

$$8 V_2^2 + 200 = \frac{1}{2} V_2^2 + 200 + 6$$

$$7,5 V_2^2 = 6$$

$$V_2 = \sqrt{\frac{6}{7.5}} \approx 0.89 \ m/s$$

$$V_1 = 3,56 \ m/s$$

VFR: $VFR = A \cdot V = A_1 \cdot V_1 =$

$$= \pi (0.2)^2 \cdot 3.56 = 0.447 \frac{m^3}{s}$$

or

$$VFR = A_2 \cdot V_2 = \pi (0.4)^2 \cdot 0.89 = 0.447 \frac{m^3}{s}$$

the same!

$$MFR = \rho \cdot VFR = 1000 \cdot 0.447 = 447 \frac{kg}{m^3} \cdot \frac{m^3}{s} = 447 \frac{kg}{s}$$