The Final Exam Schedule is Now Final!

PHYS 1020: Monday, December 17, 6 - 9 pm
Frank Kennedy Brown & Gold Gyms
The whole course
30 multiple choice questions
Formula sheet provided

Seating (from exam listing on Aurora)

Brown Gym

A - SIM

Gold Gym

SIN - Z

GENERAL PHYSICS I: PHYS 1020

Schedule - Fall 2007
(lecture schedule is approximate)

11	M	12	**Remembrance Day**			Experiment 4: Centripetal Force
	W	14	28	Chapter 11 exclude 11.11	Fluids	
	F	16	29			
12	M	19	30	Chapter 12 sections 1 - 8	Temperature and heat (some small sections, notably thermal stress will be omitted)	Tutorial and Test 4 (chapters 8, 9, 10)
	W	21	31			
	F	23	32			
13	M	26	33	Chapter 13	Transfer of Heat -- Self study only. **Required for last lab.** This chapter **IS** examinable on the final.	Experiment 5: Thermal Conductivity of an Insulator
	W	28	34	Chapter 14	The Ideal Gas Law & Kinetic Theory	
	F	30	35			
14	M	**Dec 3**	36			No lab or tutorial
	W	5	37	**Last Day of Classes**		

Week of November 19
Tutorial & Test 4: chapters 8, 9, 10
Week of November 26
Experiment 5: Thermal conductivity

Chapter 11: Fluids

- Density
- Pressure, variation of pressure with depth in a fluid
- Pascal's Principle
- Archimedes' Principle
- Fluids in motion -
  - equation of continuity
  - Bernoulli's equation
- Leave out 11.11, viscous flow

Density

The density of a gas, liquid or solid is its mass divided by its volume:

$$\text{Density, } \rho = \frac{\text{mass}}{\text{volume}} = \frac{m}{V} \ (\text{kg/m}^3)$$

Specific gravity is the density of a substance relative to water:

$$\text{Specific gravity } = \frac{\text{Density of substance}}{\text{Density of water at } 4^\circ \text{ C}} = \frac{\text{Density of substance}}{1000 \text{ kg/m}^3}$$

$$\text{Mass, } m = \rho V$$

Table 11.1 Mass Densities[a] of Common Substances

Substance	Mass Density ρ (kg/m^3)
Solids	
Aluminum	2700
Brass	8470
Concrete	2200
Copper	8890
Diamond	3520
Gold	19 300
Ice	917
Iron (steel)	7860
Lead	11 300
Quartz	2660
Silver	10 500
Wood (yellow pine)	550
Liquids	
Blood (whole, 37 °C)	1060
Ethyl alcohol	806
Mercury	13 600
Oil (hydraulic)	800
Water (4 °C)	1.000×10^3
Gases	
Air	1.29
Carbon dioxide	1.98
Helium	0.179
Hydrogen	0.0899
Nitrogen	1.25
Oxygen	1.43

[a] Unless otherwise noted, densities are given at 0 °C and 1 atm pressure.

11.92/6: A chunk of concrete of mass 33 kg has a hollow spherical cavity inside. The volume of the chunk is 0.025 m^3. What is the radius of the spherical cavity? The density of concrete is 2,200 kg/m^3.

If the mass of the chunk is 33 kg, then its volume should be, V = m/ρ:

V = (33 kg) / (2,200 kg/m^3) = 0.015 m^3.

Its actual volume is 0.025 m^3, so the volume of the spherical cavity is 0.025 – 0.015 = 0.010 m^3.

Volume of a sphere: $V = \frac{4}{3}\pi r^3$

$$\text{So, } r = \left[\frac{3V}{4\pi}\right]^{1/3} = \left[\frac{3 \times 0.01}{4\pi}\right]^{1/3} = 0.134 \text{ m}$$

11.9: An antifreeze solution is made by mixing ethylene glycol (density = 1116 kg/m^3) with water. The specific gravity of the solution is 1.073. Find the percentage of ethylene glycol by volume.

Density of the antifreeze = 1.073 × 1000 = 1073 kg/m^3.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{m_1 + m_2}{V_1 + V_2} = \frac{\rho_1 V_1 + \rho_2 V_2}{V_1 + V_2}$$

$$\rho_1 = 1116 \text{ kg/m}^3 \text{ (ethylene glycol)}$$
$$\rho_2 = 1000 \text{ kg/m}^3 \text{ (water)}$$

$$\text{Put } \frac{V_1}{V_1 + V_2} = \alpha, \text{ then } \frac{V_2}{V_1 + V_2} = 1 - \alpha$$

α = fraction of ethylene glycol by volume

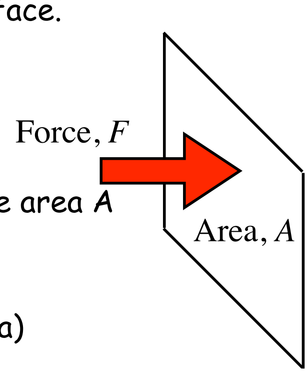
$$\text{Density of antifreeze } = \rho_1 \alpha + \rho_2 (1 - \alpha) = 1073 \text{ kg/m}^3$$

$$\text{So, } 1116\alpha + 1000(1 - \alpha) = 1073$$

$$\rightarrow \alpha = 0.629, \text{ i.e. 62.9 percent ethylene glycol by volume}$$

Pressure

Pressure is the force exerted by a fluid on its surroundings.
The force is measured per unit area of surface.

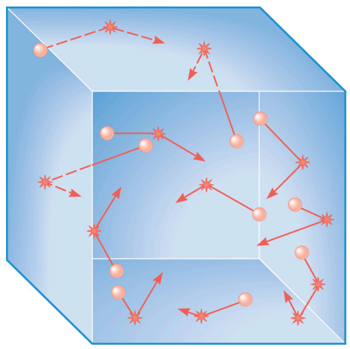


The pressure exerted by the force F on the area A perpendicular to the force is:

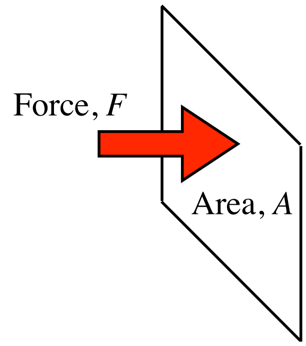
P = F/A, Units: 1 N/m^2 = 1 Pascal (Pa)

Normal atmospheric pressure is 1.013 × 10^5 Pa = 101.3 kPa.

Pressure is exerted equally in all directions.



Pressure



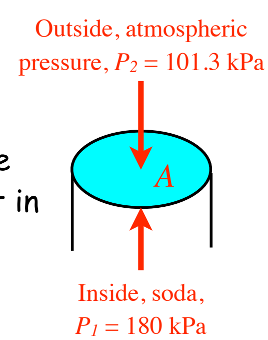
Pressure is due to the impact of molecules with the surface – the molecules of the fluid carry momentum and exert an impulse on the surface when they bounce from it.

The resulting force is equal to the rate of change of momentum of the molecules as they bounce from the surface.

The total force on a surface is proportional to its area.

11.12/10: A bottle of soda has a screw cap. The absolute pressure inside the bottle is 180 kPa.

If the cap has an area 4.1×10^{-4} m^2, calculate the force exerted on the cap by the screw thread that keeps it in place.



Inside the bottle: P_1 = 180 kPa → outward force on cap = P_1A

Outside the bottle: P_2 = 101.3 kPa → inward force on cap = P_2A

The net outward force on the cap is $F = (P_1 - P_2)A$

$F = [(180 - 101.3) \times 1000 \text{ Pa}] \times (4.1\times10^{-4} \text{ m}^2) = 32.3 \text{ N}$

The thread exerts an inward force of 32.3 N

11.11: An airtight box has a removable lid of area 0.013 m^2 and negligible weight. The air is removed from the box and the box is taken up a mountain where the air pressure outside the box is 85 kPa. What force is needed to remove the lid?

There is zero pressure inside the box and 85 kPa outside, so there is a force pushing the lid onto the box.

The force is F = PA = (85,000 Pa)(0.013 m^2) = 1105 N

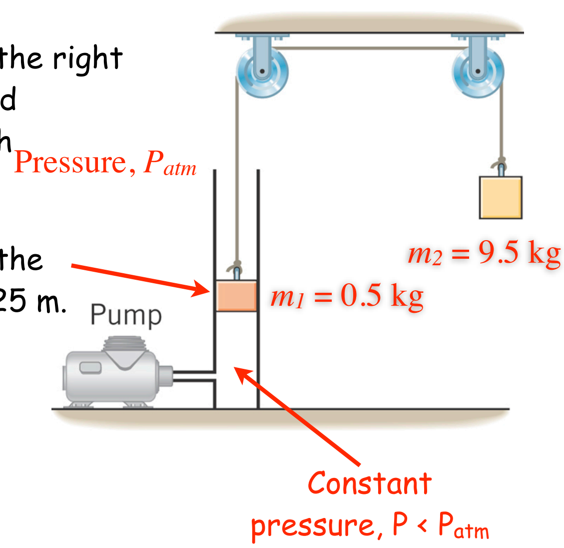
If instead the airtight box contained air at normal atmospheric pressure, 101.3 kPa, there would be a net outward force on the lid, as the pressure inside would be greater than the pressure on the outside.

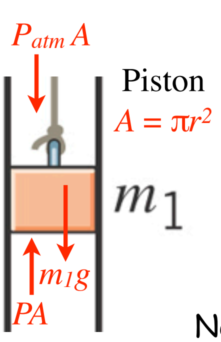
The outward force would be $(P_{in} - P_{out})A$ = (101,300 - 85,000)(0.013 m^2)

F = 212 N, outwards.

11.18/95: Given that the block at the right falls 1.25 m from rest in 3.3 s, find the pressure in the cylinder, which is held constant by the pump. Ignore friction.

The radius of the piston is r = 0.025 m.





Net force accelerating the two masses:

$$F = (m_2 - m_1)g + (P - P_{atm})A = (m_1 + m_2)a$$

$$\rightarrow P = \frac{(m_1 + m_2)a - (m_2 - m_1)g}{A} + P_{atm}$$

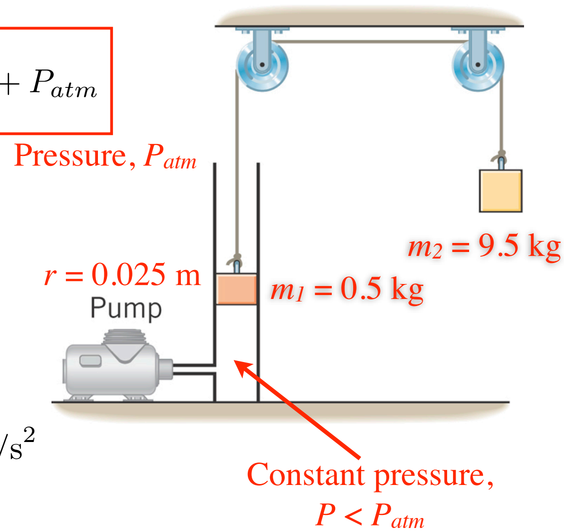
$$P = \frac{(m_1 + m_2)a - (m_2 - m_1)g}{\pi r^2} + P_{atm}$$

Block at the right falls 1.25 m from rest in 3.3 s.

Acceleration of the block:

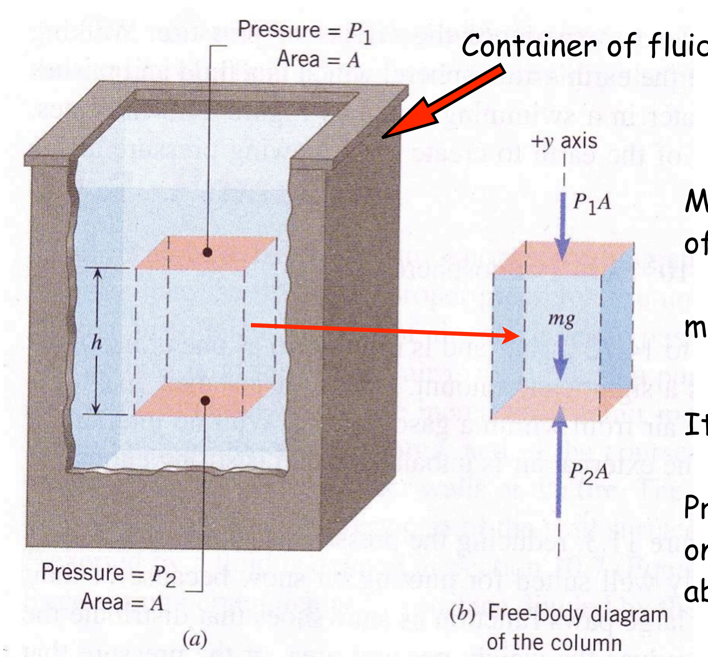
$$s = \frac{1}{2}at^2$$

$$\text{So, } a = \frac{2s}{t^2} = \frac{2 \times 1.25}{3.3^2} = 0.23 \text{ m/s}^2$$



$$\begin{aligned} P &= \frac{(0.5 + 9.5) \times 0.23 - (9.5 - 0.5)g}{\pi \times 0.025^2} + P_{atm} \\ &= -43,749 + P_{atm} \\ P &= 57.6 \text{ kPa} \end{aligned}$$

Variation of Pressure with Depth



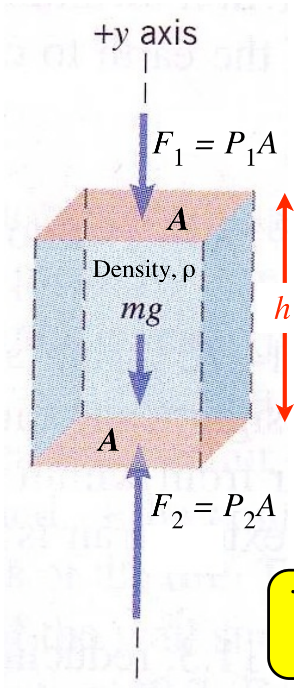
Mass of small column of fluid is:

m = ρ V = ρ Ah

It is in equilibrium

Pressure forces act on the column from above and from below

Variation of Pressure with Depth



For the column of fluid to be in equilibrium:

$$-mg - F_1 + F_2 = 0$$

So, $-mg - P_1A + P_2A = 0$

or, $P_2 = P_1 + \dfrac{mg}{A}$

The mass of the column of fluid is:

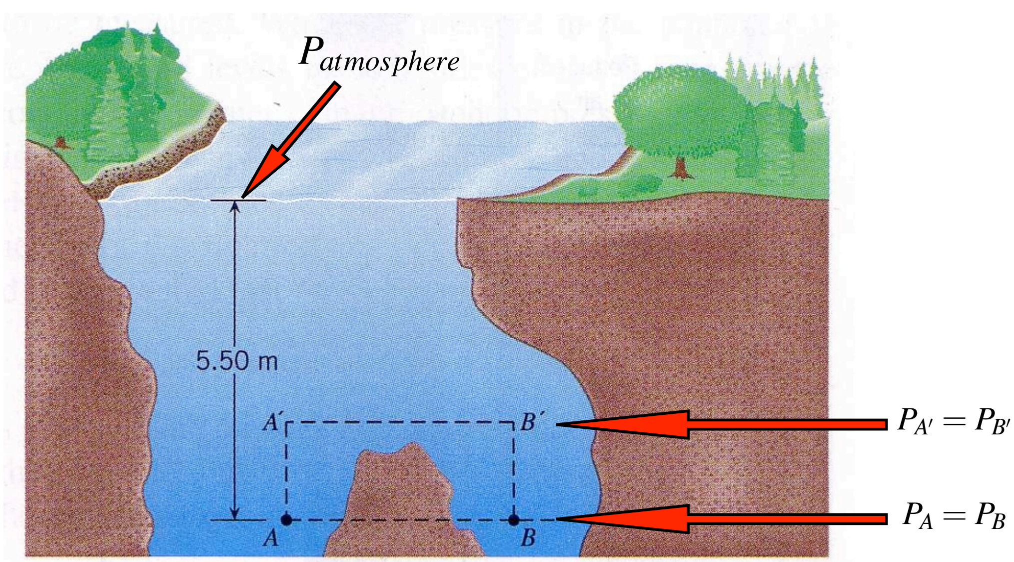
$$m = \rho V = \rho A h$$

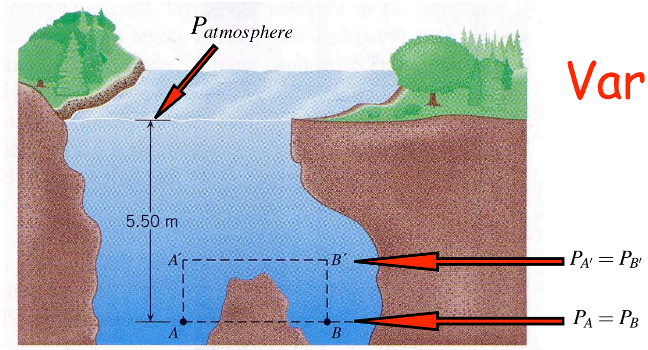
Therefore, $P_2 = P_1 + \rho g h$

The pressure is the same at all points at the same depth

Variation of Pressure with Depth

The pressure is the same at all points at the same depth





Variation of Pressure with Depth

Both A and B are 5.5 m below the surface of the water.

$$P_A = P_B = P_{atmosphere} + \rho g h$$

$$= P_{atmosphere} + (1000\ \mathrm{kg/m^3})(9.8\ \mathrm{m/s^2})(5.5\ \mathrm{m})$$

$$= P_{atmosphere} + 53,900\ \mathrm{Pa}$$

Standard atmospheric pressure is 101.3 kPa,

so P_A = 1.53 atmospheres (i.e., 1.53 × $P_{atmosphere}$)

PHYS 1020 Final Exam

Monday, December 17, 6 - 9 pm

The whole course
30 multiple choice questions
Formula sheet provided

Seating (from exam listing on Aurora)

Brown Gym

A - SIM

Gold Gym

SIN - Z

GENERAL PHYSICS I: PHYS 1020

Schedule - Fall 2007
(lecture schedule is approximate)

11	M	12	**Remembrance Day**			Experiment 4: Centripetal Force
	W	14	28	Chapter 11 exclude 11.11	Fluids	
	F	16	29			
12	M	19	30	Chapter 12 sections 1 - 8	Temperature and heat (some small sections, notably thermal stress will be omitted)	Tutorial and Test 4 (chapters 8, 9, 10)
	W	21	31			
	F	23	32			
13	M	26	33	Chapter 13	Transfer of Heat -- Self study only. **Required for last lab**. This chapter **IS** examinable on the final.	Experiment 5: Thermal Conductivity of an Insulator
	W	28	34	Chapter 14	The Ideal Gas Law & Kinetic Theory	
	F	30	35			
14	M	**Dec 3**	36			No lab or tutorial
	W	5	37	**Last Day of Classes**		

Week of November 19

Tutorial & Test 4: chapters 8, 9, 10

Week of November 26

Experiment 5: Thermal conductivity

An Opportunity

You can switch to the calculus stream next term and study even more physics...

(if you want!)

– PHYS 1070 and beyond –

if you get a B (B^+ for honours physics) in PHYS 1020

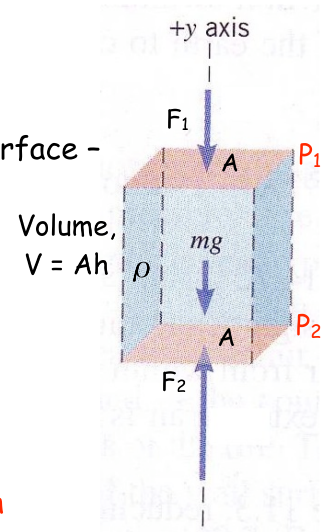
Fluids, the story so far...

Density = Mass/Volume

Specific gravity $= \dfrac{\text{Density of substance}}{\text{Density of water at } 4°\text{C}}$

Pressure = Force/Area

Pressure – due to impact of molecules with a surface – acts equally in all directions



Increase of pressure with depth:
Mass m of fluid is in equilibrium, so $mg = F_2 - F_1$

As $m = V\rho = Ah\rho$,

$Ah\rho g = A(P_2 - P_1) \rightarrow P_2 = P_1 + \rho gh$

Pressure depends only on depth

11.20: The blood pressure in the heart is 16 kPa. If an artery in the brain is 0.45 m above the heart, what is the pressure in the artery? Ignore any pressure changes due to blood flow.

P_1 The brain

h = 0.45 m

P_2 The heart

$P_2 = P_1 + \rho gh$,

so $P_1 = P_2 - \rho gh$

Density of blood = 1060 kg/m^3

$P_1 = 16{,}000 - (1060\ \text{kg/m}^3)\times(9.8\ \text{m/s}^2)\times(0.45\ \text{m}) = 11{,}325$ Pa.

Note: P_1, P_2 are pressures **above** atmospheric pressure, the so-called "gauge pressure". A tire pressure gauge measures gauge pressure – zero on the gauge means the tire is flat and the pressure inside the tire is atmospheric pressure.

Pumping water from a well

Which method will pump water from a deep well?

For the pipe at the right:

$P_1 = P_{atmos} - \rho gh$

water

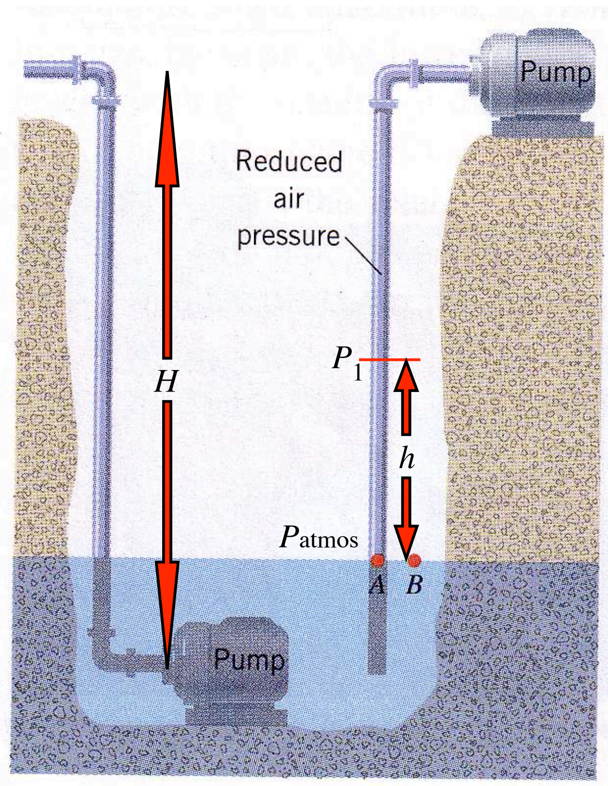
P_1 is reduced to zero (vacuum), when

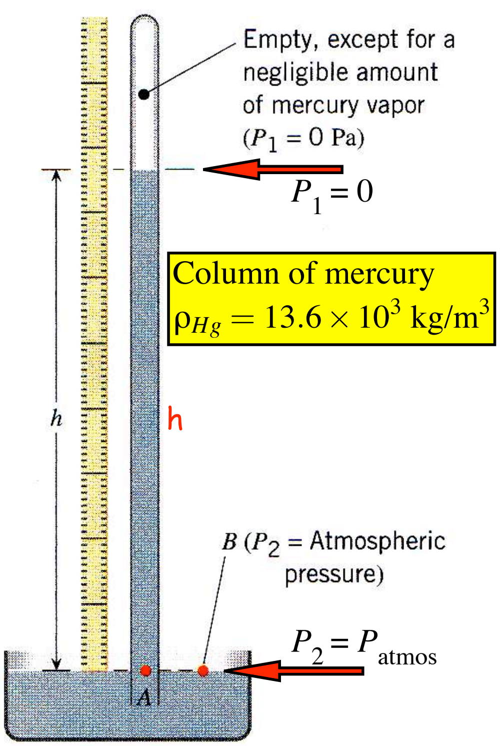
$h = P_{atmos}/\rho g$

$= 101{,}300/(1000\times 9.8)$

$= 10.3$ m

= maximum depth





Mercury Barometer

$$P_2 = P_{atmos} = P_1 + \rho gh$$

$$P_{atmos} = 0 + \rho gh$$

Atmospheric pressure can be measured in "mm of mercury".

Standard atmospheric pressure:

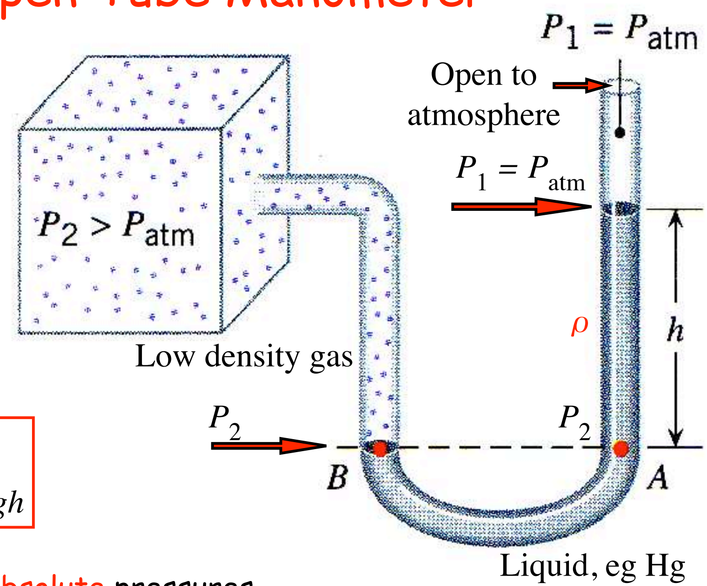
$$101.3\times 10^3 \text{ Pa} = \rho_{Hg}\, gh$$

$$h = \frac{101.3\times 10^3}{13.6\times 10^3\times 9.8}$$

h = 0.76 m = 760 mm Hg

1 mm Hg = 1 Torr

Open Tube Manometer



$$P_2 = P_1 + \rho g h$$
$$= P_{atm} + \rho g h$$

P_1, P_2, P_{atm} are absolute pressures

$P_2 - P_{atm} = \rho gh =$ "gauge pressure" inside the box

11.-/26: A mercury manometer reads 747 mm on the roof of a building and 760 mm on the ground. Assuming a constant value of 1.29 kg/m^3 for the density of the air, find the height of the building.

$$P_{ground} = P_{roof} + \rho_{air}\, gh$$

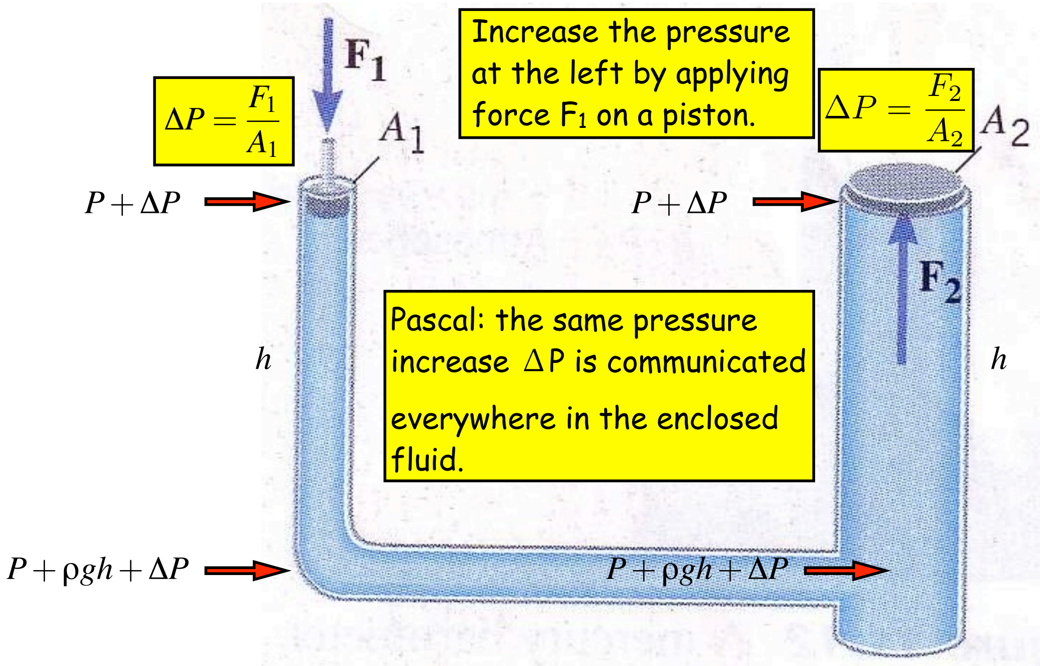
$$\text{So, } h = \frac{P_{ground} - P_{roof}}{\rho_{air}\, g}$$

The atmospheric pressure increases by 13 mm Hg, that is, by:

$$\frac{13}{760}\text{ atmospheres} = \frac{13}{760} \times 101.3 = 1.733 \text{ kPa}$$

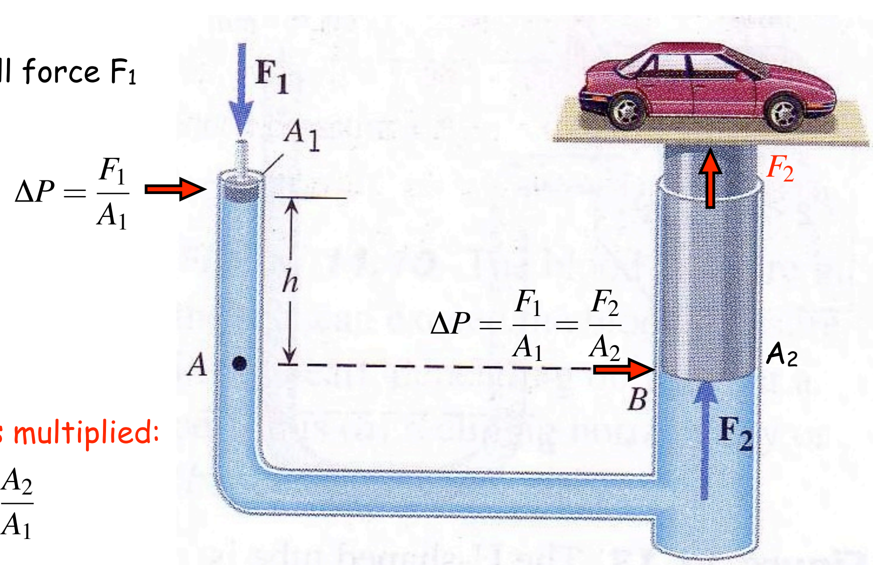
$$\text{Therefore, } h = \frac{1733}{1.29 \times 9.8} = 137 \text{ m}$$

Pascal's Principle



Pascal's Principle

Apply a small force F_1 at the left:



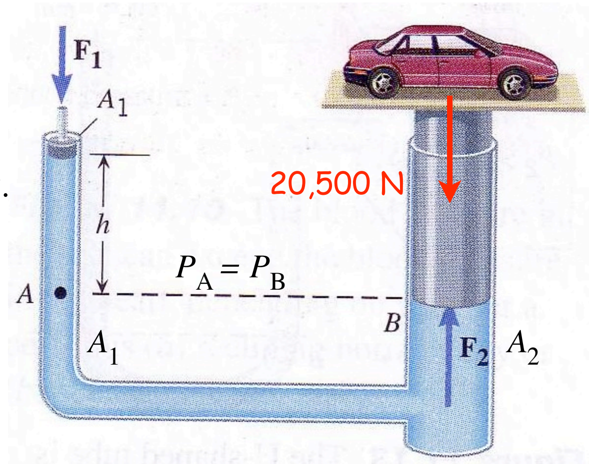
The force is multiplied:

$$F_2 = F_1 \times \frac{A_2}{A_1}$$

Hydraulic jack

The input piston (on the left) has a radius r_1 = 0.012 m and at the right r_2 = 0.15 m. The combined weight of car and plunger is 20,500 N. The oil in the jack has density 800 kg/m^3.

(a) What force F_1 is needed to support the car and output plunger when the bottom surfaces of piston and plunger are at the same height? (h = 0)



$$F_2 = F_1 \times \frac{A_2}{A_1} = 20,500 \text{ N} \quad \text{so}, F_1 = 20,500 \times \left(\frac{0.012}{0.15}\right)^2 = 131 \text{ N}$$

Hydraulic jack

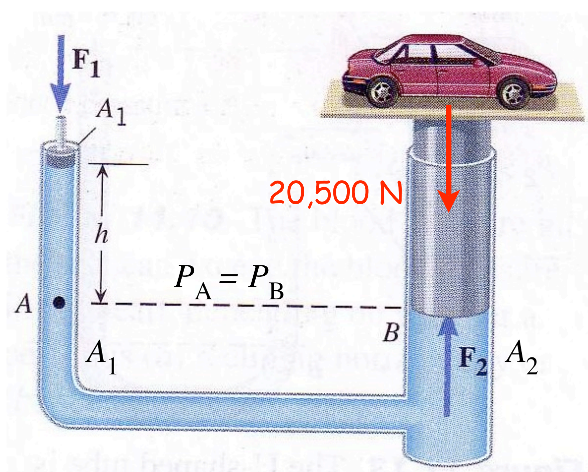
(b) When h = 1.1 m?

$$P_B = P_A = \frac{F_1}{A_1} + \rho g h$$

$$P_B = \frac{F_2}{A_2}$$

$$\text{So}, \frac{F_2}{A_2} = \frac{F_1}{A_1} + \rho g h$$

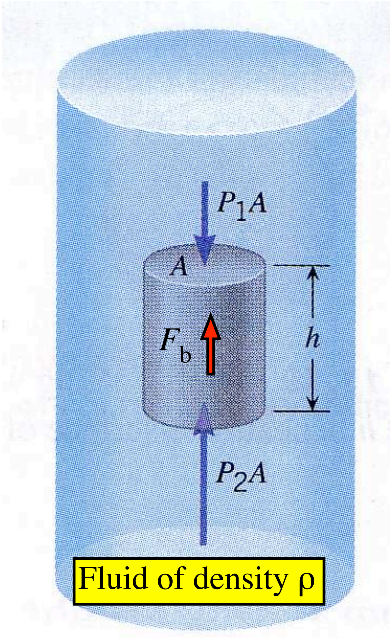
$$\frac{F_1}{A_1} = \frac{F_2}{A_2} - \rho g h$$



$$\frac{F_1}{\pi \times 0.012^2} = \frac{20,500}{\pi \times 0.15^2} - 800 \times 9.8 \times 1.1$$

$F_1 = 127$ N (was 131 N when $h = 0$)

Archimedes' Principle



Consider the equilibrium of the column of fluid. It experiences pressure forces from above and below.

The net upward force (buoyant force) on the column is:

$$F_b = (P_2 - P_1)A$$

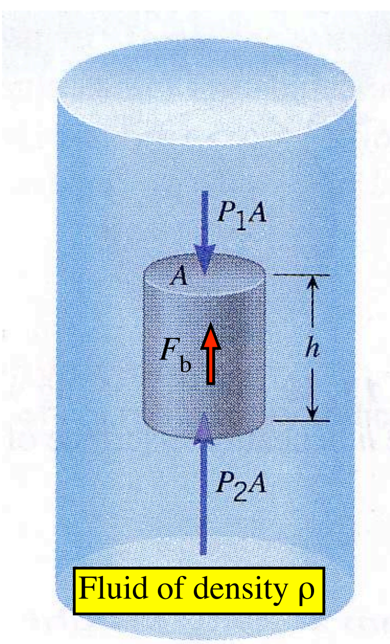
and $P_2 - P_1 = \rho g h$ increase of pressure with depth

So, $F_b = \rho h A g = \rho V g$

ρ V = mass of fluid that occupied the volume V.

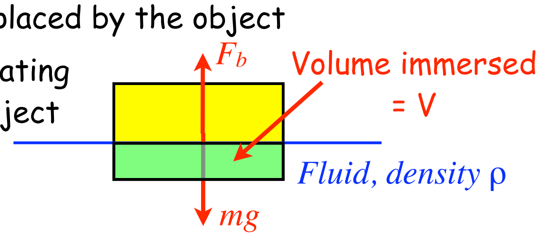
Buoyant force = weight of displaced fluid

Archimedes' Principle



Buoyancy force = ρ Vg = weight of fluid displaced by the object

Floating object



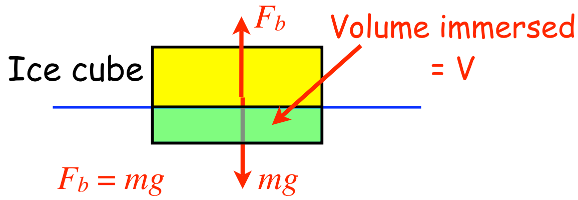
The buoyant force acting on an object partially or completely immersed in a fluid is the weight of the fluid that is displaced.

For a floating object, F_b = mg

That is, ρ Vg = mg

Clickers!

11.C14: You put an ice cube in a glass and fill the glass with water. As the ice cube melts, does the water level drop, stay the same, or rise?



A) The level of water rises
B) The level of water falls
C) The level of water remains the same

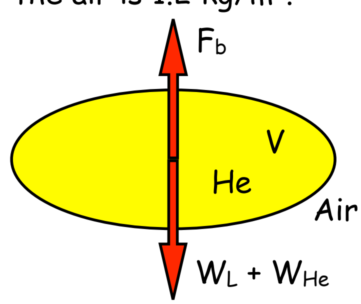
The ice cube floats by displacing its own weight of liquid water.

So, when the ice cube melts, it occupies a volume equal to that of the liquid water it displaced when it was floating...

That is, the ice cube contracts into the volume coloured green...

The Goodyear blimp contains 5400 m^3 of helium of density 0.179 kg/m^3. Find the weight of the load W_L that the airship can carry if the density of the air is 1.2 kg/m^3.

To float in the air:
$F_b = W_L + W_{He}$



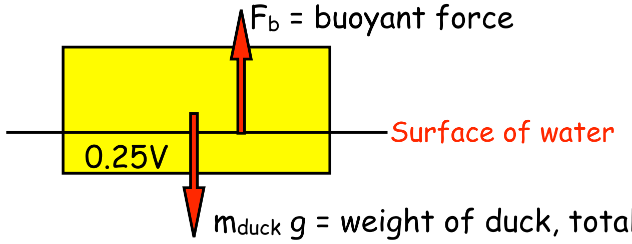
The buoyant force is, F_b = weight of air displaced by balloon

$= V\rho_{air}\, g = 5400 \times 1.2g = 63{,}500$ N

The weight of the helium is $W_{He} = V\rho_{He}\, g = 5400 \times 0.179g = 9473$ N

So, $63{,}500 = W_L + 9473$ N $\rightarrow W_L = 54{,}000$ N

11.38: A duck is floating on a lake with 25% of its volume beneath the water. What is the average density of the duck?



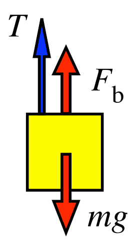
The duck floats, so the weight of the duck is equal to the weight of water with 25% of the volume of the duck.

That is, $m_{duck}\, g = \rho_{water} \times 0.25V\, g$

But, $m_{duck} = \rho_{duck} \times V$

Therefore, $\rho_{duck} = 0.25\,\rho_{water} = 250\ \text{kg/m}^3$

11.44/46: A solid object has an apparent weight of 15.2 N when completely immersed in ethyl alcohol. When completely submerged in water, its apparent weight is 13.7 N. What is the volume of the object? Density of ethyl alcohol = 806 kg/m^3.



Weigh the object by supporting it by a string and measuring the tension in the string.

In ethyl alcohol: $T_1 = mg - F_{b1} = 15.2\ \text{N}$

In water: $T_2 = mg - F_{b2} = 13.7\ \text{N}$

So, $mg = 15.2 + F_{b1} = 13.7 + F_{b2}$

$F_{b2} - F_{b1} = 1.5\ \text{N}$ and, $F_{b2} - F_{b1} = (\rho_{H_20} - \rho_{ethyl})Vg$

Therefore, $1.5 = (1000 - 806)gV$

$$V = \frac{1.5}{194g} = 7.9 \times 10^{-4}\ \text{m}^3$$

PHYS 1020 Final Exam

Monday, December 17, 6 - 9 pm

The whole course
30 multiple choice questions
Formula sheet provided

Seating (from exam listing on Aurora)

Brown Gym

A - SIM

Gold Gym

SIN - Z

GENERAL PHYSICS I: PHYS 1020

Schedule - Fall 2007 (lecture schedule is approximate)

11	M	12	**Remembrance Day**			Experiment 4: Centripetal Force
	W	14	28	Chapter 11 exclude 11.11	Fluids	
	F	16	29			
12	M	19	30	Chapter 12 sections 1 - 8	Temperature and heat (some small sections, notably thermal stress will be omitted)	Tutorial and Test 4 (chapters 8, 9, 10)
	W	21	31			
	F	23	32			
13	M	26	33	Chapter 13	Transfer of Heat -- Self study only. **Required for last lab.** This chapter **IS** examinable on the final.	Experiment 5: Thermal Conductivity of an Insulator
	W	28	34	Chapter 14	The Ideal Gas Law & Kinetic Theory	
	F	30	35			
14	M	**Dec 3**	36			No lab or tutorial
	W	5	37	**Last Day of Classes**		

Week of November 19

Tutorial & Test 4: chapters 8, 9, 10

Week of November 26

Experiment 5: Thermal conductivity

Mastering Physics Assignment #5

On chapters 8, 9, 10, 11

Due Monday, December 3 at 11 pm

Mastering Physics Survey

Welcome to Physics 1020!

Instructors	Required Materials	Schedule	Policies/Evaluation	Suggested Problems	Formula Sheet
Answers to Even-Numbered Problems			Answers for tutorial test problems		
Answers for midterm test			Answers for final exam		
Marks files					

Mastering Physics Assignment #5
Due Monday, December 3 at 11 pm

Information on "Mastering Physics"

→ **Mastering Physics Survey** ←

Please complete the Mastering Physics survey to let the Mastering Physics people know how well (or not) Mastering Physics works, what is good, bad, how it could be improved...

http://www.zoomerang.com/recipient/survey-intro.zgi?p=WEB22742JUNCEZ

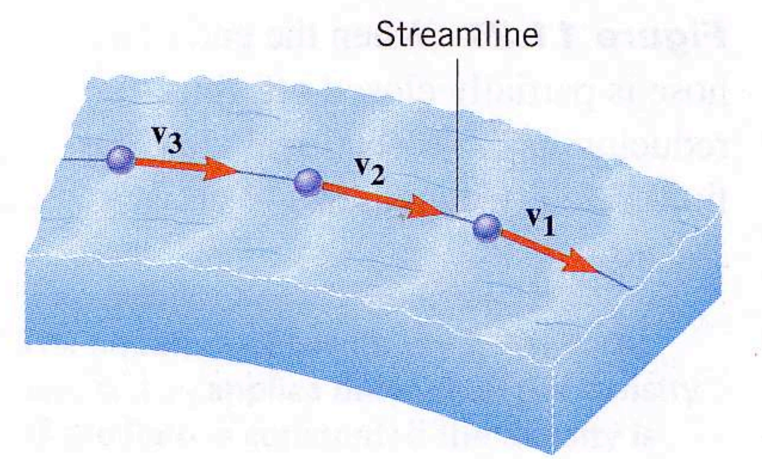
Fluids, continued...

Pascal's Principle: a change in pressure is transmitted equally throughout an enclosed fluid.

Archimedes' Principle: the buoyant force acting on an object is equal to the weight of fluid displaced by the object.

Fluids in Motion

Streamline (steady) flow – the velocity of a fluid at some point does not change with time. Streamlines show the path of fluid particles. Streamlines do not cross.



Fluids in Motion

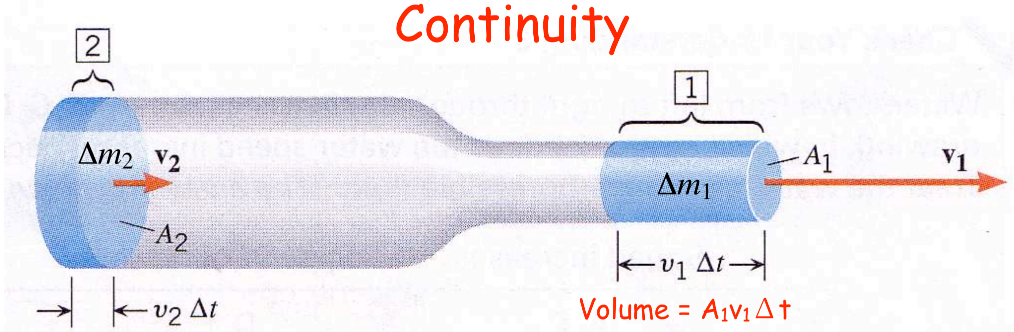
Unsteady flow – the velocity at a point in the fluid changes with time.

Turbulent flow is an extreme case of unsteady flow for a fast-moving fluid – the velocity changes erratically from moment to moment, as at sharp obstacles or bends.

Viscous flow – a type of friction impeding the relative motion of layers of a fluid, as in molasses.

Bernoulli's equation, to follow, applies to streamline flow.

Freely Flowing Fluids: The Equation of Continuity



Volume = $A_1 v_1 \Delta t$

Volume = $A_2 v_2 \Delta t$

What goes in must come out

Mass flowing in = mass flowing out

That is, $\rho_2 A_2 v_2 \Delta t = \rho_1 A_1 v_1 \Delta t$

and $\rho_2 A_2 v_2 = \rho_1 A_1 v_1$ Equation of continuity

The Equation of Continuity

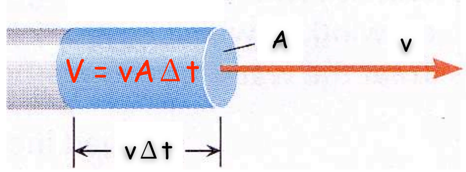
$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

$$\frac{\Delta m}{\Delta t} = \rho A v = \text{mass flow rate}$$

If the fluid is incompressible, $\rho_1 = \rho_2$,

and the volume flow rate (volume per second) is

$$Q = v_1 A_1 = v_2 A_2$$



11.52: The volume rate of flow in an artery supplying the brain is 3.6×10^{-6} m^3/s. If the radius of the artery is 5.2 mm, determine the average blood speed.

$$v = \frac{Q}{A} = \frac{3.6 \times 10^{-6}\ \mathrm{m^3/s}}{\pi \times 0.0052^2} = 0.0424\ \mathrm{m/s}$$

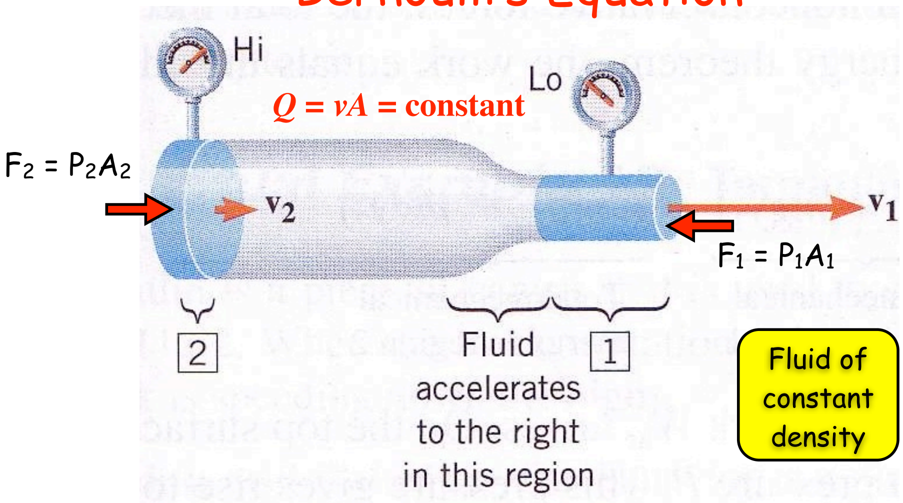
Find the average blood speed if a constriction reduces the radius of the artery by a factor of 3 (without reducing the flow rate).

v = Q/A, and r is reduced to r/3,

so the speed is increased by a factor of $3^2 = 9$.

So, v = 9 × 0.0424 = 0.381 m/s

Bernoulli's Equation

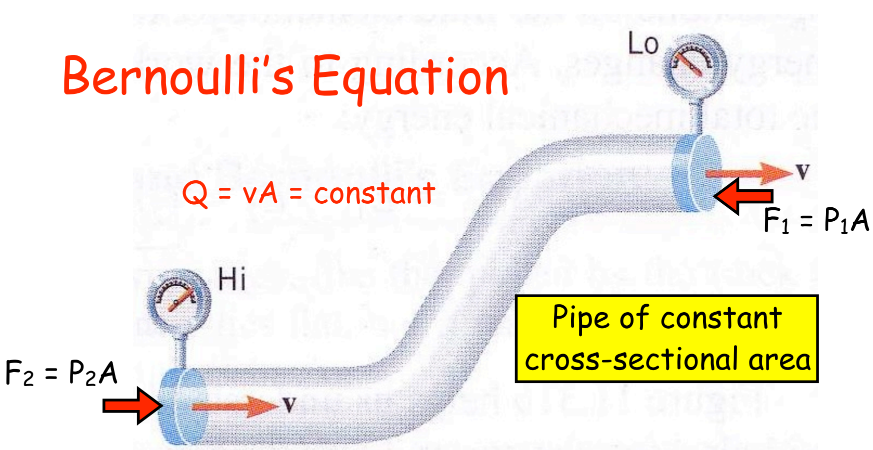


The fluid speeds up when it gets to the constriction. What is the force that causes this acceleration?

There must be a drop in pressure that accelerates the fluid to the right.

$$P_2 > P_1$$

Bernoulli's Equation

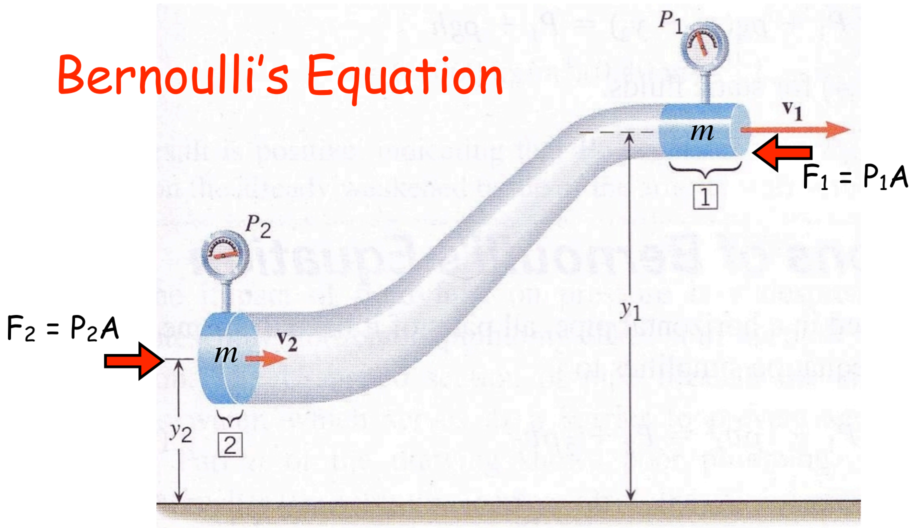


The fluid flows up hill at constant speed through a pipe of constant area. Where does the force come from to push the fluid up the hill at constant speed?

There must be a decrease in pressure that pushes the fluid up the hill.

$$P_2 > P_1$$

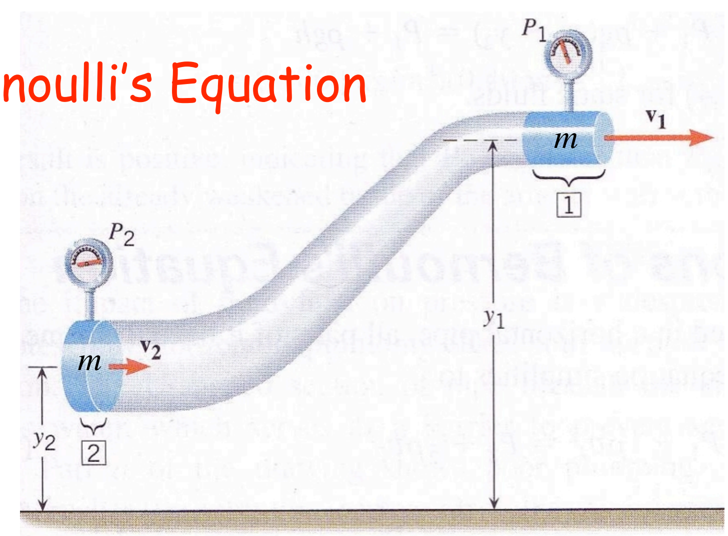
Bernoulli's Equation



Follow a fluid element of mass m through the pipe from region 2 at the left to region 1 at the right.

Work W_{nc} done by the pressure forces increases the mechanical energy of the fluid element.

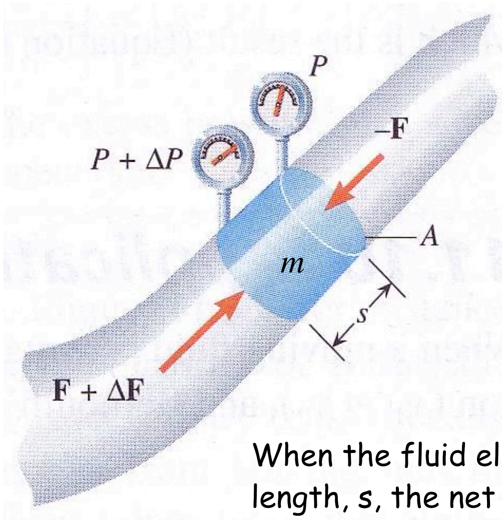
Bernoulli's Equation



Work-energy equation:

$$\begin{aligned} W_{nc} &= \Delta PE + \Delta KE \\ &= (mgy_1 - mgy_2) + (\frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2) \end{aligned}$$

What is the work done by non-conservative forces?



Bernoulli's Equation

The pressure difference between the two ends of the fluid element of mass m exerts a net force on the mass –

$$(F+\Delta F)-F=(P+\Delta P)A-PA$$

So that, $\Delta F=\Delta P\times A$

When the fluid element moves through its own length, s, the net force does work on it:

$$\Delta W_{nc}=\Delta F s=\Delta P(A\times s)=\Delta P\times V$$

The work done by the whole pressure difference between the ends of the pipe, P_2 – P_1 should then be:

$$W_{nc}=(P_2-P_1)\times V$$

Bernoulli's Equation

Back to the work-energy equation: $W_{nc}=\Delta PE+\Delta KE$

$$W_{nc}=(P_2-P_1)\times V=(mgy_1-mgy_2)+(\frac{1}{2}mv_1^2-\frac{1}{2}mv_2^2)$$

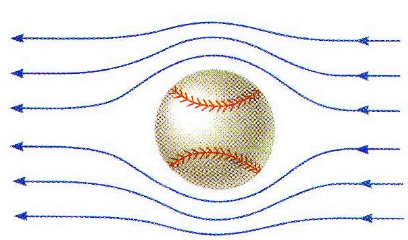
Divide by V and use density ρ = m/V

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

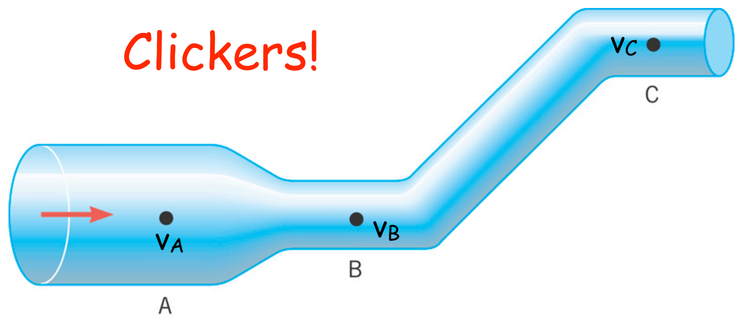
$$P_1+\rho g y_1+\frac{1}{2}\rho v_1^2=P_2+\rho g y_2+\frac{1}{2}\rho v_2^2$$

Bernoulli's Equation

- For streamline flow
- Streamlines form "virtual pipes"



Clickers!



Fluid is flowing from left to right through the pipe. Points A and B are at the same height, but the cross-sectional areas of the pipe differ. Points B and C are at different heights, but the cross-sectional areas are the same.
Rank the pressures at the three points, from highest to lowest.

A) A and B (a tie), C
B) C, A and B (a tie)
C) B, C, A
D) C, B, A
E) A, B, C

$v_B > v_A$, what force speeds up the fluid?

C is higher than B, what force pushes the fluid uphill?

Applications of Bernoulli's Equation

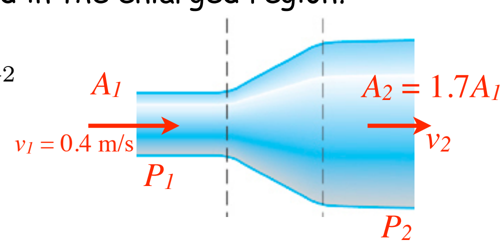
Because of the enlargement of a blood vessel, the cross-sectional area A_1 of an aorta increases to $A_2 = 1.7A_1$. The speed of the blood (ρ = 1060 kg/m^3) through a normal portion of the aorta is

v_1 = 0.4 m/s. Assuming that the aorta is horizontal, find the amount by which the pressure P_2 in the enlarged region exceeds P_1 in the normal region.

First, what is the speed of the blood in the enlarged region?

Equation of continuity: $v_1 A_1 = v_2 A_2$

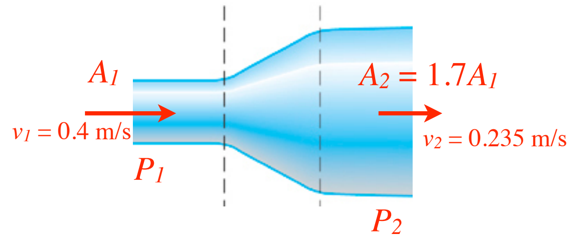
so, $v_2 = \frac{v_1 A_1}{A_2} = \frac{0.4}{1.7} = 0.235 \text{ m/s}$



Bernoulli:

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$ (no change of height)

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



$$\text{So, } P_2 - P_1 = \frac{1}{2}\rho[v_1^2 - v_2^2]$$

$$P_2 - P_1 = \frac{1}{2}(1060\ \text{kg/m}^3)[0.4^2 - 0.235^2] = 55\ \text{Pa}$$

That is, the pressure is greater in the already weakened enlarged section, putting greater stress on it.

The pressure must be larger because there has to be a force that slows down the blood as it enters the enlarged section.

11.60/-: Water is circulating through a closed system of pipes in a two-floor building. On the first floor, the water has a gauge pressure of 3.4×10^5 Pa and a speed of 2.1 m/s. On the second floor, which is 4 m higher, the speed of the water is 3.7 m/s. The speeds are different because the pipe diameters are different.

What is the gauge pressure on the second floor?

$$\text{Bernoulli: } P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

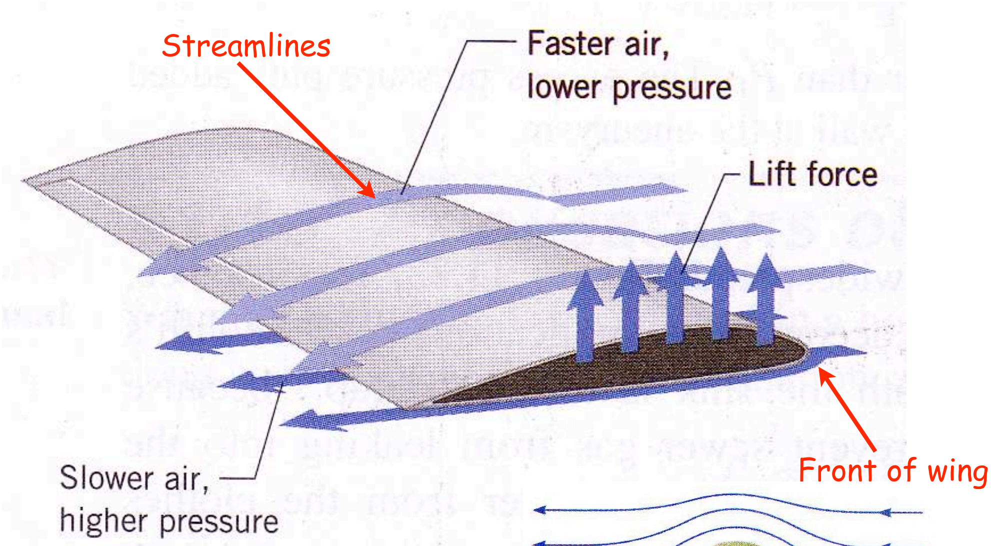
$$P_1 = 3.4 \times 10^5\ \text{Pa}, h_1 = 0, v_1 = 2.1\ \text{m/s}$$

$$P_2 = ?, h_2 = 4\ \text{m}, v_2 = 3.7\ \text{m/s}$$

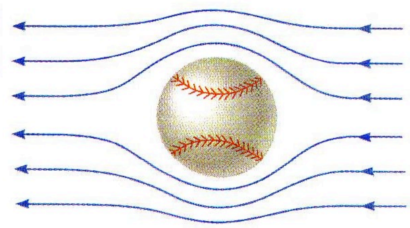
$$\rho = 1000\ \text{kg/m}^3$$

$$P_2 = 3 \times 10^5\ \text{Pa}$$

Lift force on an airplane wing



Compare:



11.59: An airplane wing is designed so that the speed of the air across the top of the wing is 251 m/s when the speed of the air below the wing is 225 m/s. The density of the air is 1.29 kg/m^3. Find the lift on a wing of area 24 m^2.

Imagine streamlines with uniform air conditions in front of the plane and that the streamlines divide and pass above and below the wing.

$$P_0 + \rho g y + \frac{1}{2}\rho v_0^2 = P_1 + \rho g y + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y + \frac{1}{2}\rho v_2^2$$

In front of plane — Above wing — Below wing

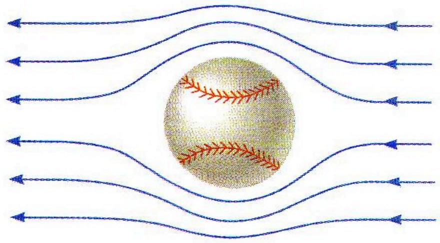
$$\text{So, } P_2 - P_1 = \frac{1}{2}\rho(v_1^2 - v_2^2) = \frac{1}{2} \times (1.29\ \text{kg/m}^3) \times (251^2 - 225^2) = 7983\ \text{Pa}$$

The net upward force is then: 7983A = 7983×(24 m^2) = 191,600 N

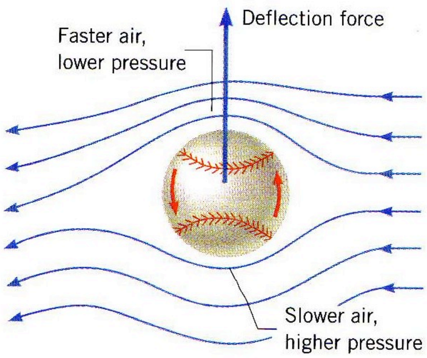
View from above

Ball is moving to the right

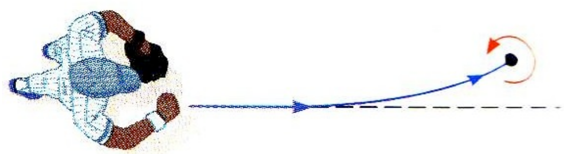
Streamlines of air moving relative to the ball



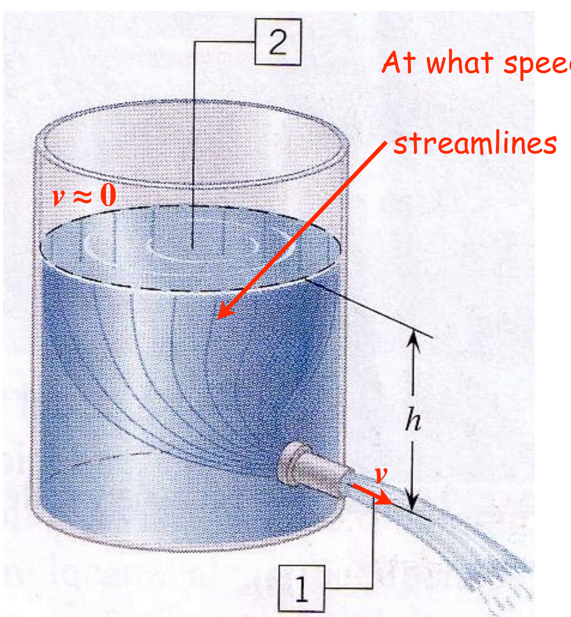
(a) Without spin

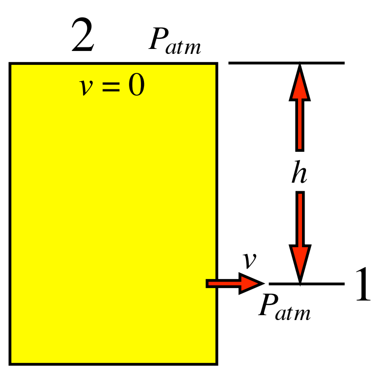


(b) With spin



At what speed does the water leave the hole?





Bernoulli: at 2 and 1

$$\cancel{P_{atm}} + \rho g h = \cancel{P_{atm}} + \frac{1}{2}\rho v^2 \rightarrow v^2 = 2gh, \text{ as if the water had fallen a distance } h$$

What the water loses in potential energy, it gains in kinetic energy

11.96/68: (a) Find v

Bernoulli:

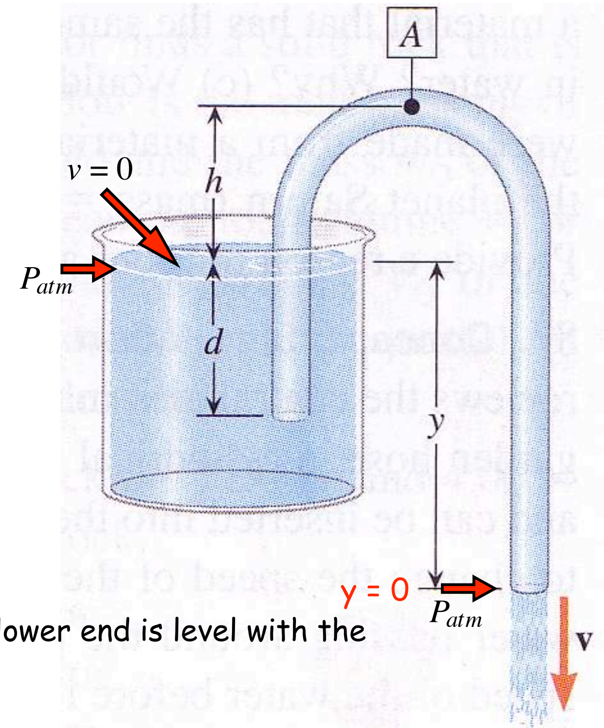
$$P_{atm} + \rho g y = P_{atm} + \frac{1}{2}\rho v^2$$

At surface of water — At exit of tube

So, $v = \sqrt{2gy}$

(b) At what value of y will the syphon stop working?

v = 0 when y = 0, i.e. when the lower end is level with the water surface.



(c) Find the absolute pressure at A.

Bernoulli, at surface of water and at A:

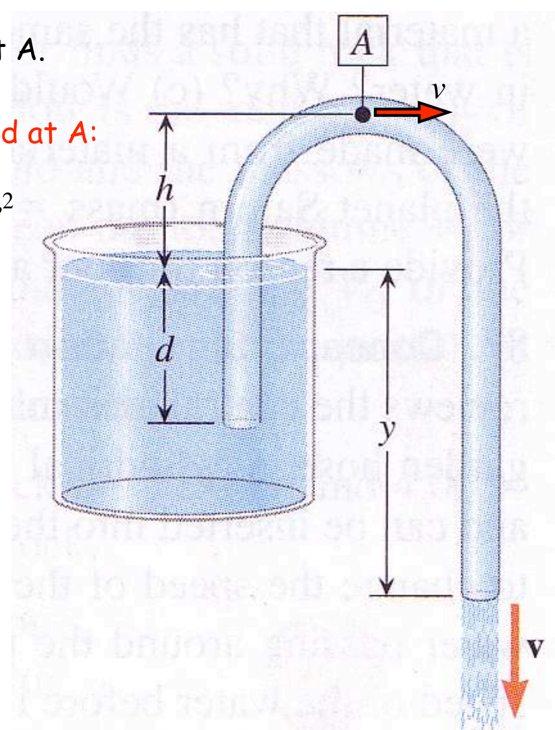
$$P_{atm} + \rho g y = P_A + \rho g (y + h) + \frac{1}{2}\rho v^2$$

$$P_A = P_{atm} - \rho g h - \frac{1}{2}\rho v^2$$

Since, $v = \sqrt{2gy}$,

$$P_A = P_{atm} - \rho g h - \frac{1}{2}\rho \times 2gy$$

$$= \underline{P_{atm} - \rho g (h + y)}$$



Summary of Motion of Fluids

Equation of continuity:

$$\rho_1 v_1 A_1 = \rho_2 v_2 A_2 = \text{mass flowing per second}$$

If the density does not change:

$$v_1 A_1 = v_2 A_2 = \text{volume flowing per second}$$

Bernoulli's Equation:

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2 = \text{constant}$$

– based on work-energy theorem, assumes streamline flow