# 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<br>exclude 11.11 | Fluids | |
| | F | 16 | 29 | | | |
| 12 | M | 19 | 30 | Chapter 12<br>sections 1 - 8 | Temperature and heat<br>(some small sections, notably thermal stress will be omitted) | Tutorial and Test 4<br>(chapters 8, 9, 10) |
| | W | 21 | 31 | | | |
| | F | 23 | 32 | | | |
| 13 | M | 26 | 33 | Chapter 13 | Transfer of Heat -- Self study only.<br>**Required for last lab.**<br>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

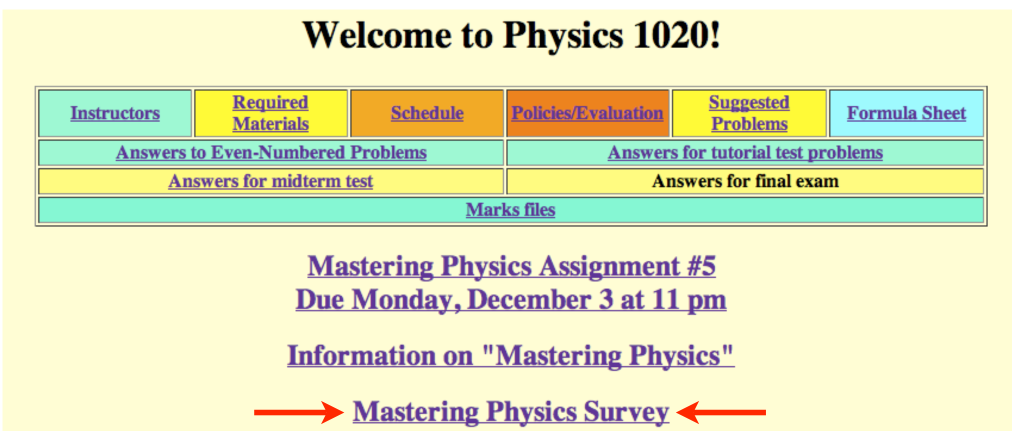
# Mastering Physics Assignment #5

On chapters 8, 9, 10, 11

Due Monday, December 3 at 11 pm



# Mastering Physics Survey




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...

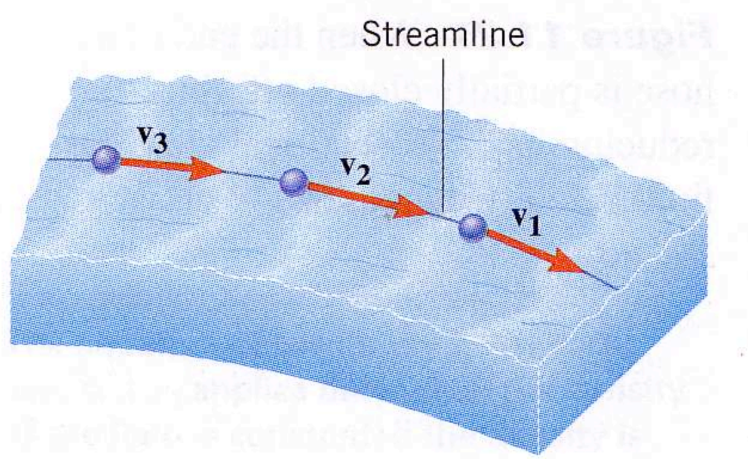
Pascal's Principle: a change in pressure is transmitted equally throughout an enclosed fluid.

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.

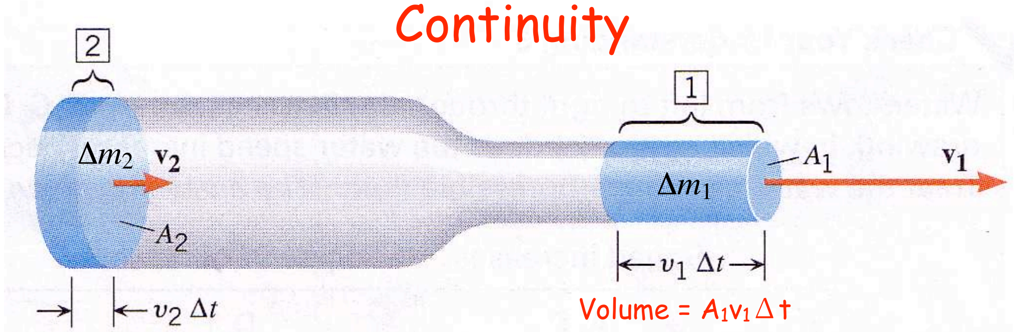
Turbulent flow is an extreme case of unsteady flow for a fast-moving fluid – the velocity changes erratically from moment to moment, as at sharp obstacles or bends.

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 = $A_1v_1\Delta t$

Volume = $A_2v_2\Delta t$

What goes in must come out

Mass flowing in = mass flowing out

That is, $\rho_2 A_2v_2\Delta t = \rho_1 A_1v_1\Delta t$

and $\rho_2 A_2v_2 = \rho_1 A_1v_1$ Equation of continuity

# The Equation of Continuity

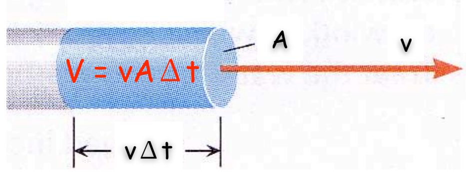
$$\boxed{\rho_1 \; A_1 \; v_1 = \rho_2 \; A_2 \; v_2}$$

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

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 $3.6 \times 10^{-6}$ $m^3/s$. If the radius of the artery is 5.2 mm, determine the average blood speed.

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

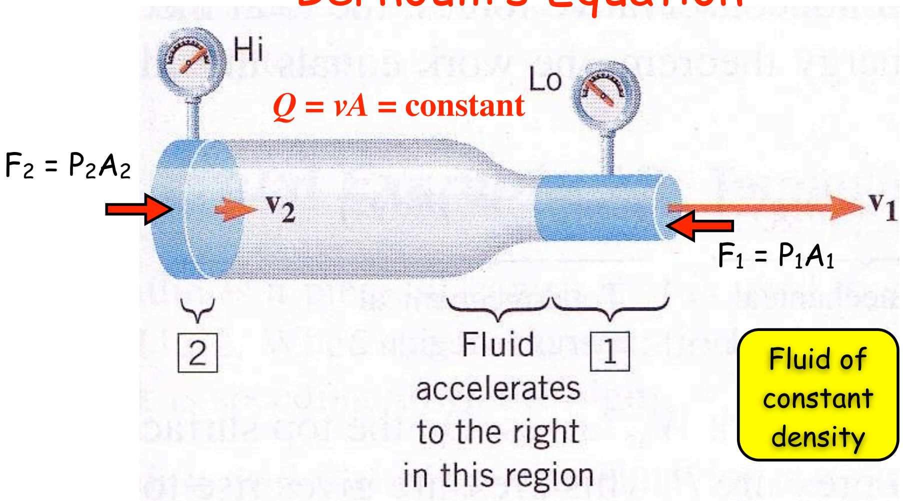
Find the average blood speed if a constriction reduces the radius of the artery by a factor of 3 (without reducing the flow rate).

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



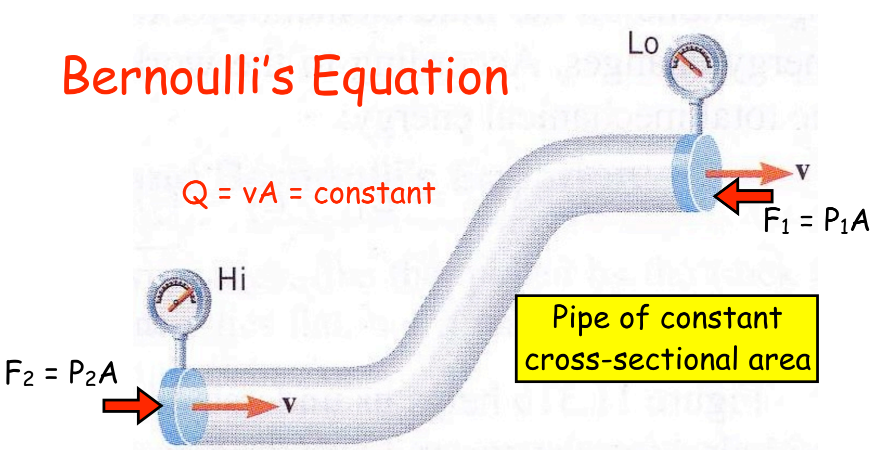

The fluid speeds up when it gets to the constriction. What is the force that causes this acceleration?

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

$$P_2 > P_1$$



# Bernoulli's Equation

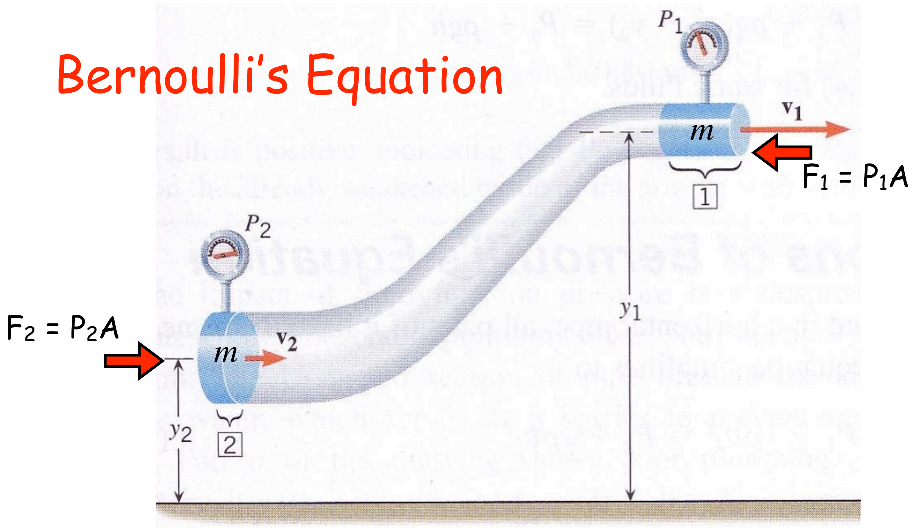



The fluid flows up hill at constant speed through a pipe of constant area. Where does the force come from to push the fluid up the hill at constant speed?

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

$$P_2 > P_1$$

# Bernoulli's Equation

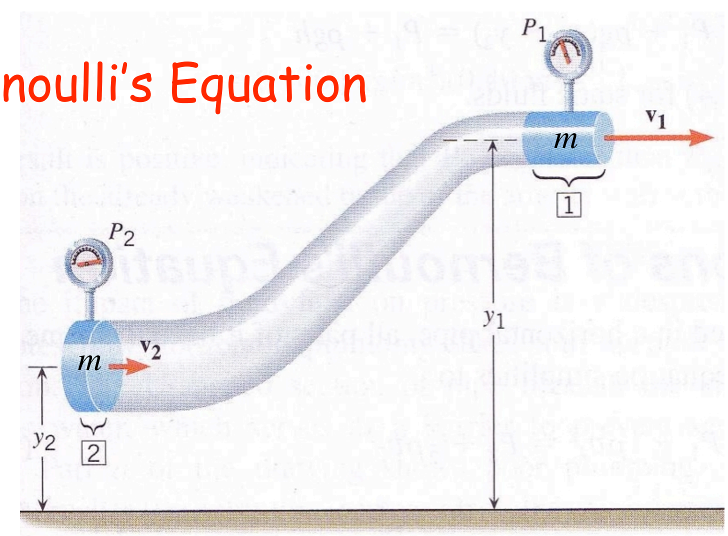



Follow a fluid element of mass m through the pipe from region 2 at the left to region 1 at the right.

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



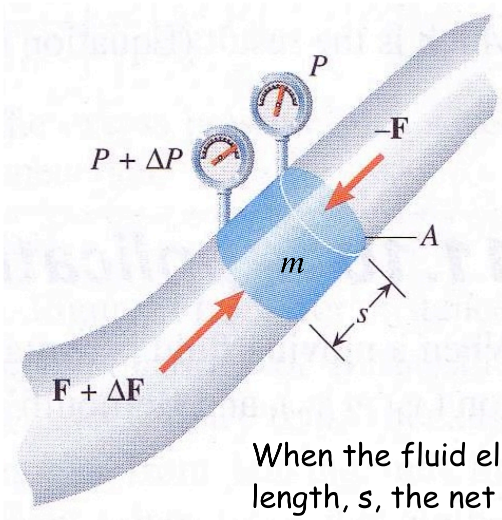
# Bernoulli's Equation




Work-energy equation:

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

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: $W_{nc}=\Delta PE+\Delta KE$

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

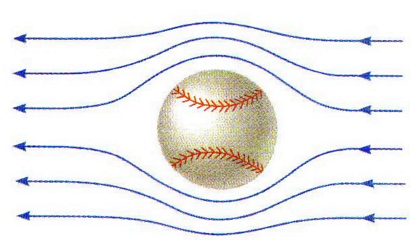
Divide by V and use density $\rho$ = m/V

$$P_2-P_1=(\rho gy_1-\rho gy_2)+(\frac{1}{2}\rho v_1^2-\frac{1}{2}\rho v_2^2)$$

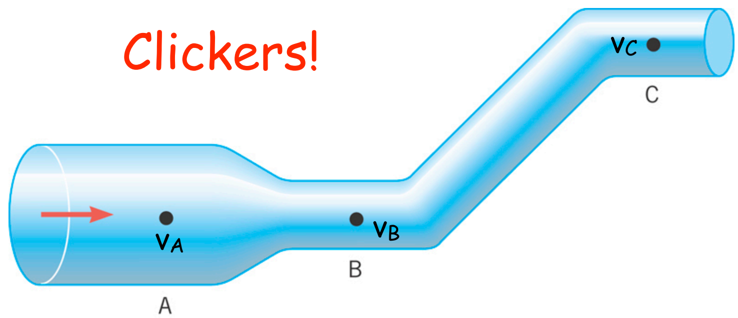
$$P_1+\rho gy_1+\frac{1}{2}\rho v_1^2=P_2+\rho gy_2+\frac{1}{2}\rho v_2^2$$

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?



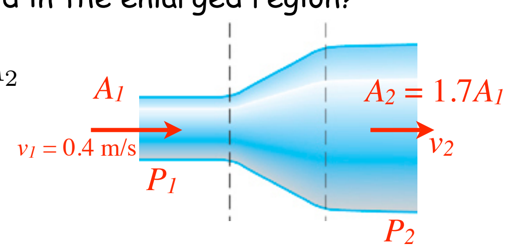
# Applications of Bernoulli's Equation

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 ($\rho$ = 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, $v_2 = \dfrac{v_1 A_1}{A_2} = \dfrac{0.4}{1.7} = 0.235 \text{ m/s}$

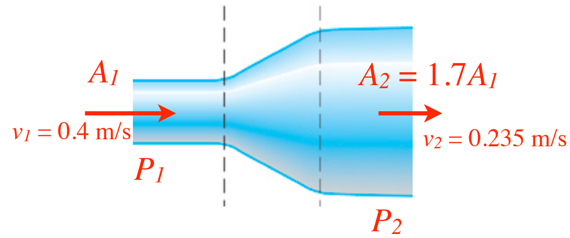



Bernoulli:

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

(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 $3.4\times10^5$ 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?

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

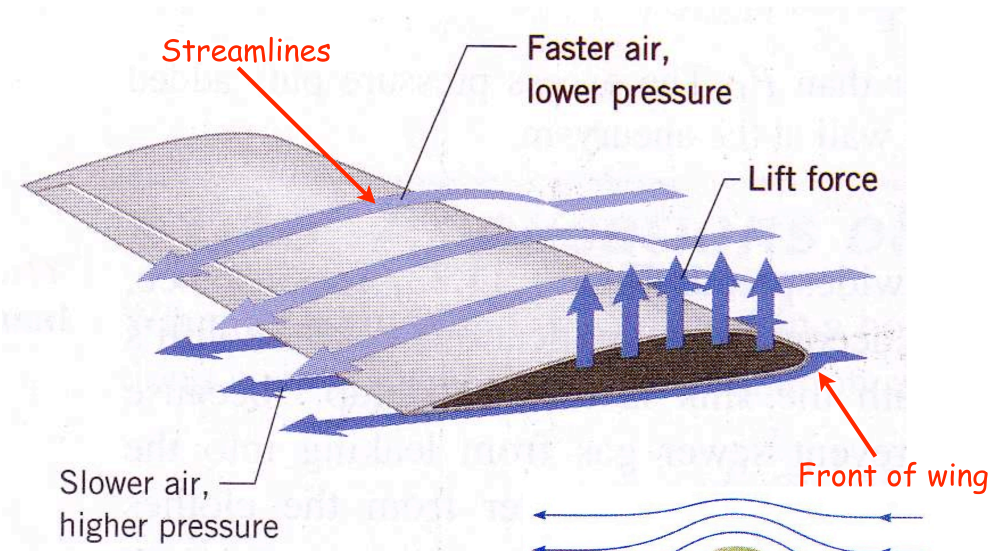
$$P_1 = 3.4 \times 10^5 \text{ Pa}, h_1 = 0, v_1 = 2.1 \text{ m/s}$$

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

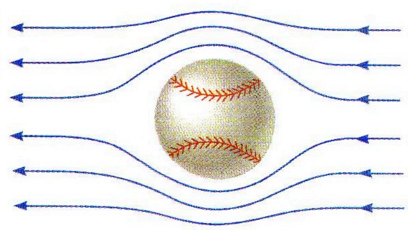
$$\rho = 1000 \text{ kg/m}^3$$

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

# 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

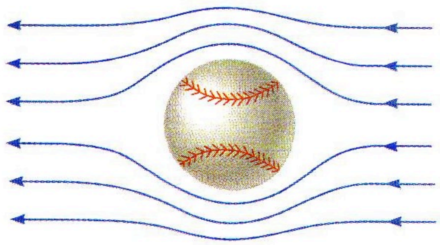
$$\text{So, } P_2 - P_1 = \frac{1}{2}\rho(v_1^2 - v_2^2) = \frac{1}{2} \times (1.29\ \text{kg/m}^3) \times (251^2 - 225^2) = 7983\ \text{Pa}$$

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

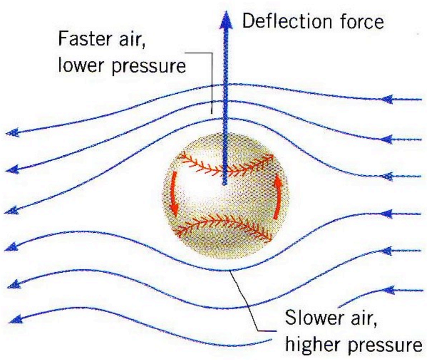
# View from above

Ball is moving to the right

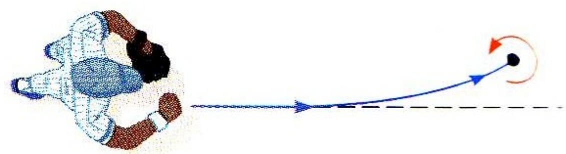
Streamlines of air moving relative to the ball



(a) Without spin



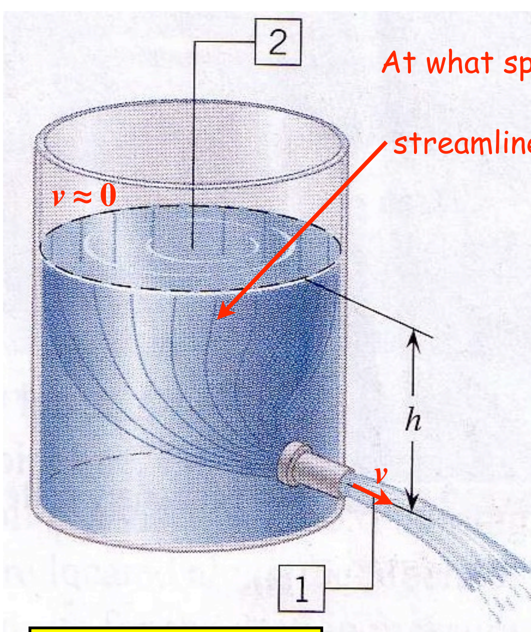

(b) With spin

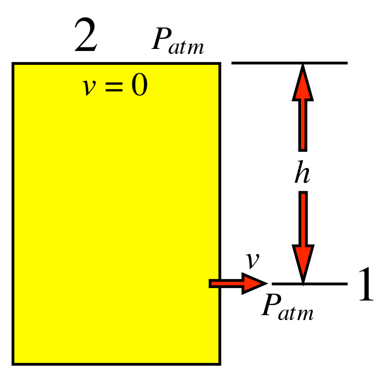




At what speed does the water leave the hole?

streamlines




Bernoulli: at 2 and 1

$P_{atm} + \rho g h = P_{atm} + \frac{1}{2}\rho v^2 \rightarrow v^2 = 2gh$, 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:

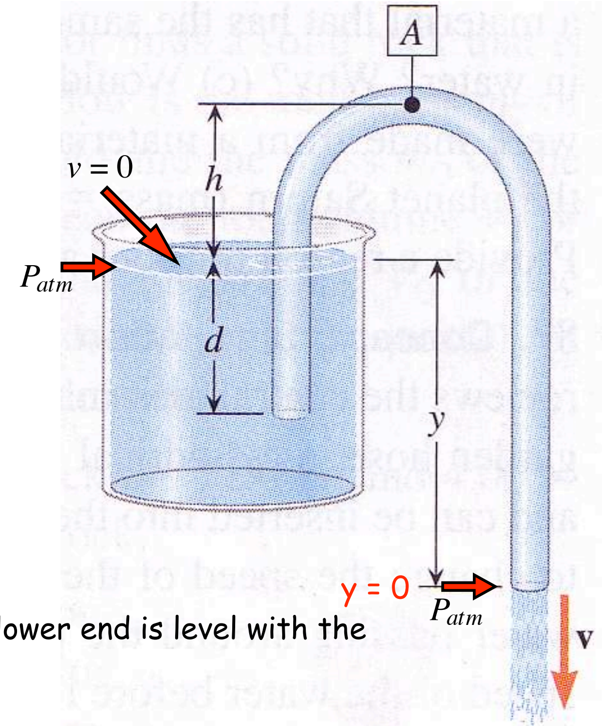
$$P_{atm} + \rho g y = P_{atm} + \frac{1}{2}\rho v^2$$

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:

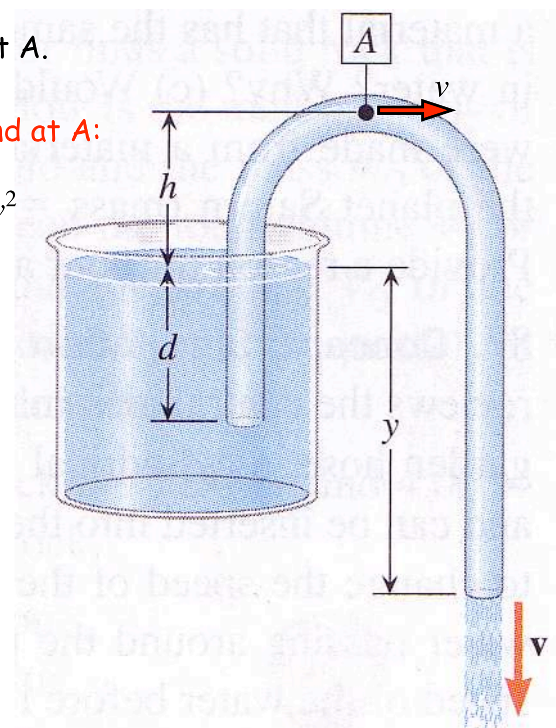
$$P_{atm} + \rho g y = P_A + \rho g (y + h) + \frac{1}{2}\rho v^2$$

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

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

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

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



# 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